



**Universidade de Brasília**  
Instituto de Geociências  
Programa de Pós-graduação em Geologia



# **Petrogenesis of Mafic-ultramafic Intrusions in the Southern Goiás Magmatic Arc, Central Brazil**

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**Tese de Doutorado Nº 190**

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**Brasília, 06/09/2022**



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Tese apresentada ao Programa de Pós-Graduação em Geologia – Instituto de Geociências – IG da Universidade de Brasília – UnB como requisito parcial obrigatório para a obtenção do título de Doutor em Geologia.

**Área de concentração:**  
Mineralogia e Petrologia

**Orientador:** Prof. Dra. Maria Emília Schutesky e Prof. Dr. James Mungall

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| Prof. Dr. Michael Lescher         | (Laurentian University); |
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**Brasília, 06/09/2022**

Ap

Augustin, Cláudia Tharis

Petrogenesis of Mafic-ultramafic Intrusions in the Southern Goiás Magmatic Arc, Central / Cláudia Tharis Augustin; orientador Maria Emília S Schutesky; co-orientador James Mungall. -- Brasília, 2022.  
317 p.

Tese (Doutorado - Doutorado em Geologia) -- Universidade de Brasília, 2022.

1. Rochas Máfico-ultramáficas. 2. Intrusões Acamadadas. 3. Modelamento Termodinâmico. 4. Arco Magmático de Goiás. 5. Geologia. I. Schutesky, Maria Emília S, orient. II. Mungall, James, co-orient. III. Título.

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## **Abstract**

The Americano do Brasil and Mangabal Complexes belong to a cluster of Neoproterozoic mafic-ultramafic intrusions in the southern Goiás Magmatic Arc in Brazil that lies within the Brasília Belt, a complex, long-lived Neoproterozoic Orogen that formed during the amalgamation of the São Francisco/Congo, Amazonian, and Paranapanema Cratons in western Gondwana. Although deformed and partially recrystallized by a regional metamorphic overprint, the rocks of both complexes still preserve igneous textures. The rocks in both complexes show cumulate textures that range from adcumulate to orthocumulate. Petrography, geochemistry, geochronology, and petrological modeling were carried out to constrain the petrogenesis of the complexes.

Modeling indicates that the parental magma for the Americano do Brasil Complex had an OIB-like Fe-rich picrite composition, while the parental magma of the Mangabal Complex could have been a tholeiitic basalt. Considering the temporal and spatial correlations, decompression melting of upwelling asthenosphere triggered by rollback subduction and/or influence of a mantle plume are plausible mechanisms to explain the petrogenesis of these mafic-ultramafic intrusions in the vicinities of the eastern Arenópolis arc and westernmost Anápolis-Itaçu belt. The complexes have experienced a protracted metamorphic evolution with peaks indicating amphibolite facies. The rock from both complexes shows late-stage alteration associated with metasomatism by CO<sub>2</sub>-Ca-S-rich fluids.

Keywords: Mafic-ultramafic; cumulates; thermodynamic modeling; layered intrusions; petrology; Goiás Magmatic Arc.



## Resumo

Os Complexos Americano do Brasil e Mangabal pertencem a um aglomerado de intrusões máfico-ultramáficas neoproterozoicas no sul do Arco Magmático de Goiás, que se encontra na Faixa Brasília. A Faixa Brasília é um Orógeno Neoproterozóico complexo e de longa duração que se formou durante o amalgamento dos crátons São Francisco/Congo, Amazônia e Paranapanema no oeste do Gondwana. Embora deformadas e parcialmente recristalizadas devido ao efeito do metamorfismo regional, as rochas de ambos os complexos ainda preservam texturas ígneas. Ambos os complexos apresentam texturas cumuláticas que variam de adcumulados a ortocumulados. Petrografia, geoquímica, geocronologia e modelagem petrológica foram realizadas para melhor compreender a petrogênese dos complexos.

O modelamento petrológico sugere que o magma parental do Complexo Americano do Brasil tinha uma composição picrítica rica em ferro, com assinatura semelhante à OIB, enquanto o modelamento indica que o magma parental do Complexo Mangabal poderia ter sido semelhante a de um basalto toleítico. Considerando as correlações temporais e espaciais, fusão por decompressão da ascensão da astenosfera desencadeada por uma regressão da placa subductante e/ou influência de uma pluma mantélica são fontes plausíveis para explicar a petrogênese dessas intrusões máfico-ultramáficas próximo ao limite leste do arco Arenópolis e parte oeste do Complexo Anápolis-Itauçu. Os complexos foram afetados por um metamorfismo regional com picos indicando pelo menos fácies anfibolito. As rochas de ambos os complexos apresentam alteração posterior associada ao metassomatismo por fluidos ricos em CO<sub>2</sub>-Ca-S.

Palavras-chave: Máfico-ultramáfico; cumulados; Modelamento Termodinâmico, intrusões acamadadas, petrologia, Arco Magmático de Goiás

## Acknowledgments

It is a pleasure to finally express my gratitude to all the people that have, directly or indirectly, contributed to the success of this project. First and foremost, all my gratitude to my supervisors Emília Schutesky and James Mungall. Emília happily supported my project since the beginning and has become a good friend - thanks for all the geological and non-geological talks and laughs. I could not have undertaken this journey without James Mungall who accepted my idea of a cotutelle and showed me a new whole perspective on geology. You both have been an incredible help and I am thankful that you took the patience to guide me on this journey. I also thank Richard Ernst, who together with Jim, happily supported my project and welcomed me to Carleton University.

Special thanks to Victor Garcia, who has been at my side for a long time and was with me in every bad and good time. We stayed together during a pandemic, sharing desks for work, and using uncomfortable chairs while both were doing our PhD and we somehow remained sane. He always gave me support and help, discussed ideas, and reminded me about my accomplishments every time that I thought I was failing.

Thanks should also go to all of the administrative staff at Carleton University that makes my visit here possible. Special thanks to Ali Arya was very patient and guided me through the cotutelle process, and Sheila Thayer was always forthcoming to answer my questions and solve any problems. Tim Mount was always nice and patient when I needed to use the Rock Lab. I sincerely thank my officemates Chris Jenkins, Nabil Shawwa, Yao Zhuosen, William Smith, and Nico Kastek for always being so friendly in sharing the office with good discussions about everything. And Maryam Shahabi Far was very supportive of the SEM.

I would like to express my gratitude to Kevin Chamberlain, that was very patient with me and taught me a lot about geochronology while we worked together.

I want to thank my parents, especially my mother, who always supported my choices and created me to explore the world and follow my path. Also, my sister, who knows nothing about geology or research, but tries sometimes to understand to explain it to others with pride.

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. It was also financed in part by Fundação de Apoio à Pesquisa do Distrito Federal (FAP/DF - project number 800/2019). This research has been partly supported by Canadian NSERC grant CRDPJ 523131-17.

## **Dedication**

This is in memory of

My grandfather, Olavo Augustin, who taught me that it is possible in a lifetime to accomplish more than we can first dream of.

and

Professor Márcio Pimentel, who makes me feel assured about my choice to study rocks and inspired me to always pursue the answers to my questions.

## Preface

This thesis was developed under a cotutelle agreement between Universidade de Brasília (Brazil) and Carleton University (Canada). It is presented as independent chapters intended for publication (Chapters 2-4) and was formatted in form appropriate for submission to internationally recognized, peer-reviewed scientific journals. Each of these chapters is structured as an individual manuscript with an abstract, introduction, methods, results, discussions, and conclusions. It is drawn directly from manuscripts that are currently submitted or in the process to submission to peer-reviewed scientific journals. Each chapter has been formatted to comply with the Carleton University and Universidade de Brasília thesis template. A compiled list of references is included at the end. As a result of this formatting choice, there is some repetition, particularly relating to regional geology. A fifth chapter (chapter 5) was in format of a report, prepared for the LIPs Industry Consortium. I am the lead author of all the chapters, and all are co-authored with my supervisors Dr. Maria Emília Schutesky and Dr. James Mungall, and my co-supervisor Dr. Richard Ernst. The supervisors provided input during the conceptualization, data collection, data analysis, modeling, drafting, editing, and revising of manuscripts for each chapter.

Even as the theme for each paper varies individually, all are connected by the common goal of constraining the petrogenesis of the mafic-ultramafic intrusions in the southern Goiás Magmatic Arc.

Chapter 2 is titled **“Petrological and Geochemical Characteristics of the Mafic-ultramafic Americano do Brasil Complex, central Brazil, and the implications for its genesis”**. It is currently under final revision process in the journal *Ore Geology Reviews*.

In this paper, the first author went to the field to collect the samples, described all rocks and thin sections, prepared all the samples for whole-rock analyses, collected EPMA data (with assistance from technicians at the Laboratory of Electron Microprobe LMI at University of Brasilia), and conducted all petrological modeling.

Chapter 3 is titled **“U-Pb in-situ SIMS Baddeleyite dates and Thermodynamic Modeling in Mangabal Complex: Indications for Asthenospheric Mantle Influence in the Formation of Layered Intrusions at the end of the Evolution of the Brasília Orogen”**. The first author went to the field to collect the samples used in the work, described all rocks and thin sections, prepared all the samples to submit to whole-rock analyses, collected the EPMA data (with assistance from technicians at the University of Brasilia), and conducted all petrological modeling. The samples preparation for U-Pb geochronology was partially conducted at the University of Wyoming by Dr. Chamberlain and the SIMS data were obtained at UCLA by the first author and Dr. Chamberlain.

Chapter 4 is titled **“Characteristics of the Amphibolite Facies Metamorphism Overprinted in Mafic-Ultramafic Cumulates in the Mangabal and Americano do Brasil Complexes”**. The first author went to the field to collect the samples used in the work, described all rocks and thin sections, prepared all the samples for whole-rock analyses, collected the EPMA data (with assistance from technicians at the University of Brasilia), and conducted all petrological modeling.

Chapter 5 is titled **“450 Ma Mafic Dyke Linked to NW Dykes in the Sanclerlândia-Anicuns Region”** and it is in the format of a report for the Large Igneous Provinces -Industry Consortium Project ([www.supercontinent.org](http://www.supercontinent.org)) and the data it is under a 1-year confidentiality blackout agreement. The first author went to the field collect the

samples used in the work, described all rocks and thin sections. The sample preparation for U-Pb geochronology was partially conducted at the University of Wyoming by Dr. Kevin Chamberlain and the SIMS data were obtained at UCLA by the first author and Dr. Chamberlain



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# **CHAPTER 1**

## **Introduction**

# 1. Introduction

## 1.1. Background

Mafic–ultramafic intrusions can occur in varied geological environments and are known to be the most common hosts of magmatic Ni–Cu–(PGE) sulfide deposits. The mineralization is mainly hosted in komatiitic flows (e.g., Kambalda, in Australia), sills formed from flood basalts (e.g., Norilsk, Russia), or in mafic-ultramafic intrusions (e.g., Voisey’s Bay, Canada). The mineralization occurs mainly in extensional tectonic settings, but can also be associated with a compressive environment and, in exceptional cases, it is formed as a result of the impact of a meteorite as at Sudbury, in Canada (e.g., Naldrett, 2004). For a long period, exploration for world-class Ni–Cu–(PGE) deposits in convergent margin environments have not been seen as viable target areas for magmatic sulfide-rich Ni–Cu–(PGE) deposits (Ripley, 2010), but in the last years several deposits in these environments have been described. It shows an increasing resource variety and important exploration targets e.g., Aguablanca, Spain (Casquet *et al.*, 2001) , intrusions in the Portneuf-Mauricie Domain and the Giant Mascot Suite, Canada (Sappin *et al.*, 2009b; Manor *et al.*, 2016), and the Savannah Ni–Cu–Co Camp in the East Kimberley, Australia (Hoatson and Blake, 2000; Le Vaillant *et al.*, 2020) This recent enhanced attention to Ni–Cu–(PGE) mineralization worldwide in mafic-ultramafic rocks formed convergent environments draws attention towards the Proterozoic Goiás Magmatic Arc, which hosts several sulfide-bearing mafic-ultramafic rocks.

The Goiás Magmatic Arc, most specifically the Southern Segment – called the Arenópolis arc – hosts several small to medium-sized mafic-ultramafic intrusions, some of which contain Ni–Cu–(PGE) mineralization. These intrusions are in the easternmost portion

of the Arenópolis Arc, near the contact with the Anápolis-Itaçu Complex – which also hosts mafic-ultramafic intrusions. Several of these intrusions were identified in exploration surveys, but detailed mapping and petrological studies are so far limited to a few intrusions. Some examples include the Americano do Brasil Complex (Nilson, 1981; Mota-E-Silva *et al.*, 2011) and the Mangabal Complex (Candia, 1983; Augustin and Della Giustina, 2019) in the Arenópolis Arc, and Damolândia (Giustina *et al.*, 2011; Maia, 2016) and Taquaral (Giustina *et al.*, 2011) in the Anápolis-Itaçu high-grade terrain. The comparison of the petrological and geochemical characteristics of the intrusions, mineralized or not, will help identify some genetic links and help in efforts to estimate their economic potential. The region's Ni-Cu-Co potential is evidenced by the presence of Americano do Brasil Mine, which operated between 2006 and 2014, and by the known existence of Ni-Cu sulfides in other intrusions (e.g., Mangabal Complex).

The easternmost Arenópolis arc mainly comprises volcano-sedimentary sequences and calcic- to calc-alkaline orthogneisses ranging in composition from tonalite to granite (Laux *et al.*, 2005a; Fuck *et al.*, 2017). There are several studies focused in the Arenópolis arc, mainly focused on isotope data that give some insights about their conditions of formation. Laux *et al.* (2005) suggest that igneous activity in the Goiás magmatic arc took place in two episodes: between ca. 0.89 and 0.8 Ga, probably in an intraoceanic setting, and between ca. 0.66 and 0.60 Ga, in an active convergent continental margin. The area of study is located in the block at the east of the São Luis de Montes Belos Lineament, in the Turvânia Block (e.g., Araújo, 2012; Macedo *et al.*, 2018). Most gneisses from this block are dated between 660 and 600 Ma, but some are older, such as the country rocks of the Americano do Brasil Complex, which was dated at 849 Ma (e.g., Laux *et al.*, 2004). The

details of the spatial distribution of the juvenile terrains and a detailed model for the tectonic setting for the time of intrusions emplacement are not well defined due to the sparsity of geochronological, geochemical, and petrologic data.

## **1.2. Environments for Mafic-Ultramafic Rocks**

Mafic–ultramafic rocks occur in a variety of tectonic settings and their petrogenesis provides a better understanding of plate tectonic processes and crustal evolution of the Earth (e.g., Polat et al., 2011). Some suites occur within ophiolite successions, which can be considered “fossils” of oceanic lithosphere that are preserved in convergent tectonic settings and have the potential to contain podiform chromitite hosts (e.g., Nicolas, 2012; Shi et al, 2012). Mafic-ultramafic rocks are also common within large layered intrusions on the continents, which are associated with mantle plumes and extensional tectonic settings, and have the major focus of interest for the exploration of Ni–Cu–PGE and Fe–Ti–V ore deposits (e.g., Naldrett, 2004, 1999, 1969). The Alaskan-type intrusions are small intrusions in convergent plate-margin settings and are mostly considered to have originated during island arc magmatism with associated PGE mineralization. These intrusions are commonly concentrically zoned with dunite cores surrounded by clinopyroxenite and hornblendite; orthopyroxene and plagioclase are missing or occur in very low abundance (e.g., Himmelberg and Loney, 1995; Irvine, 1974; Ripley et al., 2005). In addition to the previously described settings, small mafic-ultramafic intrusions have been increasingly reported in metamorphic orogenic belts and these rocks often host Ni–Cu sulfide and/or Ti–Fe oxide deposits.

In orogenic belts, mafic-ultramafic intrusions have been correlated to several different sources/ways for their magma generations and emplacement. Some were

associated with post-orogenic settings, mainly with mantle plumes and/or LIPS, others are considered syntectonic, but some examples are interpreted as pre-orogenic intrusions, emplaced before the peak of orogeny (e.g., Sappin 2012; Manor, 2014; Maier et al. 2005, 2008, Pina et al, 2018; Su, 2014, Barnes et al. 2019).

### **1.3. Geological Settings**

#### **1.3.1. The Tocantins Province**

The Tocantins Province (de Almeida *et al.*, 1981) in central Brazil (Fig. 1.1A) is a large Neoproterozoic orogen which resulted from the collision of the Amazonian, São Francisco-Congo and Paranapanema allochthonous blocks (Pimentel, 2016). Final convergence and collision of the blocks took place during the Brasiliano orogeny in the late Neoproterozoic, as part of West Gondwana amalgamation (Fuck *et al.*, 2017). Phanerozoic sedimentary rocks cover the limits of the province: in the south by Parana Basin rocks and in the north by the Paraíba Basin rocks. Three orogenic belts comprise the Tocantins province: the Araguaia, the Paraguay and the Brasília Belt. The Araguaia and Paraguay belts are located along the eastern and southeastern margins of the Amazonian craton, respectively and the Brasília belt is located along the western and southern margins of the São Francisco craton.

#### **1.3.2. The Brasília Belt**

The Brasília belt (Fig. 1.1B) is an orogenic belt, comprising a thick package of passive margin sedimentary deposits, younger deep-sea sediments associated with volcanic arc rocks, as well as an ophiolite mélange, arc-type calc-alkaline volcanics and intrusives, and S-type collisional granites (Pimentel *et al.*, 2000b; Fuck *et al.*, 2017). Metamorphic grade increases westwards from non-metamorphic and low-grade rocks, at the cratonic

border in the east, to high-temperature amphibolite facies rocks, culminating in UHT (ultra-high temperature) granulites in the metamorphic core, and decreases again westwards to amphibolite and greenschist facies within the Goiás Arc (Fuck *et al.*, 2017). It extends north-south for more than 1100 km roughly and verges eastwards to the São Francisco craton (e.g., Fuck *et al.*, 2017; Pimentel, 2016). The belt has a curved shape with two differently oriented branches: the northern Brasília Belt that trends northeastward and the southern Brasília Belt that trends southeastwards (e.g., Fonseca *et al.*, 1995; Uhlein *et al.*, 2012; Valeriano *et al.*, 2008).

Several similar tectonic zonations have been proposed for the Brasilia Belt (e.g., Fuck *et al.*, 2017; Pimentel *et al.*, 2000a, 2000b; Valeriano, 2017; Valeriano *et al.*, 2008). Valeriano *et al.* (2008) divided the Brasilia Belt into five distinct domains from east to west: a) the autochthonous **Foreland Zone** (Sao Francisco Craton) representing the Archean-Paleoproterozoic granite-greenstone basement of the Sao Francisco Craton, covered by Neoproterozoic metasedimentary rocks; (b) the allochthonous **External Zone**, a low metamorphic grade fold-thrustbelt of proximal shelf successions, containing rare basement slivers; representing rift and passive margin metasedimentary rocks over a Paleoproterozoic crustal block (namely Cavalcante-Natividade); (c) the allochthonous **Internal Zone**, consisting of upper greenschist to granulite facies metamorphic nappes in distal shelf and slope metasediments and subordinate tholeiitic metabasalts; the granulitic rocks, with local products of ultrahigh-temperature conditions, is called Anápolis-Itaçu Complex; (d) the **Goiás Massif**, an exotic terrain composed of the Goiás Archean Block with TTG-greenstone belt terrains and three large Neoproterozoic layered mafic-ultramafic complexes and associated volcanic-sedimentary sequences; and the **Goiás Magmatic Arc**.

Fuck et al (2017) has a similar zonation divided into three main zones: Cratonic Zone, External Zone and Internal Zone, the latter including the Goiás Magmatic Arc, the Goiás Massif, and the Goiás Magmatic Arc.

### 1.3.3. The Goiás Magmatic Arc

The Goiás Magmatic Arc (Pimentel and Fuck, 1992a; Fuck *et al.*, 1994) is an important Neoproterozoic tectonic unit of the Brasilia Belt that extends NE-SW. Its northern and southern limits are covered by the Parnaíba and Parana Basins, respectively. It comprises two sectors, separated by the Goiás Archean Block (e.g., Pimentel, 2016). The northern sector is known as Mara Rosa arc and the southern is called Arenópolis arc (Pimentel *et al.*, 2000a). In both sectors, the igneous activity has two main episodes: a first magmatic stage at ca. 900 Ma. in an intraoceanic island arc with the crystallization of primitive tholeiitic to calc-alkaline volcanics and associated tonalites/granodiorites (Pimentel and Fuck, 1992a; Pimentel *et al.*, 2004; Laux *et al.*, 2005a; Pimentel, 2016). A second magmatic stage is dated around 670-600 Ma (Pimentel *et al.*, 2004; Laux *et al.*, 2005a) when volcanic and plutonic activity took place and was followed by intrusions of gabbro, diorite, tonalite to granite, accompanied of metamorphism and deformation, with an active continental margin signature (Laux *et al.*, 2004, 2005a; Matteini *et al.*, 2010; Fuck *et al.*, 2017).

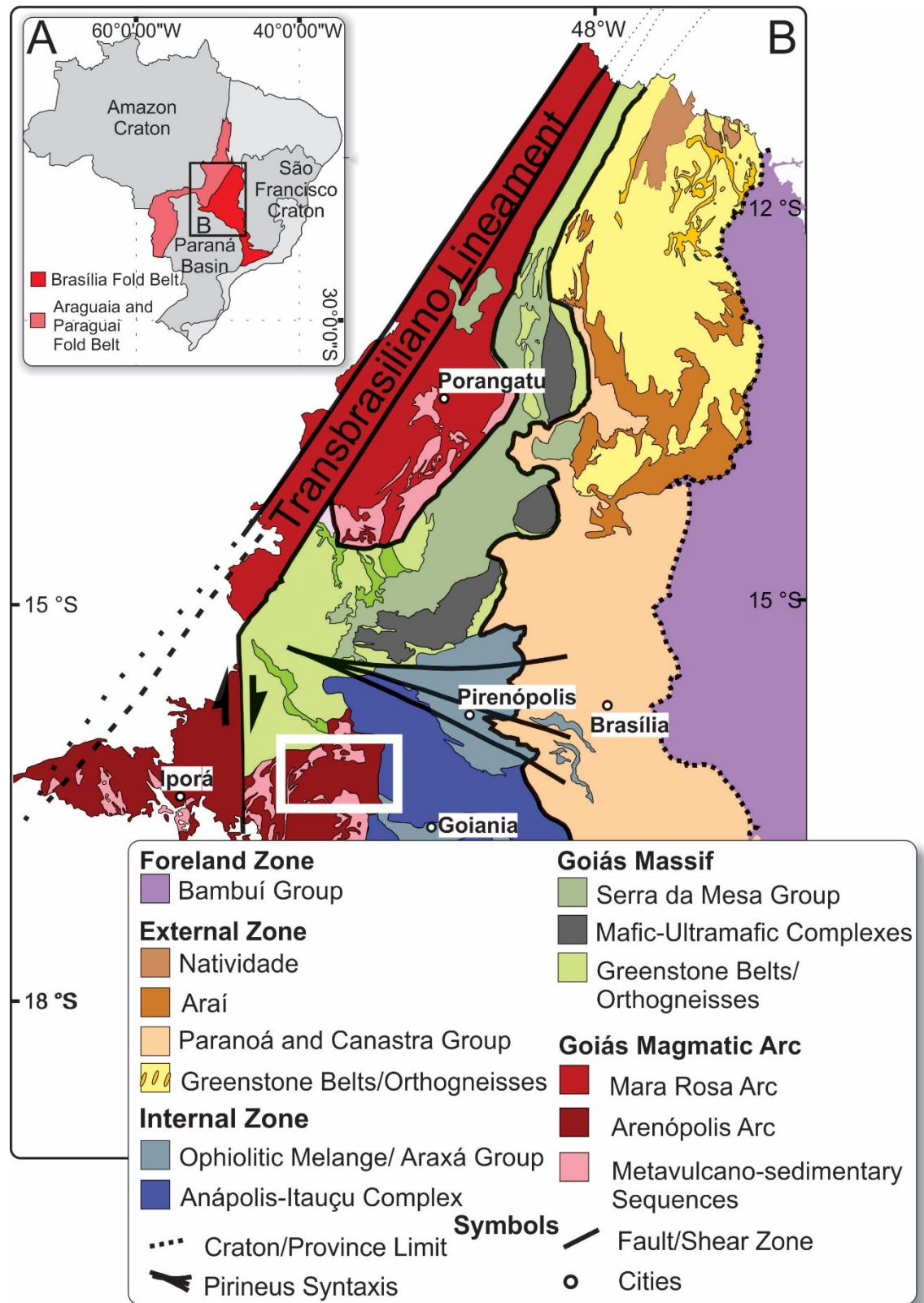


Figure 1.1 1A) Tocantins Province location in Brazil; the red region is the Brasília Belt. B) Schematic geological map of the Brasília Belt (modified from Pimentel et al., 2004).



#### 1.3.4. The Arenópolis Arc

The Arenópolis arc comprises N-S trending volcano-sedimentary sequences (namely Bom Jardim de Goiás, Arenópolis, Iporá, Jaupaci and Anicuns-Itaberaí, respectively from west to east), separated from each other by calcic to calc-alkaline orthogneisses, ranging between tonalite and granite compositions (Fuck *et al.*, 2017). The supracrustal and orthogneissic units of the Arenópolis arc are juxtaposed to each other along important NNE to NNW strike-slip faults, which are part of the continental-scale Transbrasiliano Lineaments (Pimentel *et al.*, 2000a). It is delimited to the southwest by Phanerozoic basin rocks, to the north by the Goiás Massif and to the east by the Anápolis-Itaçu-Complex. Near the Sanclerlândia-Anicuns region, close to the contact with Anápolis-Itaçu complex, the Arenópolis arc has a several small-to medium (up to 16) pre- to syn-orogenic mafic-ultramafic intrusions, some of which will be detailed in this work.

The volcanic sequences comprise mainly low-K tholeiitic metabasalts, calc-alkaline metabasalts, meta-andesites, metadacites, and rhyolites in some of these sequences (e.g., Bom Jardim de Goiás and Arenópolis), whereas other sequences comprise bimodal associations with metabasalts and rhyolites (e.g., Iporá and Jaupaci) (Fuck *et al.*, 2017). Amphibolite and metapelitic rocks, with subordinate iron formations, cherts, marbles, and ultramafic rocks of uncertain age represent the Anicuns-Itaberaí sequence, located in the eastern part of the Goiás magmatic arc and in contact with the Anápolis–Itaçu Complex. The Anicuns-Itaberaí sequence has two main periods of crystallization of mafic-ultramafic rocks: 0.89–0.82 and 0.63–0.60 Ga. (Laux *et al.*, 2004).

### 1.3.5. The Mafic-Ultramafic Intrusions

Several bodies of mafic-ultramafic rocks were intruded in Arenópolis arc and Anápolis-Itaçu complex (Fig. 1.2), near the contact between these two compartments. The intrusions in the Arenópolis arc were first recognized in geological mapping of the geology undergraduate course of the Institute of Geosciences of the University of Brasília in 1969 (Danni *et al.*, 1973). They mapped some mafic-ultramafic bodies, which they called the Mangabal Massif – current Mangabal Complex – and São João Massif – currently known as the Americano do Brasil Complex (Danni *et al.* 1973). Pfrimer *et al.* (1981) present a geological map that contains more than 14 mafic and ultramafic intrusions metamorphosed under amphibolite and granulite facies, that today correspond to the intrusions of the Arenópolis arc (the ones under amphibolite facies) and also the intrusions in the Anápolis-Itaçu Complex (granulite facies).

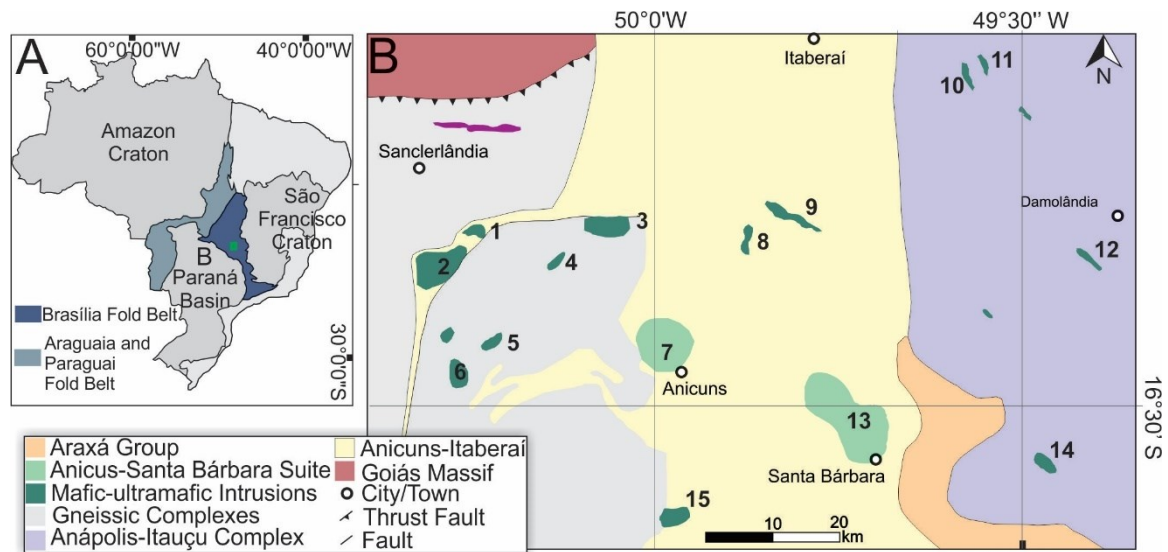


Figure 1.2 Simplified geological map including the mafic-ultramafic intrusions in the Arenópolis Arc. 1 – 2: Mangabal Complex, 3: Americano do Brasil Complex, 4: Água Fria, 5: Adelândia, 6: Fronteira Norte, 7: Córrego Seco, 8: Águas Claras, 9: Capelinha, 10-11: Taquaral, 12: Damolândia, 13: Santa Bárbara, 14: Goianira-Trindade, 15: Palmeiras. Gneissic Complex and Anicuns-Itaberaí are part of the Arenópolis Arc.

The first detailed work about Mangabal was done by Ribeiro et al. (1974), who described the northern body, formerly called Mangabal I. The body was defined as a lopolith that has an ultramafic sequence below a mafic sequence composed of norite and gabbro. Pfrimer et al. (1981), Candia (1983), Candia and Girardi (1985), Candia et al. (1991) and Candia and Gaspar (1997) focused on the petrography of the Mangabal Complex, formerly known as Mangabal I and Mangabal II intrusions. They described them as two mafic-ultramafic intrusions formed from different magma chambers with similar crystallization paths. Both were described as tectonically deformed, partially recrystallized with similar high-grade metamorphic conditions, and the northern intrusion as tectonically inverted. The Mangabal intrusions were not studied again until 2012 when the Votorantim Metais corporation started an exploration survey and drilled the intrusions. Augustin and Della Giustina (2019) re-described the two intrusions, now called the Mangabal Complex, as a single partially metamorphosed mafic-ultramafic intrusion composed of two exposures, the Northern and the Southern members, which exhibit similar igneous mineralogy and crystallization sequence and were affected by the same high-pressure amphibolite facies metamorphic conditions. The authors also documented occurrences of Ni-Cu-( $\pm$ PGE) mineralization, describing sulfide remobilization caused by superimposed post-magmatic processes.

The Americano do Brasil complex was the object of detailed geological surveys, mineral exploration, including drilling and petrographic study of cumulate rocks and associated Ni-Cu sulfide ore (Nilson, 1981, 1984; Nilson and Santos, 1982; Mota-E-Silva *et al.*, 2011). It was first drilled by METAGO in 1975, who defined a small Ni-Cu deposit (5 Mt at 0.62 wt.% Ni and 0.65 wt.% Cu). The complex is most known due the Americano

do Brasil mine, developed on the Complex. After the 1975 exploration surveys by Metago, several companies continued to explore, until 2004 when Prometalica Ltd. acquired the mining rights and re-evaluated the deposit. A Prometalica Votarantim Metals joint venture mined the deposit from 2006 to 2014. The most detailed study regarding the petrography of the complex was done by Nilson (1981), who described it as a small, layered pluton consisting of cumulate mafic and ultramafic rocks containing ubiquitous megacrysts of poikilitic pargasite-hornblende, with associated amphibolite facies minerals. He described the sulfides as disseminated to massive bodies, hosted by dunite-peridotite and pyroxenite-melanorite, probably re-equilibrated at very low temperatures. Silva et al (2011) described with more details the three main orebodies of the Complex, proposing that the parental magma was a tholeiitic high-MgO basalt with a depleted mantle source. Sm-Nd and U-Pb analyses of the rocks of the Americano do Brasil indicated positive  $\epsilon_{\text{Nd}}$  (+3,1) and U-Pb age of  $626 \pm 26$  Ma (Nilson *et al.*, 1997; Laux *et al.*, 2004).

A description of outcrops from Córrego Seco was done by Nunes (1990), who pointed out that this intrusion was different from the other intrusions due to the lack of ultramafic rocks. Laux et al (2004) argued that intrusion was coeval to the ultramafic-bearing intrusions (then called the Americano do Brasil Suite), but since it comprises gabbro-dioritic rock it was interpreted to be derived from a more evolved parental magma, so he called them Anicuns-Santa Barbara Suite to distinguish them from the Americano do Brasil Suite.

Damolândia is a small mafic-ultramafic intrusion within the Anápolis-Itaçu Complex. The intrusion was mapped and drilled by International Nickel Venture Ltd. Between 2006 and 2008. Preliminary descriptions were published by Della Giustina et al

(2011), who revealed that the intrusions are composed of ultramafic and mafic domains comprising peridotite, pyroxenite, gabbro and norite. Even though it includes widely preserved remnants of the original igneous mineralogy and texture, the complex was affected by granulite facies metamorphism, which is observed in restricted thin portions of the complex. Maia (2016) described an exotic mineralogy in a rock composed of garnet-hedenbergite granulite, indicating a UHT condition, and described evidence for intense crustal contamination and metasomatism based on the isotopic and geochemistry of the complex. Giustina et al (2011) dated the Damolândia, Taquaral and Goianira-Trindade intrusions, all located in the Anapolis-Itaçu complex; U–Pb (LA-MC-ICPMS, SHRIMP and ID-TIMS) zircon analyses from samples of these intrusions revealed a spread of concordant ages spanning age interval of 80 Myr. The oldest concordant age, ca. 670 Ma, was interpreted as the crystallization age.

#### **1.4. Objectives**

This research aimed to unveil the genesis of the mafic-ultramafic intrusions of the Americano do Brasil Suite to identify their geodynamic, petrological, and metallogenic implications, which will aid in constraining the petrogenesis, geochronology and tectonic setting of the mafic-ultramafic intrusions exposed in the Goiás Magmatic Arc. Specific objectives included the following: (1) Characterize the major and trace elements for Mangabal and Americano do Brasil Complexes. (2) Define the age of the intrusions and the geodynamic context of emplacement. (3) Determine the origins of the magmas responsible for the formation of the plutonic rocks. (4) Identify the nature of the parental magma(s) and either the type or degree of differentiation. (5) Comprehend the role of deformation and metamorphism in the intrusions and how they affect their mineralization.

## **CHAPTER 2**

**Petrological and geochemical characteristics of the mafic-ultramafic Americano do Brasil Complex, central Brazil, and the implications for its genesis**

## **2. Petrological and geochemical characteristics of the mafic-ultramafic Americano do Brasil Complex, Central Brazil, and the implications for its genesis**

### **Abstract**

The Americano do Brasil Complex occurs in the Neoproterozoic Goiás Magmatic Arc, central Brazil. It is composed of two mafic-ultramafic cumulate sequences, intruded into granodioritic gneisses. Although deformed and partially recrystallized by a regional metamorphic overprint, the complex still preserves relict igneous features, such as adcumulate to heteradcumulate textures. The Northern sequence is mostly composed of olivine and olivine-clinopyroxene cumulates, whereas the Southern consists mainly of two-pyroxene cumulate rocks, with plagioclase and olivine cumulates occurring in lesser amounts. The complex has three main orebodies, with textures that range from disseminated to massive sulfide breccias with *durchbewegung* texture. Thermodynamic modelling using a single picrite parental magma composition can predict cumulate rock compositions and mineral modes similar to all of the observed cumulate rock compositions of the Americano do Brasil Complex. Equilibrium crystallization of the liquid and assimilation-batch-crystallization involving up to 45% of the host gneisses in the upper crust produces solids similar to the cumulates described in Northern and Southern sequences, respectively. Modeled pressure-temperature emplacement conditions of the magma were c.a. 2.5 kbar and 1310 °C. Both sequences have similar incompatible trace element patterns which, together with the results of the modelling, implies a broadly comagmatic origin.

## 2.1. Introduction

Magmatic Ni–Cu sulfide deposits are most known to be hosted by mafic to ultramafic intrusions and can occur in a variety of tectonic settings. Until recently, exploration for world-class Ni-Cu-(PGE) deposits has focused on extensional tectonic environments, such as ancient rift basins, and convergent margins have not been seen as viable target areas for magmatic sulfide-rich Ni-Cu-(PGE) deposits (Ripley, 2010). In the past two decades, however, several mineralized mafic-ultramafic intrusions located in accretive or collisional tectonic settings have been studied showing an increasing resource variety and new important exploration targets. Notable examples are Aguablanca (e.g., Piña, 2019) in Spain; the intrusions in Portneuf-Mauricie Domain (e.g., Sappin et al., 2009) and the Giant Mascot Suite (Manor *et al.*, 2016), in Canada; the Savannah Ni-Cu-Co Camp in the East Kimberley (e.g., Le Vaillant et al., 2020a), in Australia; the Limoeiro (e.g., Mota-E-Silva et al., 2013) and Mirabela Intrusions (e.g., Barnes et al., 2011) in Brazil; and the Ntaka Hill intrusion, in Tanzania (Barnes *et al.*, 2019). In these compressive environments, the mafic-ultramafic intrusions have been correlated to a variety of sources and pathways for magma generation and emplacement. A few intrusions located in orogenic environments are interpreted to be pre-orogenic, but most of them are interpreted to be syn-collisional, commonly related to cumulates of magmatic arc roots or even back-arc basins, and some can be related to post-orogenic settings, commonly linked to mantle plumes and/or LIPs (e.g., Barnes et al., 2019; Le Vaillant et al., 2020a; Maier et al., 2008; Piña, 2019; Sappin et al., 2012)

The Americano do Brasil Complex is part of a group of mafic-ultramafic intrusions occurring in the southern segment of the Goiás Magmatic Arc, in the Neoproterozoic



Brasília Belt. The intrusions are broadly associated with the Brazilian Orogeny and have been interpreted as syntectonic intrusions associated with the second magmatic event in the Arenópolis Arc, but the specifics of the origin and emplacement of these mafic bodies are poorly constrained (Nilson and Santos, 1982; Laux *et al.*, 2004; Mota-e-Silva *et al.*, 2011; Augustin and Della Giustina, 2019). In this paper, we present new field and petrographic descriptions, lithogeochemistry of the cumulate rocks, and the results of thermodynamic modelling aimed at better understanding the characteristics of the parental magma of the complex.

## **2.2. Regional and Local Geology**

The Goiás Magmatic Arc (Pimentel and Fuck, 1992a; Fuck *et al.*, 1994) is a Neoproterozoic tectonic unit located in the westernmost Brasília Belt (fig. 2.1A), which is one of the three large Neoproterozoic orogens that resulted from the collisions of the Amazonian, São Francisco-Congo and Paranapanema cratons and smaller allochthonous blocks (Fig. 2.1A). The Goiás Magmatic Arc trends NE-SW and its northern and southern limits are covered by the Parnaíba and Parana Basins, respectively (Fig. 2.1B). It comprises two domains separated by the Goiás Archean Block (e.g., Pimentel, 2016). The northern domain is known as the Mara Rosa arc and the southern is called the Arenópolis arc (Pimentel *et al.*, 2000a). Both branches show geological, geochemical, and geochronological similarities, which suggests they probably shared a common evolution (Laux *et al.*, 2004, 2005a; Pimentel *et al.*, 2004; Matteini *et al.*, 2010). The igneous activity in the Goiás Magmatic Arc occurred in two main episodes: a first magmatic stage between ca. 890 and 860 Ma, characterized by eruption of primitive tholeiitic to calc-alkaline volcanic rocks and intrusion of associated tonalites and granodiorites formed in an island

arc setting, and a second magmatic stage, dated around 670-600 Ma, in which calc-alkaline magmatism was accompanied by metamorphism and deformation in an active convergent continental margin (Pimentel and Fuck, 1992b; Laux *et al.*, 2004, 2005a; Pimentel *et al.*, 2004; Matteini *et al.*, 2010; Pimentel, 2016; Fuck *et al.*, 2017).

The Arenópolis arc comprises N-S trending volcano-sedimentary sequences (e.g., Bom Jardim de Goiás, Arenópolis, Iporá, Jaupaci and Anicuns-Itaberaí, respectively from west to east), separated from each other by calcic- to calc-alkaline diorite to granite orthogneisses (Fuck *et al.*, 2017). The supracrustal and orthogneiss units of the Arenópolis arc are juxtaposed along regional NNE to NNW strike-slip fault systems, which are part of the continental-scale Transbrasiliano Lineament (Pimentel *et al.*, 2000a). The eastern portion of the Arenópolis Arc is limited by the granulite-facies gneisses of the Anápolis-Itaçu Complex (Piuzana *et al.*, 2003; Baldwin *et al.*, 2005).

The mafic-ultramafic intrusions of the Arenópolis arc were first recognized during an undergraduate geologic mapping exercise conducted by the Institute of Geosciences of the University of Brasilia in 1969 (Danni *et al.*, 1973). Two mafic-ultramafic bodies were mapped, the Mangabal Massif – currently called Mangabal Complex (Augustin and Della Giustina, 2019) – and the São João Massif – currently known as the Americano do Brasil Complex (hereafter ABC; Danni *et al.*, 1973; Nilson, 1981; Mota-e-Silva *et al.*, 2011; Fig. 2.1C).

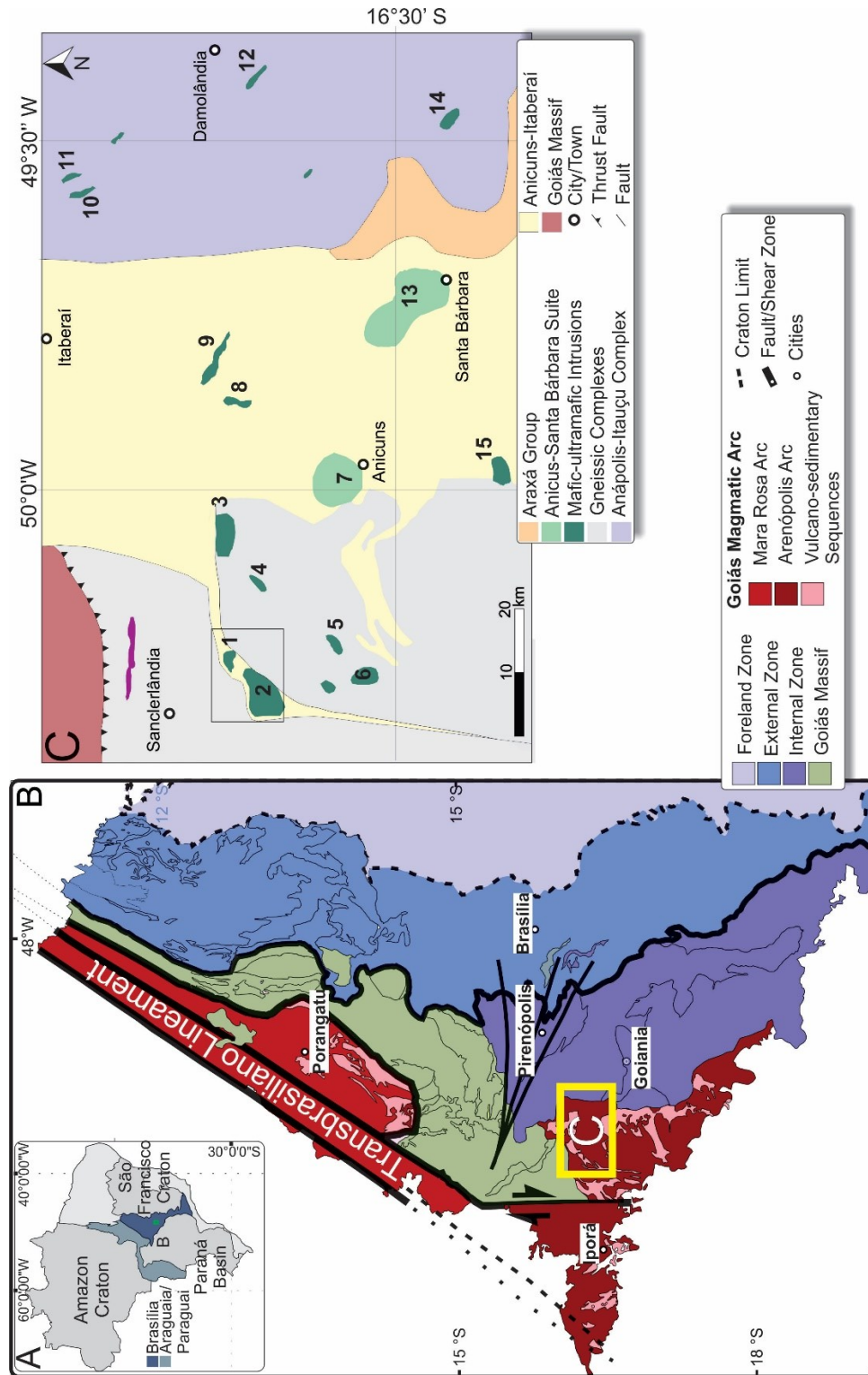


Figure 2.1. Spatial location of Brasília Belt in Brazil. B) Brasília Belt schematic geological map (modified from Pimentel *et al.*, 2004; Macedo *et al.*, 2018), colours differentiate tectonic zonation. Goiás Magmatic Arc in dark red. C) Simplified geological map of the area indicated in B. D: Analytical signal amplitude (nT/m) applied to magnetic anomalies, with the contours of the intrusions. Geophysical data from CPRM (2004).

Nilson (1981) first described the ABC as a small layered pluton consisting of mafic and ultramafic cumulate rocks containing ubiquitous megacrysts of poikilitic pargasitic hornblende, with associated amphibolite facies minerals. The ABC was emplaced into orthogneisses and minor mica-schist of the southern domain of the Goiás Magmatic Arc. The complex became well known due to the development of the Americano do Brasil underground Ni-Cu-Co mine developed through a joint venture between Prometalica Ltd. and Votorantim Metais Ltd., which ended operations in 2014. It was the object of geological survey and mineral exploration, including drilling and some petrographic studies of cumulate rocks and associated Ni-Cu sulfide ore (Nilson, 1981, 1984; Nilson and Santos, 1982; Mota-E-Silva *et al.*, 2011). In the most recent work, the ABC has been interpreted as two distinct E–W-trending mafic-ultramafic sequences juxtaposed along the Salgado fault (Silva *et al.*, 2011). Regional isotopic studies indicated positive  $\epsilon_{\text{Nd}}$  (+3.1) and a TIMS U-Pb zircon age of  $626 \pm 26$  Ma, obtained from two zircons separated from a sample described as olivine-pyroxene norite (Nilson *et al.*, 1997; Laux, 2004).

## **2.3. Analytical Methods**

### **2.3.1. Sample Collection**

Samples from four representative drill cores (numbers AMB317, AMB366, AMB443 and AMB427) were selected for sampling based on the core-logging at the mine. The rock samples were selected to represent the different lithological associations and the stratigraphy of the complex. Polished thin sections were examined under transmitted/reflected polarizing microscopes to ensure the identification of all major rock types as well as their mineral associations and crystallization sequences, textures, and superimposed recrystallization due to metamorphism and deformation.

### 2.3.2. Whole-rock Major and Trace Elements

Twenty-five sample powders from the Americano do Brasil Complex and two internal standard (samples 18-CR-14-1 and 18-CR-14-2) were analyzed at the ALS geochemistry laboratories using a package for a complete sample characterization (ALS code CCP-PKG01). Whole rock major elements were analyzed via inductively coupled plasma atomic emission spectrometry (ICP-AES) on samples prepared by the lithium borate fusion method followed by nitric acid digestion (ME-ICP06). Base metals (Ag, Cd, Co, Cu, Mo, Ni, Pb, Sc and Zn) were digested in four acids (perchloric, nitric, hydrofluoric and hydrochloric acids), and then their concentrations were also determined by ICP-AES (ME-4ACD81). The lithophile elements were analyzed by inductively coupled plasma–mass spectrometry (ICP–MS) after the same lithium borate fusion and digestion as for the major oxides method (ME-MS81). The concentrations of As, Bi, Hg, In, Re, Sb, Se, Te and Tl were analyzed by ICP-MS after digestion in aqua-regia (ME-MS42). Total sulfur and carbon were analyzed by LECO infrared spectroscopy (ME-IR08). Platinum, palladium, and gold were determined by standard lead bead collection fire assay and ICP-MS finish. The geochemical data are given in the Appendix A. To permit comparison of samples that experiences different degrees of hydrous alteration, geochemical data used in this work were normalized to a volatile-free basis.

### 2.3.3. Mineral Chemistry

The compositions of major rock-forming minerals from several polished thin sections were determined by electron probe microanalysis (EPMA). Analyses were performed using a JEOL JXA-8230 superprobe with five wavelength dispersive spectrometers (WDS) at the University of Brasilia. Operating conditions for all silicate

minerals were 15 kV accelerating voltage, a beam current of 10 nA and probe diameters of 1  $\mu\text{m}$  for all minerals except plagioclase (5  $\mu\text{m}$ ). Counting times on peak and background were 10 s and 5 s, respectively. Energy dispersive X-ray spectroscopy (EDS) of several minerals was also performed to support petrographic studies.

## **2.4. Geology of Americano do Brasil Complex**

The area around the Americano do Brasil Complex is dominated by pasture and intense weathering, which can reach up to 40 m depth locally. The exposures are mostly small loose blocks, and the best-preserved occurrences are associated with amphibole-bearing rocks. Due to the lack of spatially extensive outcrops, drill cores were important to improve the understanding of the complex and its rocks.

In general, the ABC is about 2.5 km in length and about 1.5 km in width and is divided into two sequences by the E-W oriented Salgado Fault (Fig. 2.2). It is dominated by ultramafic cumulates; to the north of the fault, the most common rocks are olivine and olivine-pyroxene-cumulates, whereas the Southern portion has more evolved compositions dominated by pyroxene and pyroxene-plagioclase cumulates. Primary igneous textures are dominant, but a metamorphic overprint is marked by fracturing and sub-grain fragmentation due to dynamic recrystallization, twinning deformation, corona reactions, recrystallization and partial to complete replacement of the primary mineralogy by a hydrous assemblage (e.g., amphiboles, serpentine, chlorite). Intense amphibolitization is ubiquitous in the complex. Pegmatitic diorite and minor dolerite (-to gabbro) dykes commonly crosscut the complex, but they are more prominent and voluminous in the Southern portion.

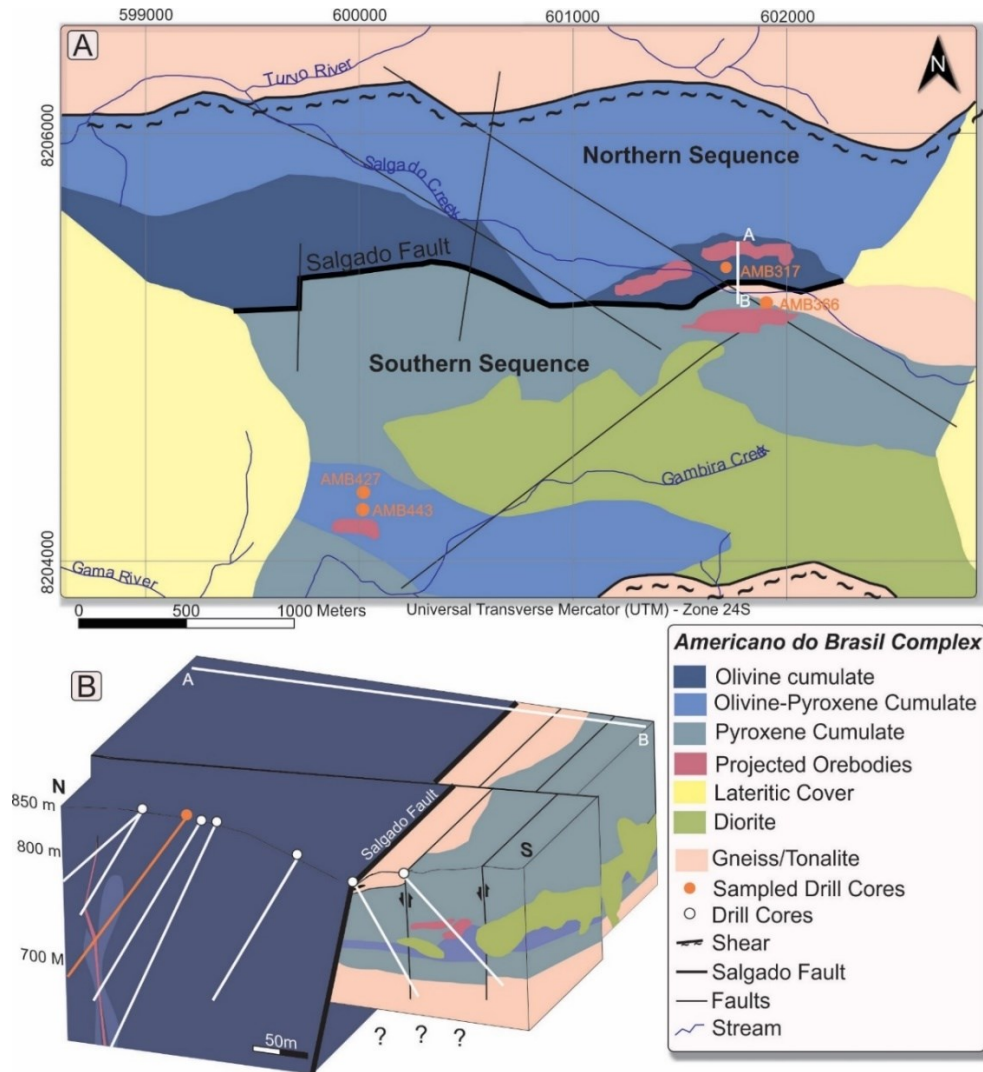


Figure 2.2 A) Geological map of the Americano do Brasil Complex. Adapted after Nilson (1981) and Silva et al (2011). B) Schematic cross section of the A-B line (drawn in 1.A) showing the simplified relationship of the southern and northern sequences along the Salgado's fault.

#### 2.4.1. Rock Types of the Americano do Brasil Complex

Although deformed and partially recrystallized, the ABC still preserves some relict igneous features which we emphasize in this work. Distinct primary rock types are distinguished on the basis of texture and mineralogical composition and will be here described according to the location related to the E-W fault (e.g., Northern and Southern sequences). The amphibolite-facies assemblage and metamorphic rocks will only be described when important to a better clarification.

The rocks of the Complex range from adcumulate to heteradcumulate texture, and the nomenclature is based on the recognizable cumulus minerals, even though some rocks contain sufficient postcumulus material to be compositionally classified in another way. The cumulate term is used in this work to describe the texture of the rock and not imply any specific mechanism for the formation of the cumulus minerals.

#### 2.4.1.1. Northern Sequence

The Northern sequence is dominated by olivine adcumulates, i.e., dunite, that gradually transition to lenses and/or layers of olivine-clinopyroxene adcumulate.

Olivine cumulate is a massive medium-grained rock, ranging in colour from black, when fresh, to yellowish-grey when weathered. It contains abundant subhedral to anhedral olivine, commonly occurring as subrounded and equidimensional to slightly elongated crystals. Cumulus Cr-spinel occurs as inclusions in olivine and in the matrix, and its amount does not exceed 2% of the volume of the rock. The texture is most commonly adcumulate with up to 5% of intercumulus pyroxene and amphibole, but it locally shows a mesocumulate texture. Olivine is commonly altered to serpentine and magnetite in a mesh texture (Fig. 2.3A), secondary chlorite, carbonate, and talc are also common alteration products in these rocks.

The olivine-clinopyroxene adcumulate (or clinopyroxene-olivine cumulate) occurs as layers or lenses, showing gradational contacts with enclosing packages of dunite in the south, and increases in volume to the north. In hand-specimen the rock is grayish, due to the appearance of clinopyroxene as cumulus mineral. It is a medium to coarse-grained cumulate, which consists of rounded to sub-rounded olivine and subhedral clinopyroxene grains (Fig. 2.3B); the former is commonly altered to serpentine in a mesh texture and the



latter into amphibole (tremolite to magnesium hornblende). Minor (<1 vol. %) cumulus chromium-rich magnetite occurs either as inclusions or interstitial to cumulus olivine and pyroxene. Subordinate orthopyroxene occurs locally as distinct equant cumulus grains rather than as oikocrysts, generally not exceeding 5% of the cumulus portion. Some isolated portions of the rock contain higher amounts of interstitial amphibole (up to 10%), typically with a dusty appearance resulting from needle-like exsolution of iron-titanium oxides. Locally, it is possible to identify the replacement of the borders of olivine by granoblastic orthopyroxene (Fig. 2.3C) and/or orthopyroxene-magnetite symplectites in corona textures.

#### 2.4.1.2. Southern Sequence

To the south of the Salgado fault, the rocks of the ABC are rich in pyroxenes, plagioclase and/or hornblende. The primary mineralogy is widely transformed into secondary hydrous minerals due to superimposed regional metamorphism and/or hydrothermal alteration spatially associated with dioritic dykes. The Southern sequence has a more intense amphibolitization compared to the Northern sequence and more voluminous dioritic veins.

The most common rock in this portion is clinopyroxene-orthopyroxene cumulate, ranging locally to pyroxene-plagioclase cumulate. In places, thick packages of these rocks have their original texture and mineralogy completely overprinted by metamorphic assemblages, and here are described as metaultramafics.

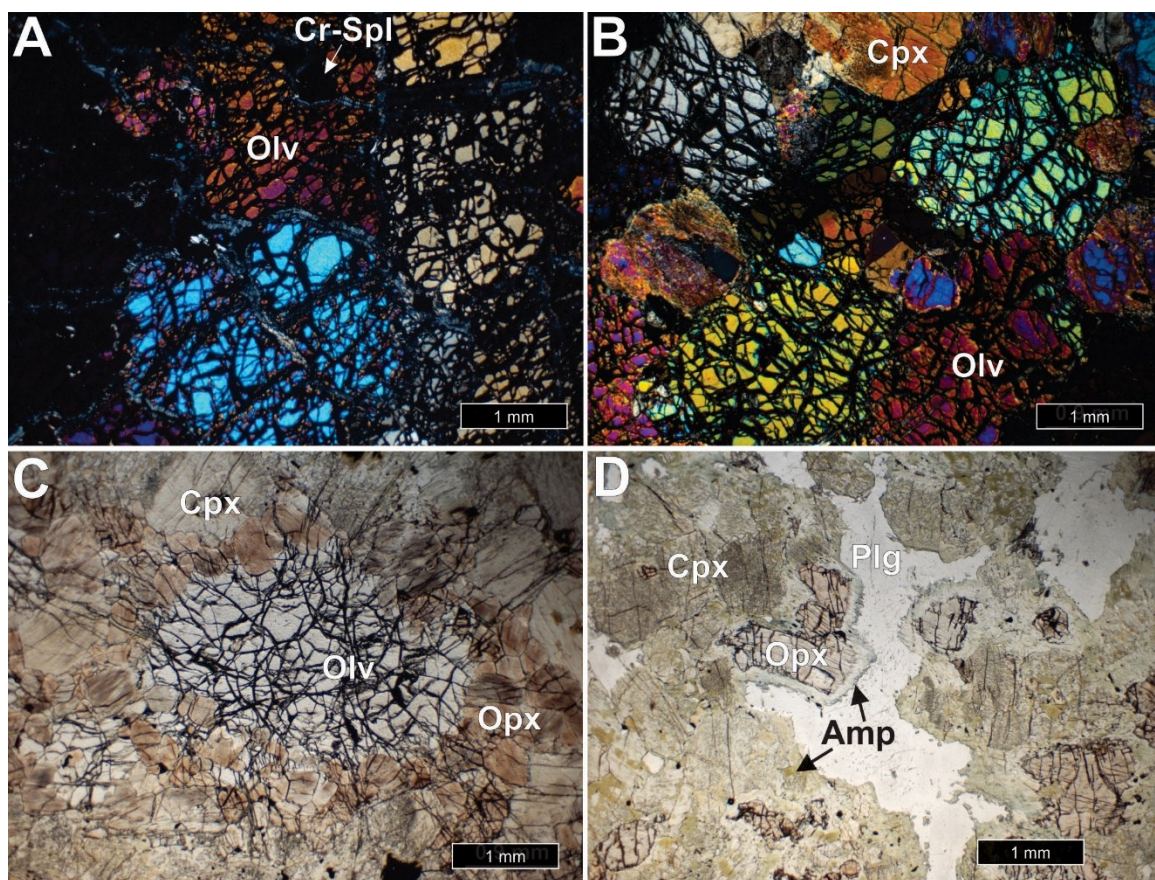


Figure 2.3. Photomicrographs of cumulate rocks of the Americano do Brasil Complex. (A) Olivine cumulate in cross-polarized light. (B) Olivine-clinopyroxene cumulate in cross-polarized light. The clinopyroxene is partially replaced by amphibole and olivine by serpentine in mesh texture. (C) Detail in plane-polarized light of clinopyroxene-olivine cumulate, with granular orthopyroxene corona around olivine. (D) Pyroxene-cumulate in plane-polarized light; clinopyroxene is intensely replaced by amphibole with needle-like exsolutions of Fe-Ti oxides. Pyroxene-plagioclase contact is almost completely mantled by an amphibole corona.

Two-pyroxene cumulate is medium-grained, with approximately equal amounts of cumulus clinopyroxene and orthopyroxene that range from subhedral to euhedral. Clinopyroxene crystals commonly show substitution by secondary hornblende along crystallographically controlled planes and rims, locally small preserved relict clinopyroxene grains remaining in the core. Orthopyroxene is generally rimmed by secondary amphibole when in contact with plagioclase (Fig. 2.3D), similar to clinopyroxene. Plagioclase and minor hornblende are the most common interstitial minerals; the latter can occur as poikiloblasts, encompassing the relict orthopyroxene

crystals. The modal proportion of cumulus and intercumulus grains is difficult to define due to intense reaction of pyroxenes and plagioclase with metamorphic hydrous fluids to form amphiboles. This transformation is mainly spatially associated with the diorite veins. In addition to pyroxene, a smaller amount of cumulus olivine or plagioclase appears locally. Olivine, when present, is partially to almost completely replaced by orthopyroxene in corona textures and/or replaced by symplectites of iron oxides and orthopyroxene. Sulfides and oxides occur as interstitial material between pyroxene and are commonly included in the other interstitial minerals such as plagioclase. The pyroxene-plagioclase cumulate is found locally as layers/lenses. It is textured similarly to the two-pyroxene cumulate rocks, marked by the appearance of small amounts of cumulus plagioclase.

The southwestern portion of the ABC contains some olivine-pyroxene cumulates, which are associated with massive to semi-massive sulfides. These are composed of olivine, clinopyroxene and orthopyroxene, the latter occurring as minor cumulus grains and more voluminous oikocrysts encompassing olivine. The silicates occur mainly as clasts in a sulphide-matrix breccia. In sulfide-poor portions, interstitial amphibole (pargasite) occurs in poikilitic texture and commonly replaces clinopyroxene oikocrysts almost completely. The textural relations between the primary cumulus phases are obscure due to the lack of preserved primary contact and pervasive recrystallization of the igneous minerals.

#### 2.4.1.3. Sulfide Mineralization

The sulfide mineralization in Americano do Brasil forms 3 orebodies, one of them, named S2, located within the Northern sequence, and the other two, known as G2 and S1, appearing in the Southern sequence.

The S2 orebody is composed of cumulus olivine, partially serpentinized to a mesh-texture, enclosed in a net-textured to semi-massive sulfide matrix (Fig. 2.4A). The intercumulus sulfide consists of pyrrhotite, chalcopyrite, and pentlandite, in descending order of abundance. Pyrrhotite exhibits minor exsolved flames of pentlandite. Pentlandite also occurs as polycrystalline aggregates along with pyrrhotite crystals, mainly close to serpentine-filled fractures and commonly in contact with olivine. Chalcopyrite occurs in anhedral aggregates. Pyrite is secondary and occurs filling fractures and/or parting planes of sulfides, commonly associated with serpentine veins. Extensive serpentinization has visible effects on the sulphides, which are highly fractured. Serpentine and magnetite veins crosscut the primary sulphides. The sulphides cut by veins associated with hydrous alteration are commonly replaced by secondary minerals along the fractures, where magnetite replaces pyrrhotite and cubanite is formed after chalcopyrite.



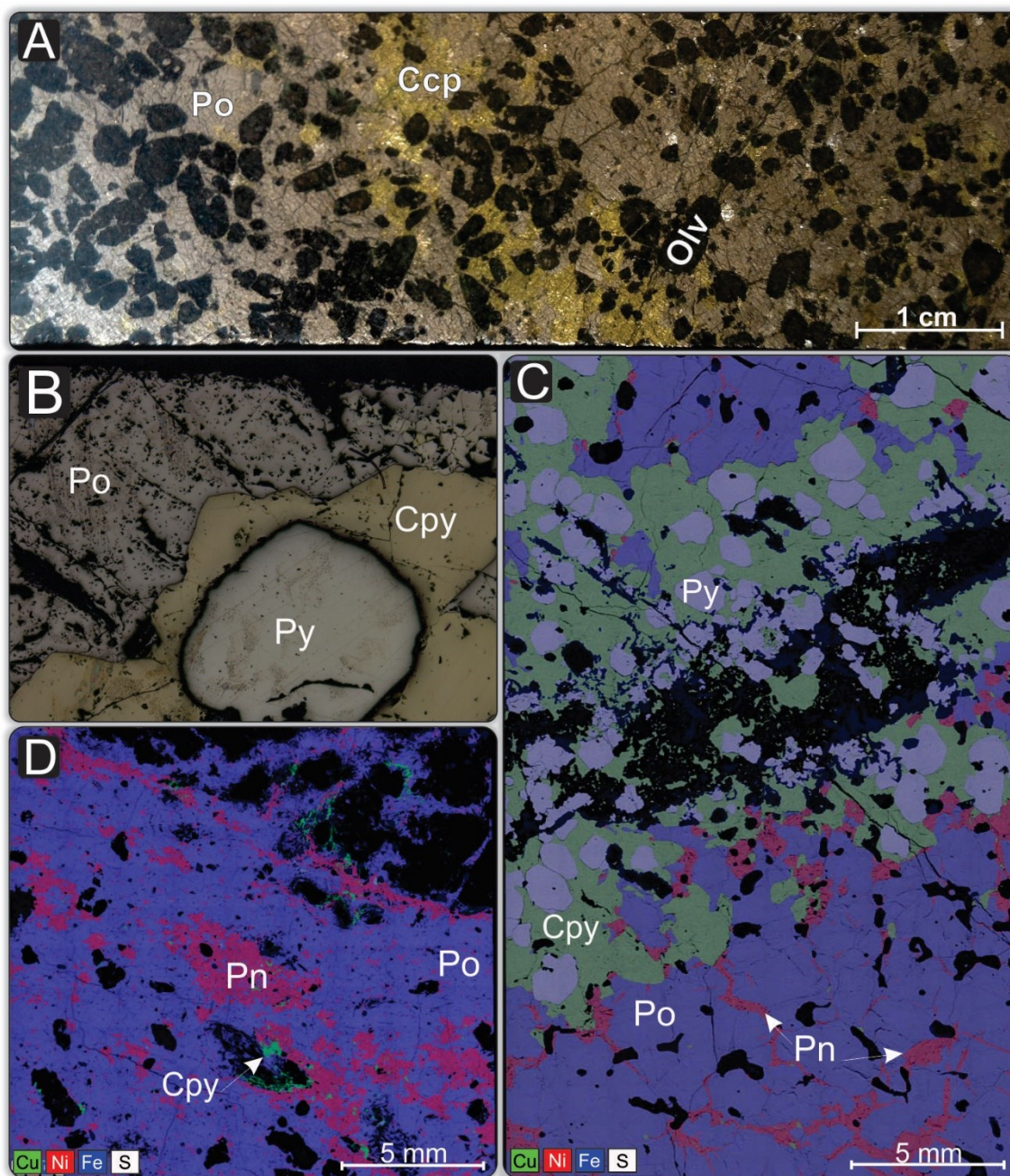


Figure 2.4. (A) Semi-massive ore in olivine cumulate, sample from S2 orebody. (B) Reflected light photomicrograph of the thin section containing core of pyrite, surrounded by rim of chalcopyrite in pyrrhotite matrix. (C) C-D) Compositional EDS maps. (C) Massive sulfide sample from the S1 orebody showing close relationship of pyrite-chalcopyrite-magnetite assemblage with hydrous-rich vein crosscutting the section. (D) Massive ore from G2 orebody with tectonically mobilized and recrystallized massive ore, showing granoblastic textures and foliation defined by flattened pentlandite aggregates.

In the northeastern portion of the Southern sequence, the S1 orebody, which ranges from disseminated to lenses of massive sulphide, is mainly hosted by pyroxene cumulates

and pyroxene-plagioclase cumulates. The sulphides are composed of pyrrhotite with associated pentlandite, chalcopyrite, and pyrite. The S1 orebody includes portions with typical magmatic textures as large blebby pyrrhotite and pentlandite exsolution (loops or flames can occur) and minor chalcopyrite. The pyrite is commonly surrounded by chalcopyrite rims and immersed in the pyrrhotite matrix, with zoning visible on a macroscopic as well as at microscopic scales (Fig. 2.4B). Pyrite-rich domains are commonly associated with hydrothermal veins rich in carbonates and/or silicates, such as quartz, biotite, amphibole. Anhydrite is also found associated with alteration zones. The sulfides closely associated with hydrous minerals/veins are altered from pyrrhotite-pentlandite-chalcopyrite association into pyrite-chalcopyrite, with magnetite locally occurring close to silicate phases (Fig. 2.4C).

The G2 orebody occurs in the southwestern portion of the Southern sequence and is hosted by olivine-pyroxene cumulates. The ore textures range from net-textured to massive breccia, with localized tectonic *durchbewegung* (german for "through motion or movement", defined by Ramdohr, 1960) breccias. The massive ore comprises a matrix of sulphide with floating or imbricated inclusions of the ultramafic clasts and/or minerals, with phenocrysts commonly replaced by sulfides. The sulphide mineralization has the typical magmatic sulphide assemblage of pyrrhotite, pentlandite and chalcopyrite, but is intensely recrystallized, evidenced by granoblastic textures and foliation defined by flattened pentlandite aggregates (Fig. 2.4D). Portions richer in phyllosilicates such as serpentine can show preferred strong planar alignment and folding, concordant with exsolved pentlandite in pyrrhotite. In these foliated portions, silicate inclusions are strongly

replaced by hydrous phases including serpentine, amphiboles, and talc. Some inclusions of silicate minerals were replaced by pseudomorphs of sulfide.

#### 2.4.1.4. Country Rocks and Later Intrusions

The complex was emplaced into the tonalitic gneiss of the Turvânia block (Fig. 2.1B), which is commonly composed of a thinly banded and foliated rock dominated by plagioclase, hornblende, quartz, biotite, and epidote, with minor K-feldspar, chlorite, garnet and titanite. At the northernmost exposures, a garnetiferous mica schist crops out, concordant with the foliation of the gneisses. All the observed contacts of the ABC complex with the gneissic rocks are tectonic and marked by shear zones, in which gneisses are mylonitized and altered to an assemblage of sericite, epidote and carbonate.

The dioritic veins can be varitextured, showing variations from fine to very coarse-grained over short distances. They are more commonly pegmatoidal, consisting basically of equal amounts of euhedral hornblende, reaching up to 4 cm in length, and plagioclase, which is commonly white due to intense saussuritization. The veins vary from millimetres to meters in thickness and occur in more than one generation. The rocks in contact with and close to the veins show intense amphibolitization, reaching locally up to 80% of amphibole. These amphibole-dominant rocks adjacent to diorite were previously described in core logging as hornblendites, metapyroxenites and/or pyroxenites.

Dolerite occurs as dykes that range from 1 cm to up 5 m in thickness that crosscut the complex, the gneissic host rocks and the dioritic veins. It is commonly recrystallized to granoblastic assemblages of clinopyroxene, plagioclase, orthopyroxene, ilmenite, and magnetite. It is very fine grained, with relict porphyritic texture, where it is possible to identify former plagioclase phenocrysts that have undergone dynamic recrystallization. Fe-

Ti oxides are abundant, occurring both as relict phenocrysts and in the matrix. Sulfide minerals, including pyrite, chalcopyrite, and pyrrhotite, are present in trace amounts. In the interiors of larger dolerite dikes (~5 m), the grain size increases to a medium-grained but still non-cumulate (diabase-textured) gabbro. Where the dolerite has undergone local deformation, it is completely transformed into a very fine-grained foliated rock with an amphibolite assemblage marked by hornblende, plagioclase, oxides, and apatite.

## **2.5. Geochemistry**

### **2.5.1. Mineral Chemistry**

Although the olivine is largely replaced by serpentine, it is still possible to identify relict grains preserved well enough to permit quantitative analysis on the EPMA. Analyzed olivine in the Americano do Brasil Complex ranges from Fo<sub>80</sub> to Fo<sub>87</sub> (Fig. 2.5A). In the Northern sequence, the forsterite content (Fo) ranges from 80 to 84, while Ni content varies from 1300 to 2950 ppm. In the Southern sequence, olivine was identified only in the G2 orebody, where it has compositions ranging from Fo<sub>85</sub> to Fo<sub>87</sub>, and Ni content ranging from 479 to 1524 ppm. In a plot of Ni in olivine versus Fo content (Fig. 2.5A), the Ni concentrations in olivine increase slightly with increasing Fo in the Northern sequence; the Southern sequence has a lower Ni content.

Clinopyroxene in both sequences is diopside with a few compositions straddling the augite-diopside boundary (Fig. 2.5B). Clinopyroxene from the Southern sequence of Americano do Brasil contains up to 0.5 wt.% TiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> up to 3.4, Cr<sub>2</sub>O<sub>3</sub> reaching up to 0.3, and magnesium-number (molar 100\*Mg/Mg+Fe; Mg#) ranging from 70 to 88. Clinopyroxene from the Northern sequence is similar with values of up to 0.68 wt.% TiO<sub>2</sub>, 4.7 wt.% Al<sub>2</sub>O<sub>3</sub>, 0.828 wt.% Cr<sub>2</sub>O<sub>3</sub> and Mg# between 78 and 93. Orthopyroxene is



classified as enstatite with compositions ranging between En<sub>81</sub> and En<sub>84</sub> in the Northern sequence and from En<sub>74-84</sub> in the Southern sequence.

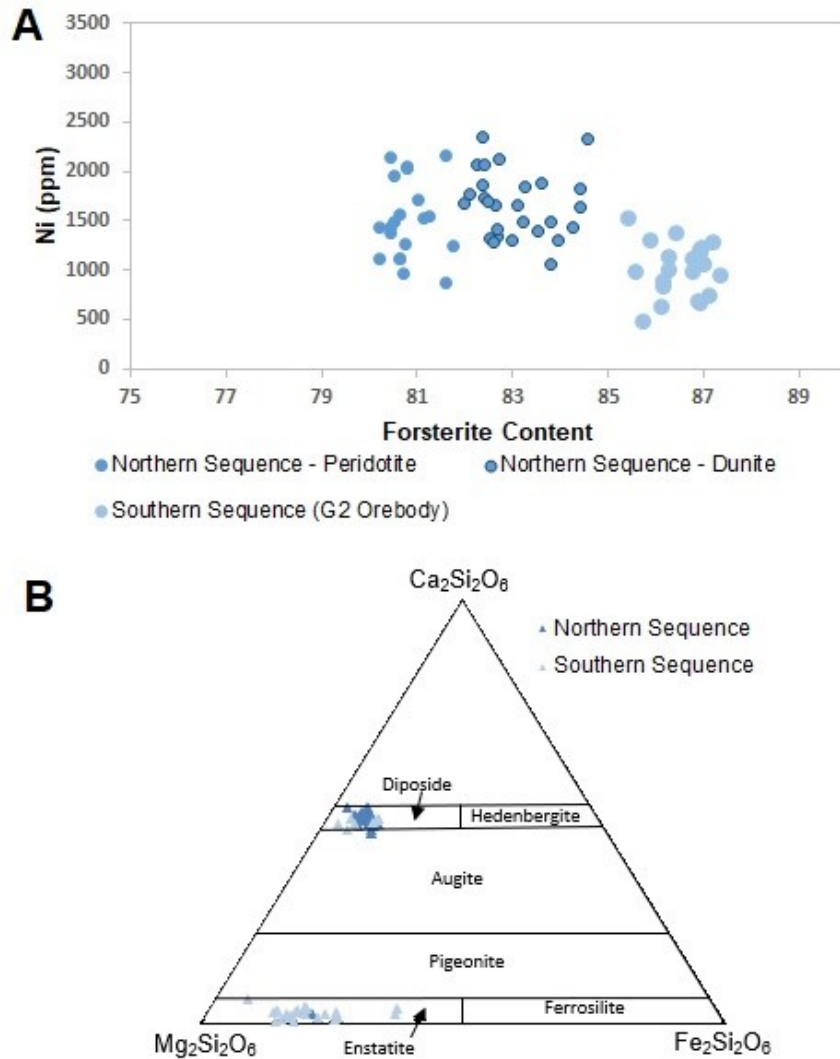


Figure 2.5. A: Plot of forsterite content vs Ni (ppm) in analyzed olivine. B: Orthopyroxene and clinopyroxene compositions for cumulate minerals. Pyroxene nomenclature is from (Morimoto, 1988).

### 2.5.2. Major Element Geochemistry

Whole-rock compositions of the different lithologies analyzed in this study are given in Appendix A. The concentration of the major elements in rocks of the Americano do Brasil Complex is inferred to be mainly controlled by variation in the proportions of the cumulus minerals (olivine and/or clinopyroxene), but the quantity of intercumulus material

has some influence, mainly in the Southern sequence, where the textures are more variable compared to the Northern sequence and there is more interstitial plagioclase. Rocks from the Northern Sequence analyzed in this study have MgO content that ranges from 42 to 24 wt.%. There are well-defined trends of negative correlation of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{CaO}$  and  $\text{Na}_2\text{O}$  with MgO (Fig. 2.6), consistent with the removal of mafic minerals from a liquid. The FeO has a positive correlation with MgO.

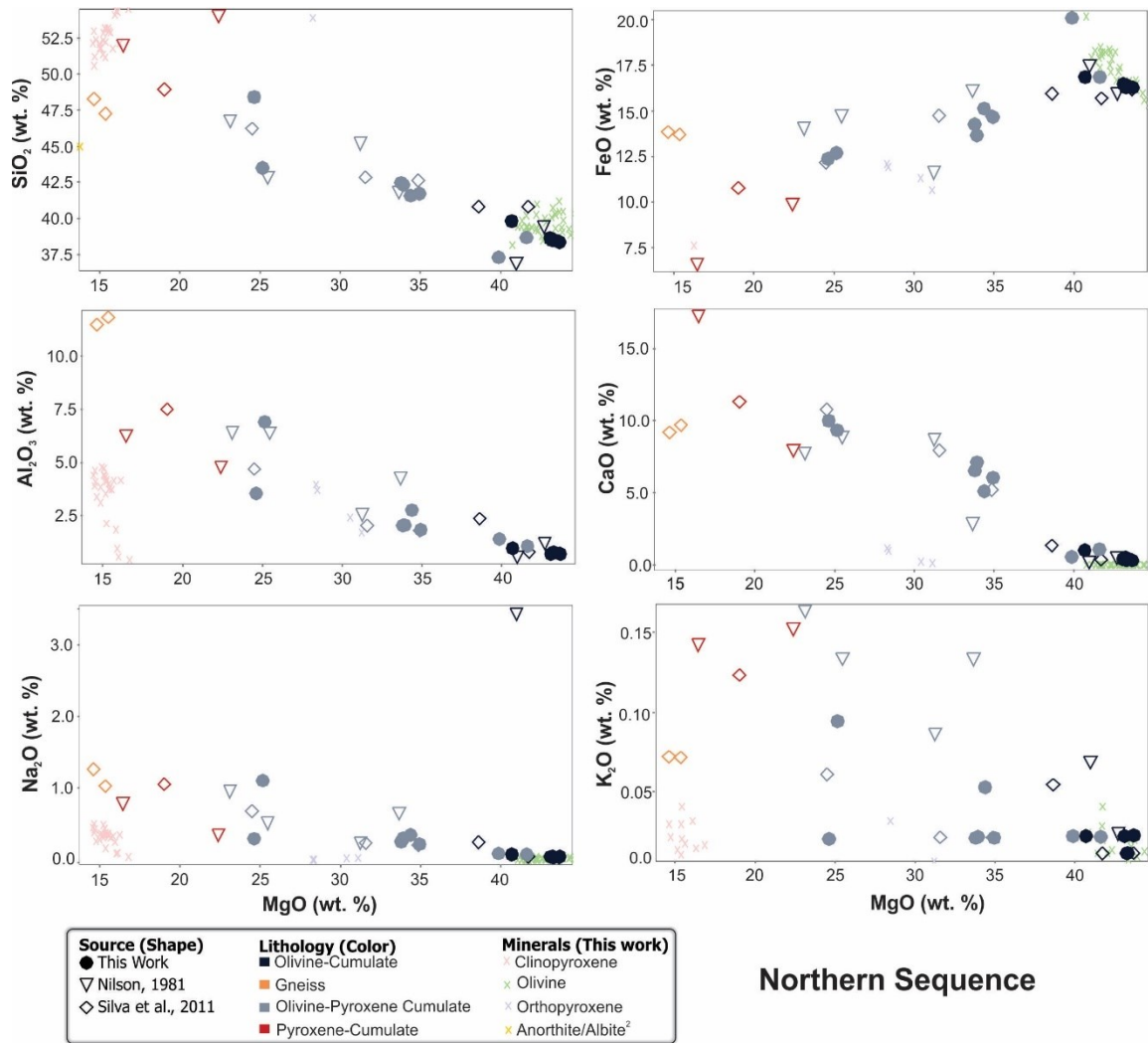


Figure 2.6. Whole-rock  $\text{SiO}_2$ , FeO,  $\text{Al}_2\text{O}_3$ , CaO,  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  vs MgO bivariate plots for Northern sequence. Filled circles are from this work, outlined triangle and diamond shapes are from Silva et al (2011) and Nilson (1981) respectively. Olivine (OLV), clinopyroxene (CPX) and orthopyroxene (OPX) were values measured in this work. DU olivine cumulates, PD olivine-pyroxene cumulate, PX pyroxene cumulate, GT pyroxene-plagioclase cumulate, GN gneiss.

Although the pyroxene cumulates of the Southern portion show similar trends (Fig. 2.7), these are not as well defined, due to highly variable modal proportions of cumulus phases and intercumulus material, which reaches up to 40 % vol. In rocks of the Southern sequence, the MgO concentrations are much lower, ranging from 12.4 wt% to 18.4 wt% while the FeO content ranges from 12 to 14 wt%. The  $\text{Al}_2\text{O}_3$  and  $\text{Na}_2\text{O}$  contents show well-defined trends due to the presence of plagioclase, ranging from 8 to 15.5 wt.% and up to 0.5 wt.% respectively. The CaO concentration is variable, ranging from 7 up to 13 wt.%, where the highest values occur in rocks richer in clinopyroxene than orthopyroxene.

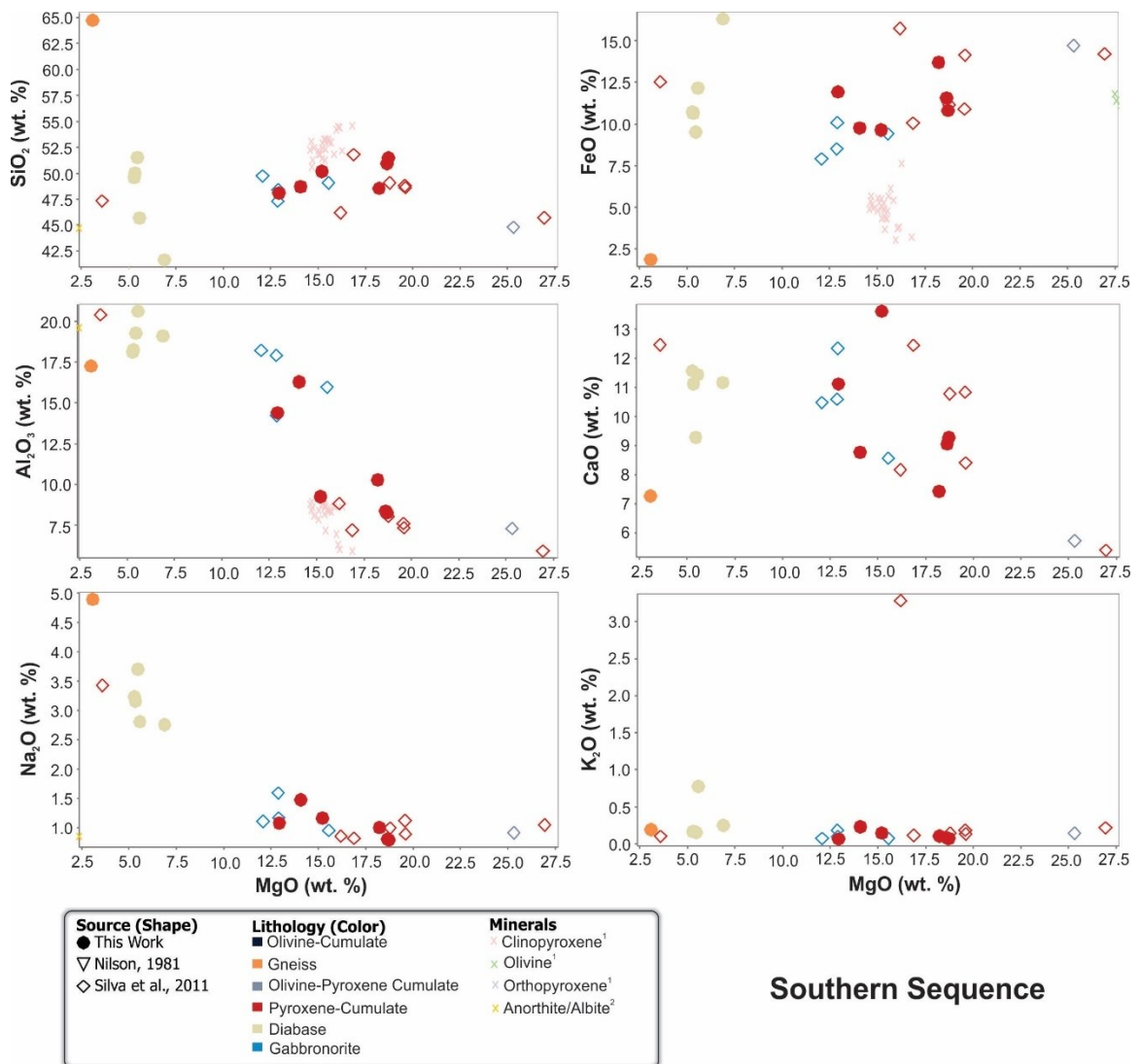


Figure 2.7 Whole-rock  $\text{SiO}_2$ ,  $\text{FeO}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{CaO}$ ,  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  vs  $\text{MgO}$  bivariate plots for Southern sequence. Filled circles are from this work, outlined triangle and diamond shapes are from Silva et al (2011), ) and Nilson (1981) respectively. Olivine, clinopyroxene, orthopyroxene and plagioclase were values measured in this work (X symbol). The colours are the same as in Figure 2.5. PX pyroxene cumulate, GT pyroxene-plagioclase cumulate, GN gneiss. DB diabase.

The diabasic rocks (and related gabbros) have characteristics of more evolved rocks. They have lower values of  $\text{MgO}$  ranging from 5 to 8 wt%, and values of  $\text{Na}_2\text{O}$  and  $\text{Al}_2\text{O}_3$  ranging up to almost 5 wt. % and 21 wt. % respectively. Overall, the diabase has much more evolved compositions than the rocks of the complex, with distinct lower  $\text{MgO}$  content, and higher  $\text{Na}_2\text{O}$  and  $\text{Al}_2\text{O}_3$ , showing a separate cluster from the measured rocks of the complex.

### 2.5.3. Trace Element Geochemistry

Primitive mantle-normalized rare earth element (REE) and incompatible trace-element patterns of rocks from Americano do Brasil are shown in Figure 2.8. In general, the rocks from the southern sequence have higher values in REE and trace elements. Olivine-clinopyroxene and clinopyroxene-orthopyroxene cumulates are enriched in middle REE (MREE) relative to both light REE (LREE) ( $\text{La}_N/\text{Sm}_N = 0.1$  to  $0.5$  and  $0.7 - 0.9$  in the Northern and Southern respectively) and heavy REE (HREE) ( $\text{Sm}_N/\text{Yb}_N = 1.6-3.1$  and  $1.6-2.2$  in the Northern and Southern respectively). The Northern sequence shows a deeper HREE depletion compared to the Southern sequence ( $\text{Gb}_N/\text{Yb}_N = 1.7$  to  $4.0$  in the Northern sequence, and  $1.2$  to  $1.8$  in the Southern sequence). The olivine cumulates from the Northern sequence and the diabase rocks from the Southern sequence are enriched in LREE relative to HREE without the MREE enrichment in the clinopyroxene cumulates.

Most of the rocks show some similarities in the patterns in the multi-element diagram. The samples are not enrichment in large-ion lithophile elements (LILE) relative to the high-field strength elements (HFSE) in general, but some of them (Th, U and Ta) are below or close to detection limit. A distinctive positive Sr anomaly is ubiquitous, and negative Zr, Hf, P, and Nb anomalies are identified in all rocks of the Southern sequence.

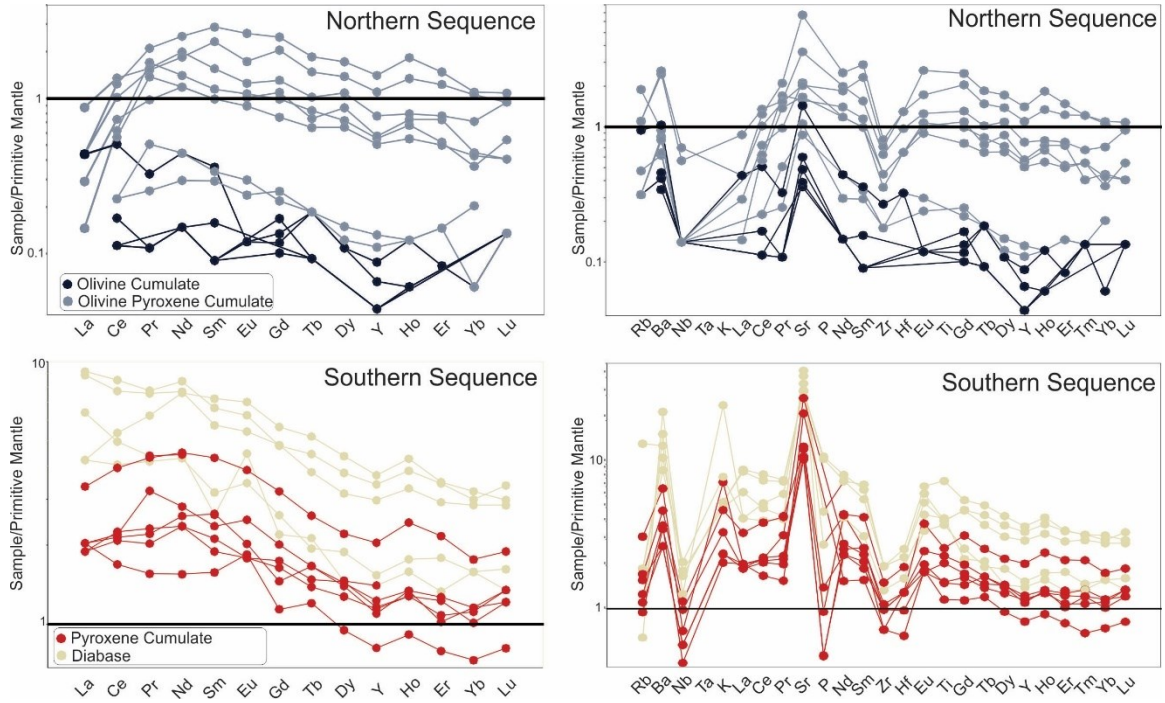


Figure 2.8. Primitive mantle-normalized REE and multi-element trace element patterns for both Northern and Southern sequences of Americano do Brasil Complex. Normalization from Sun and Mcdonough (1989).

## 2.6. Discussion

### 2.6.1. Thermodynamic Modeling

In order to address the composition and evolution of the melt parental to the cumulates of both the Northern and Southern portions of the Americano do Brasil Complex, we have modelled crystallization using the alphaMELTS thermodynamic software 1.9 (Ghiorso and Sack, 1995; Asimow, 1998; Smith and Asimow, 2005). The contacts of the complex with the country rocks are marked by intense shearing and/or metamorphic/hydrothermal alteration, preventing the preservation and identification of a chilled margin. Also, no volcanic rocks or dikes have been identified that could be inferred to be compositional equivalents to the initial liquid. Several basaltic compositions representing mafic rocks/liquids described elsewhere along the extent of the Brasília Belt (e.g., Girardi *et al.*, 1986; Laux *et al.*, 2010; Correia *et al.*, 2012; Brown *et al.*, 2020;

Piauilino *et al.*, 2021) were tentatively used to estimate the composition of the initial liquid, but the mafic volcanic rocks described so far do not have Mg# high enough to form the most magnesian olivine of the Complex, nor would they generate similar cumulus assemblages in general.

In an effort to find a reasonable starting liquid composition for modeling of the evolution of the suite, a wide variety of other known primitive basaltic liquid compositions were considered, all of which have been proposed as the parental magmas to other known layered intrusions around the world, e.g., Penchenga, Jinchuan, Duke Island, Georgia Arc picrites (Ramsay *et al.*, 1984; Chai and Naldrett, 1992; Naldrett, 2004; Thakurta *et al.*, 2008; Li and Ripley, 2011). All petrological simulations were done using various pressures between 1.0 and 7.5 kbar, H<sub>2</sub>O contents ranging from 0.5% to 4% and oxygen fugacities  $fO_2$  between -1.5 and +1.5 log units relative to FMQ (fayalite–magnetite–quartz solid oxygen buffer). However, the thermodynamic modelling results from all of these hypothetical parental magmas were inconsistent with the observed mineral assemblages and chemical compositions of the natural rocks.

We eventually settled on the composition of a picrite from the Mid-Continent Rift (of the Keweenaw large igneous province) in Minnesota, USA (Lightfoot *et al.*, 1999), which we selected because it combined a relatively Fe-rich character with moderate LILE and HFSE enrichment, similar to the patterns observed in the ABC, and is of broadly similar Proterozoic age in agreement with the Goiás Magmatic Arc ages. Comparison of the composition of this parental liquid and the ultramafic cumulates of the Northern Sequence of Americano do Brasil complex suggests that the Northern sequence formed from a magma very similar to the Mid-Continent Rift magma, with little to no evidence of

contamination by its country rocks nor any other persuasive indication of a crustal signature.

Efforts to reproduce the observed cumulate compositions using a model of their accumulation from the parental liquid during a process of fractional crystallization were unsuccessful for two reasons. First, due to the peritectic reaction between olivine and orthopyroxene, concomitant precipitation of olivine and pyroxene was not achieved in any fractional crystallization models. In contrast, in an equilibrium crystallization model, olivine and orthopyroxene coexist over a wide range of temperatures and modal proportions. Second there is no evidence of a systematic decrease in whole-rock Mg#, forsterite content of olivine or decreasing anorthite content of plagioclase with stratigraphic position consistent with fractional removal of forsteritic olivine and anorthitic plagioclase..

Thus, the working hypothesis was that it might be possible to produce representatives of each cumulate via batch crystallization from a primitive liquid. Nilson (1981) estimated that the pressure of emplacement for the Americano do Brasil Complex was up to 5 kbar. Using the empirical model described by Putirka (2008), the clinopyroxene-orthopyroxene in cumulates of the Northern Sequence indicates ranges of 2-5 kbar, with  $K_D(\text{Fe-Mg})^{\text{cpx-opx}}$  ranging from 0.7 – 0.8, which lies around the indicated parameters for subsolidus equilibration (Putirka, 2008). Thus, we considered a pressure consistent with previous geological constraints (Nilson, 1981). Cooling of our chosen picrite under isobaric conditions at 2.5 kbar and  $f\text{O}_2$  0.5 log units above FMQ produced a similar sequence of crystallization and modal proportions of solids to the observed bulk-rock and mineral compositions of all major constituents of the Northern sequence of Americano do Brasil. This model predicts the crystallization of olivine ( $\text{Fo}_{88}$ ) starting at a



liquidus temperature of 1310 °C, followed by the appearance of clinopyroxene (Mg# 82) at 1190 °C and orthopyroxene (Mg#81) at 1170 °C. Between 1220 °C and 1150 °C the model predicts the entire range of ultramafic rocks analyzed in the Northern sequence. Modeled olivine, clinopyroxene and orthopyroxene compositions show good agreement with much of what is measured in the rocks (Fo<sub>83-79</sub>, En<sub>82-80</sub>, En<sub>80</sub>, respectively), as well as the whole-rock major element concentrations. A comparison of modeled solids and natural occurrences is shown in Table 1. The range of compositions of olivine and pyroxene could be entirely accounted for by a model of batch crystallization of the picrite liquid, followed by accumulation of crystals in slightly different proportions, and subsequent re-equilibration of minerals and up to 5% trapped liquid during cooling, consistent with the adcumulate texture. The REE distribution pattern of the measured samples and model is comparable in Figure 2.9. The success of the batch crystallization model implies that the cumulates were emplaced into the complex as batches or slurries of crystals that remained entrained in the magma during varying degrees of cooling.

*Table 2-1 Results of alphaMELTS model compared with rocks of the Americano do Brasil Complex. Picrite liquid used is sample #7 from Lightfoot et al. (1999).*

| Sequence Conditions: | Northern                                  |                    |                                   |                                   |                                                  |                                                  |
|----------------------|-------------------------------------------|--------------------|-----------------------------------|-----------------------------------|--------------------------------------------------|--------------------------------------------------|
|                      | 2.5 Kbar, FMQ +0.5, H <sub>2</sub> O 0.5% |                    |                                   |                                   |                                                  |                                                  |
|                      | Olivine Cumulate                          |                    | Olivine-Clinopyroxene Cumulate    |                                   | Olivine-Clinopyroxene-Orthopyroxene Cumulate     |                                                  |
|                      | Model                                     | Natural            | Model                             | Natural                           | Model                                            | Natural                                          |
| Liquidus (°C)        | 1220-1200                                 | -                  | 1180-1190                         | -                                 | 1170-1190                                        | -                                                |
| Mineralogy           | Olivine, Cr-spinel                        | Olivine, Cr-spinel | Olivine, Cr-spinel, Clinopyroxene | Olivine, Cr-spinel, Clinopyroxene | Olivine, Cr-spinel, Clinopyroxene, Orthopyroxene | Olivine, Cr-spinel, Clinopyroxene, Orthopyroxene |
| Fo                   | 83                                        | 82-83              | 80-81                             | 80-82                             | 77-79                                            | 80-81                                            |
| mg# (Cpx)            | -                                         | -                  | 82                                | 78-87                             | 81-80                                            | 83-84                                            |
| mg#(Opx)             | -                                         | -                  | -                                 | -                                 | 80-81                                            | 78-82                                            |

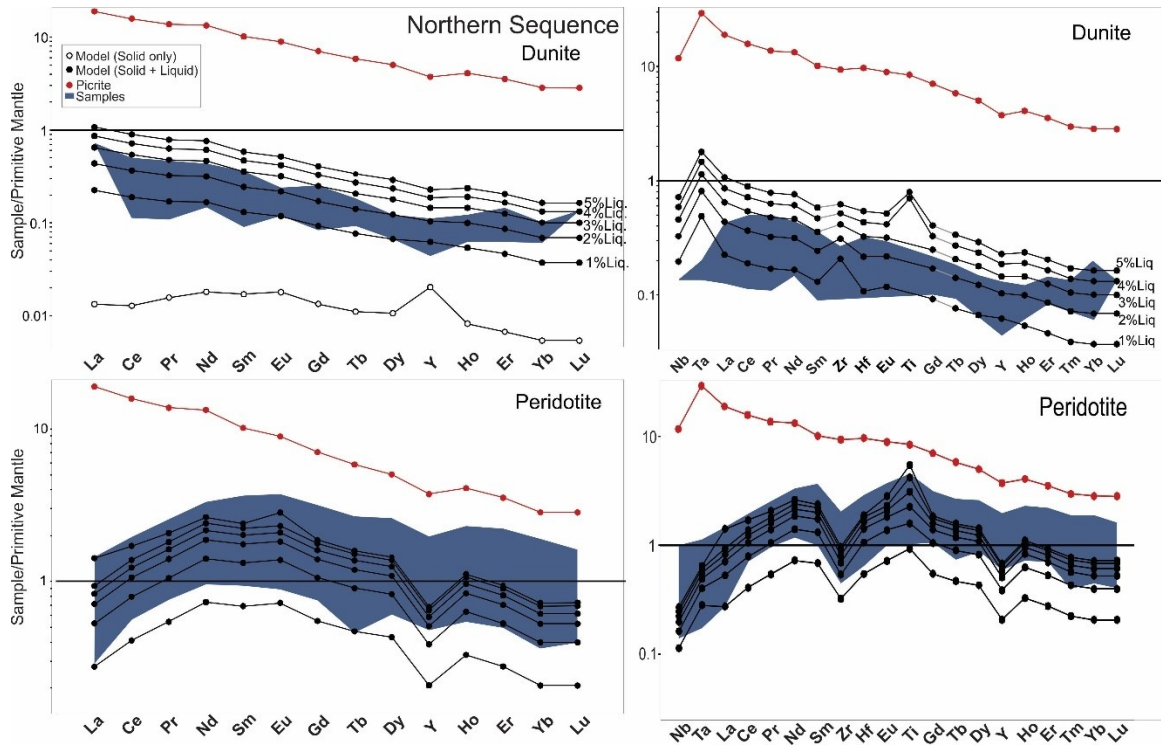


Figure 2.9. Primitive mantle-normalized REE and multi-element plots for natural and model rocks from the Northern sequence of the ABC. The shaded portion shows the range of compositions of rocks of Americano do Brasil Complex. Normalization from Sun and Mcdonough (1989). The black lines represent modeled cumulate rocks with indicated weight fractions of trapped liquid and red is the picrite magma used as the parental liquid in the models (#7, Lightfoot et al., 1999).

The Southern sequence is represented mainly by pyroxene cumulates and minor pyroxene-plagioclase cumulates. Rocks similar to the ones in this sequence can be predicted by modelling the same picrite combined with the assimilation of country rock in an isenthalpic process following an assimilation-batch crystallization process. We use similar conditions to the Northern sequence, at 2.5 kbar and  $fO_2 + 0.5$  log units above the FMQ. A granodioritic country rock from Americano do Brasil Complex, at an initial temperature of 300 °C, was assimilated in 1 g increments into 100 g of the picrite (beginning at a temperature of 1310 °C) under isenthalpic conditions at a constant pressure of 2.5 kbar and  $fO_2$  0.5 log units above FMQ solid oxygen buffer. During a process of between 22 and 45% assimilation of granodiorite, the system cools to 1120 °C and crystallizes solids similar to the rocks analyzed in the Southern sequence. The modeled

rocks range from orthopyroxene-clinopyroxene cumulates to gabbro, with different modal proportions of the main minerals. To match the overall abundance of incompatible trace elements in the bulk cumulate rocks, model cumulates require the presence of up to 15 wt.% trapped liquid with the solids. Because there are different degrees of contamination, the ranges of compositions of the rocks vary. The trace-element abundances of the cumulates ranging from the least evolved pyroxene cumulate to the most evolved gabbro and their modeled equivalents are shown in Figure 2.10. The model results are given in Appendix B and C.

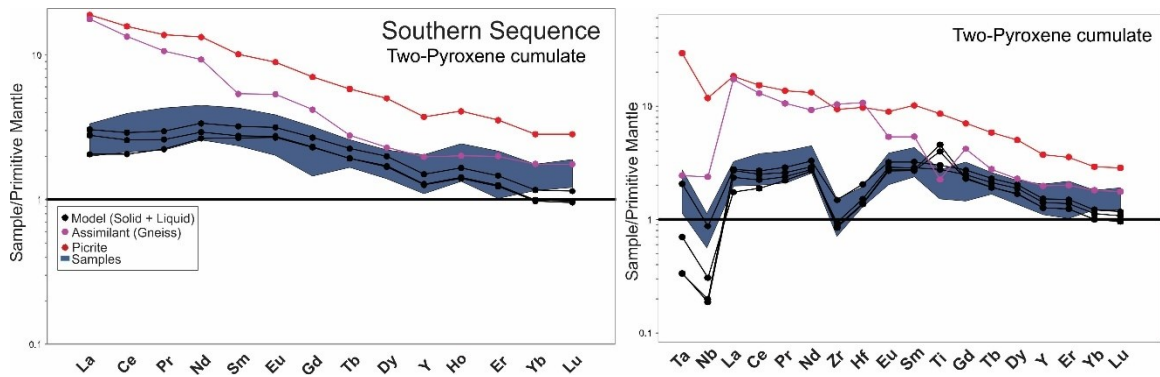


Figure 2.10. Primitive mantle-normalized REE and multi-element plots for rocks from the Southern sequence of the ABC compared with model results. Normalization from Sun and McDonough (1989). The blue polygon covers the range of compositions of rocks of Americano do Brasil Complex samples. The black lines represent modeled cumulate rocks with trapped liquid, red is the picrite used as initial liquid (#7, Lightfoot et al., 1999), and pink is the composition of the assimilant gneiss.

### 2.6.2. Mantle Source and Parental Magma

In order to have a better understanding of the tectonic setting and conditions of formation of the Americano do Brasil Complex, it is important to constrain the nature of the mantle source and crystallization order of the parental magma of the rocks. The petrographic analyses show that the crystallization order for the intrusions was olivine-clinopyroxene-orthopyroxene-plagioclase for the Northern sequence, and olivine-orthopyroxene-clinopyroxene-plagioclase for the Southern sequence. The crystallization order differs partially from the previous works. Silva (2011) described the same order of

crystallization for both sequences, with orthopyroxene preceding clinopyroxene; whereas Nilson (1981) did not subdivide the complex into two sequences and concluded from the textures that clinopyroxene crystallized prior to orthopyroxene in the Northern sequence. Therefore, our results are partially in agreement with both works, showing that indeed there are slight differences in the crystallization orders of the two sequences. The highest forsterite content in olivine from Americano do Brasil measured in this study was Fo<sub>87</sub>. The well known olivine-melt distribution coefficient ( $K_D$ : 0.3; Roeder and Emslie, 1970) indicates that the liquid in equilibrium with the most primitive olivine grains had an Mg/Fe ratio of 2.3, which indicates that the parental liquid for the earliest olivine cumulates had similar Mg/Fe (ratio) as the picritic liquid used in the modeling.

The clinopyroxene-cumulate rocks of both sequences are enriched in MREE relative to both LREE and HREE (Fig. 2.8). The two sequences have previously been interpreted to have crystallized from similar a parental magma due to a similar crystallization trend and both being enriched in MREE relative to LREE and HREE (Mota-E-Silva *et al.*, 2011). The REE and trace element patterns for rocks from both sequences documented here have some similar patterns and are accounted for well by the thermodynamic modeling described above, which shows that rocks from both sequences could be formed from the same parental liquid, which evolved along distinctly different paths under different conditions such as degrees of contamination, indicating that the intrusions are potentially comagmatic and could represent different portions of the same system.

The significance of the enrichment in MREE relative to LREE and HREE, was previously assigned as a characteristic inherited from the parental liquid and it was used to infer a depleted-mantle source to the liquid due to the LREE depletion (Mota-E-Silva *et*

*al.*, 2011). In contrast to this idea, our modeling indicates that the LREE depletion relative to MREE can be attributed to accumulation of clinopyroxene, which shows this pattern due to the variation of partition coefficients along the lanthanide series. The presence of abundant MREE-enriched clinopyroxene also explains the higher LREE depletion compared to MREE in olivine-clinopyroxene adcumulates than in the two-pyroxene-cumulates, which we infer to have contained more trapped liquid. The HREE depletion relative to LREE and MREE, on the other hand, is not related to specific cumulate minerals and is probably a signature of the parental magma. Although the model parental liquid may have a slightly stronger relative depletion in HREE than the real parental magma for the complex, the Americano do Brasil Complex still has moderate HREE fractionation indicating the parental magma probably had at least moderate fractionation in heavy rare earth elements too, which may require residual garnet in a deep source or a contribution from pyroxenitic mantle. The picrite liquid used in our model is more similar to an ocean-island basalt (OIB) than to a normal-type mid-ocean ridge basalt (N-MORB) (Shirey *et al.*, 1994; Lightfoot *et al.*, 1999), but displaced to lower concentrations than typical OIB. The lower overall trace element concentrations are consistent with its picritic composition as compared to the basaltic compositions used to define typical OIB signatures. We use the close match of our modeled cumulate compositions to the natural compositions to infer that the parental magma of the Americano do Brasil complex was an OIB-like Fe-rich picrite, and that all of the rocks of both the Northern and Southern portions of the complex were likely to have shared this common parent. Despite the similarities in patterns, the Southern sequence has higher concentrations of REE and trace elements when compared to the Northern one. The difference is explained by the assimilation of the country rock as

well as the influence of trapped liquid, as shown by the modeling. We do not intend to correlate the Americano do Brasil Complex directly with the MCR picrite; rather, we used it only to infer the chemical characteristics and suggest that a liquid with a similar composition and age could have formed by similar asthenospheric processes to generate the rocks of the complex.

### 2.6.3. Constraint from Sulfide Chemistry

The equation described by Campbell and Naldrett (1979) is used to calculate the distribution of a metal between silicate melt and an immiscible sulfide liquid, for a given mass ratio  $R$  of silicate liquid to sulfide liquid in a closed system. The  $R$ -factor equation is  $X_{sulf} = X_0 \times \frac{D(R+1)}{R+D}$ , where  $X_{sulf}$  is the concentration of the element in the sulfide melt,  $X_0$  is the concentration of the element in the initial silicate melt, and  $D$  is the partition coefficient defined as the concentration in the sulfide phase divided by the concentration in the silicate melt at equilibrium. However, post-magmatic processes such as metamorphism and deformation may influence the distribution and morphology of the ore, which is evident by the presence of *Durchbewegung* texture in massive sulfide, serpentinization in net-textured sulfide and the presence of pyrite in some zones associated with hydrous secondary mineral assemblages. Figure 2.11 shows the sulfide metal tenors for mineralization in ABC and the closed-system  $R$ -factor model curves for the parental picrite liquid used in the modelling and for the liquid remaining after 45% of assimilation. The measured sulfide compositions fall at  $R$  values between 100 and 10,000 and are bracketed by the model curves for sulfide segregation from melts ranging from the parental picrite to the most strongly contaminated magma we have modeled.

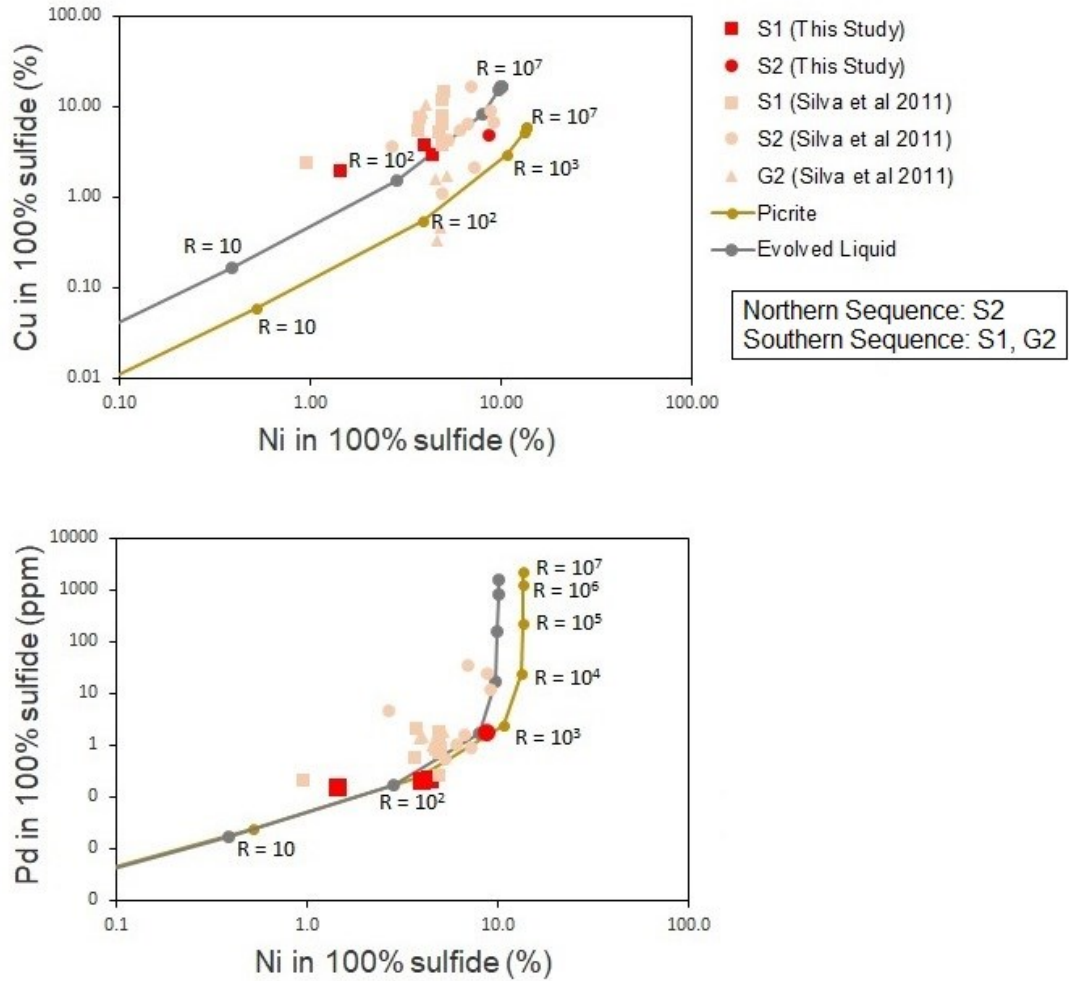


Figure 2.11. Bivariate plot showing the calculated sulfide metal tenors for individual samples for the three orebodies of Americano do Brasil (S1, S2 and G2) compared to picrite used in model and the most evolved liquid modeled for pyroxene-cumulates after assimilation. Red are data acquired in this study, pink is from Silva et al. (2011). Calculated base metal sulfide tenors (Cu in 100% sulfide vs Ni in 100% sulfide). R-factor model curves were calculated using the closed-system R-factor model (Campbell and Naldrett, 1979). The model picrite had a bulk composition with 59 ppm Cu, 540 ppm Ni, and 2.5 ppb Pd. The partition coefficients ( $D$ ) between the sulfide and basaltic liquids were 1,000, 250, and 1,000,000 for Cu, Ni, and Pd, respectively. The evolved liquid had a bulk composition of 168 ppm Cu, 400 ppm Ni, and 1.7 ppb Pd.

There is a wide range of ore tenors between the various ABC ore bodies and, to the extent that compositions have not changed during metamorphism, it could imply an inhomogeneous system with wide local variations in effective  $R$ -factor. The metal content of S1 orebody has a broad variation, ranging from values similar to the other orebodies (S2 and G2) to very low Ni and Cu content when compared to sulfide abundance. Overall, the S1 body appears to result from sulfide saturation later in the evolution of the magma than

does S2 or G2. Also, the  $R$  factor required to model some samples in the S1 orebody shows a large variation and does not follow a single path for equilibration with the magmatic liquids inferred to have been present based on the thermodynamic modeling above. The failure of a simple model of primary  $R$ -factor control of sulfide tenor for some samples implies that some post-emplacement changes in the system may have promoted S or metal mobilization. The post-magmatic events, such as deformation and interaction with hydrothermal fluids, may have locally overprinted some of the primary magmatic textures, resulting in localized sulfide mobilization and the variations of Ni/Cu ratio between sulfide samples. The relative roles of primary  $R$  factor control versus post-magmatic alteration will be approached in a further study focused on the post-magmatic overprints.

#### 2.6.4. Emplacement Constraints

The intrusion does not show much evidence for exclusively fractional crystallization from a single pulse of magma. Neither the forsterite content nor the enstatite content of pyroxenes shows a clear fractionation trend according to stratigraphic height, nor are there very well-defined layers. Our observations and model results indicate that evolution of the magmatic system by fractional crystallization, as classically understood, would not have produced the observed sequence of rock types. In particular, the occurrence of olivine-orthopyroxene cumulates is forbidden by the peritectic relationship between these two phases. On the other hand, there is a wide range of conditions under which olivine and orthopyroxene can coexist during batch crystallization, with or without the concurrent process of host rock assimilation.

In order to enable batch crystallization, a system with a hot and low viscosity magma is required for the crystals to be able to re-equilibrate continuously, a situation



avored by turbulent flow and/or vigorous forced convection to keep the crystals suspended while they react with the melt (e.g., Barnes *et al.*, 1995; Yao *et al.*, 2021). Assimilation-batch crystallization processes, as applied in this work, have been used to model the evolution of magmas that fed large mafic-ultramafic intrusions such as the Bushveld and Stillwater complexes, but also can be applied to smaller and irregular-shaped intrusions like Americano do Brasil (Jenkins and Mungall, 2018; Jenkins *et al.*, 2021; Yao *et al.*, 2021). In addition, previous works focused on modelling and field relations have shown that picrite and komatiites can assimilate high amounts of crustal rocks because the heat generated by the fusion of the assimilant is compensated by the heat of crystallization of the cumulates (e.g., Mungall, 2007). As shown by these previous studies and our present modeling results, the picrite liquid used in the present study is capable of large degrees of host rock assimilation due to its high temperature and steeply descending liquidus slope.

Several geologic criteria for defining magma conduit systems were previously described (Li *et al.*, 2001; Maier *et al.*, 2001, 2011) such as a high proportion of sulfides, presence of associated volcanic rocks overlying the intrusion, tube shape and evidence for multiple phases of intrusion. Unfortunately, the record of metamorphism, tectonism, and erosion, in addition to poor exposure and hence few constraints on the shape of the intrusion, makes it difficult to grasp the details of the geometry of the ABC or link it to some conduit system or related lava flows. However, the rocks of the Complex are dominated by cumulates, and hence must be lacking some residual liquid complement. The country rocks have been previously interpreted as representing rocks of the island arc stage of the Brasilia Belt (Laux *et al.*, 2004) and the area of study is related to the younger deep crustal Magmatic Arc (e.g., Laux *et al.*, 2004); however, the pressure of crystallization of

the Complex appears to have been typical of the upper to middle crust and there is no petrographic or geochemical evidence for high-pressure crystallization as would be expected in the roots of a continental magmatic arc. We suggest that the intrusion could have been emplaced in the middle or upper crust due to ascent in locally extensional weak zones, possibly in a sill-like conduit system.

#### 2.6.5. Element Mobility and Post-Cumulus Modifications

Post-magmatic processes, such as metamorphism or weathering, may result in considerable changes to the original geochemistry of the rocks. The degree of alteration in the AMB can be noted in the high loss on ignition (LOI) of the rocks, which ranges from below 0.5 to up to 13%, with the highest values associated with intensely serpentized olivine cumulates. The intrusion has been affected by amphibolite-facies metamorphism (Nilson, 1981), and has zones showing intense alteration to amphiboles and the apparent input of hydrothermal/metamorphic fluid, evidenced by increased abundance of secondary pyrite associated with these alteration zones. This pervasive alteration is associated with the percolation of fluids close to shear zones, with the notable presence of anhydrite, carbonate- and/or amphibole in veins linked to cross-cutting diorite dikes and associated alteration. Abundances of fluid-mobile elements as Ba, K and Sr show different patterns than predicted from geochemical modelling; but because they are highly mobile elements, these mismatches could directly be attributed to fluid-mediated metasomatism during the regional metamorphism.

A variety of plots based on comparison of trace elements ratios to igneous suites of well-understood provenance are commonly used as indicators of petrogenetic affinity (e.g., La/Sm, Ba/Yb, Nb/Ce). However, there are several reasons why most of them cannot be

used to discuss the lithogeochemical signature of Americano do Brasil Complex. Firstly, most of them are constructed based on liquid compositions, which made the cumulate rocks not suitable for application (e.g., Pearce *et al.*, 2021). Elements that can be compatible with the cumulus minerals in these rocks cannot be meaningfully compared with highly incompatible elements that could represent the trapped liquid, because this would have no petrogenetic significance. Elements prone to fluid transfer also cannot be used reliably to classify rocks that have been subjected to extensive metamorphic overprints.

On the other hand, the diabasic-textured doleritic rocks follow similar major and trace element geochemical trends as the pyroxene cumulates of the Southern sequence, but cross-cutting relations with both the cumulate rocks of the Southern sequence of the complex and the dioritic-veins suggest a younger age for the diorites.

## **2.7. Conclusions**

The Americano do Brasil Complex is composed of ultramafic to mafic cumulates and has been affected by metamorphism to the amphibolite facies, resulting in intense amphibolitization and recrystallization. Much of the intrusion maintains its primary magmatic textural features because deformation and hydrothermal alteration tend to have been restricted to discrete shear zones, veins and/or the margins of the intrusion. Post-magmatic processes such as metamorphism or deformation may have influenced the distribution and morphology of the mineralization.

Modeling indicates that the parental magma of the intrusion had an OIB-like Fe-rich picrite composition and that the same primary liquid could be parental to rocks from both the Northern and Southern sequences. The differences between the Northern and Southern sequences resulted from different degrees of crustal assimilation, within different

portions of the same magmatic system. The intrusion was formed by equilibrium crystallization with different proportions of assimilation, emplaced at a mid- to upper-crustal level, at pressure around 2.5 kbar, and melt temperatures as high as 1310 °C. The depletion in HREE indicates a deep source with some residual garnet, and the MREE enrichment in some rocks is associated with the accumulation of clinopyroxene instead of being a signature of the parental magma.

## **CHAPTER 3**

**U-PB *in-situ* SIMS baddeleyite dates and thermodynamic modeling in Mangabal Complex: indications for asthenospheric mantle influence in the formation of layered intrusions at the end of the evolution of the Brasília Orogen**

### **3. U-Pb in-situ SIMS Baddeleyite dates and Thermodynamic Modeling in Mangabal Complex: Indications for Asthenospheric Mantle Influence in the Formation of Layered Intrusions at the End of the Evolution of the Brasília Orogen**

#### **Abstract**

The Mangabal Complex lies within the Brasília Belt, a complex, long-lived Neoproterozoic orogen that formed during the amalgamation of the São Francisco/Congo, Amazonian, and Paranapanema Cratons in western Gondwana. The complex has two sequences separated by less than 3 km and both have been variably deformed and metamorphosed, but still locally preserve almost pristine igneous textures. The complex is composed of mafic and ultramafic cumulates, with a crystallization sequence of olivine ( $\pm$  Cr-spinel), orthopyroxene, plagioclase, and clinopyroxene. The origin and parental magma for the complex remain poorly constrained. We present petrography, whole-rock lithogeochemistry, mineral chemistry, and U-Pb in-situ SIMS data from micro-baddeleyite from Mangabal Complex rocks collected from drill holes. We show that a simple thermodynamic model of batch crystallization using a single tholeiitic basalt as parental magma in the upper crust produces a close match to the studied rocks and agrees with a broadly comagmatic origin for the two sequences. Baddeleyite inferred to represent a primary igneous phase of the complex gives a minimum age of  $653 \pm 30$  Ma, suggesting that the Mangabal Complex, hosted in the Arenópolis-Arc segment, is coeval with the Damolândia and Taquaral intrusions, hosted in the high-grade Anápolis-Itauçu Complex. Considering the temporal and spatial correlations, we propose that decompression melting of upwelling asthenosphere triggered by rollback subduction and/or the influence of a

mantle plume is required to explain the petrogenesis of the mafic-ultramafic intrusions in the eastern Arenópolis Arc and westernmost Anápolis-Itaçu.

### **3.1. Introduction**

Mafic-ultramafic intrusions are widely known as favorable hosts for magmatic Ni-Cu( $\pm$ Co, $\pm$  PGE) mineralization, identified in diverse rock types and at various stratigraphic levels in intrusions of any age and magmatic lineage (e.g., Maier, 2005). This type of deposit occurs in a variety of tectonic settings, most commonly related to old or active extensional tectonic settings (Naldrett, 2004). In the past decade, an number of studies have been published describing mineralized intrusions associated with orogenic belts and associated high-grade metamorphic terrains around the world, such as Aguablanca in Spain (e.g., Piña, 2019), the Giant Mascot in Canada (e.g., Manor et al., 2016), the Savannah Ni-Cu-Co Camp (e.g., Le Vaillant et al., 2020) and Nova-Bollinger in Australia (e.g., Barnes et al., 2020), Ntaka Hill in Tanzania (e.g., Barnes et al., 2019), Mirabela (e.g., Barnes et al., 2011) and Limoeiro (Mota-e-Silva *et al.*, 2013) in Brazil, and intrusions in Central Asian Orogenic Belt (e.g., Su et al., 2013).

In orogenic belts, mafic-ultramafic intrusions have been correlated to a wide range of different sources and pathways for magma generation and emplacement. Some intrusions are associated with pre-orogenic or post-orogenic settings, commonly inferred to be related to mantle plumes and/or LIPs (Ernst, 2014); others are considered syn-tectonic, frequently related to cumulates of magmatic arc roots or even back-arc basins, whereas others are even considered to be pre-orogenic, emplaced before the peak of orogeny. The environment of each mafic-ultramafic intrusion hosted by an orogenic belt

has its peculiarities and its context should be analyzed critically in recognition that there is no single model for the emplacement of this kind of intrusion.

The Mangabal Complex is part of a cluster of mafic-ultramafic intrusions that has been broadly associated with the Brazilian Orogeny, but the relative timing and settings of emplacement, deformation, and magmatic sulfide mobilization have remained unknown (e.g., Augustin and Della Giustina, 2019; Candia, 1983; Mota-e-Silva et al., 2011). Intrusions located in orogenic belts that have undergone pervasive deformation and metamorphism can be difficult to contextualize within the regional geological setting. In this study, we use the results of a wide range of analytical techniques, such as lithogeochemistry, mineral chemistry, U-Pb geochronology, and thermodynamic modeling, to evaluate the petrogenesis of the Mangabal Complex. We aim to achieve a better understanding of the timing and emplacement conditions for the Complex, to assess possible linkages with the other mafic-ultramafic intrusions in the area and establish the age relations between the Complex and its host metamorphic rocks.

### **3.2. Regional Geology**

The Goiás Magmatic Arc (GMA) is a Neoproterozoic tectonic unit located in the westernmost Brasília Belt (Fig. 3.1A), which is one of three large Neoproterozoic orogens that resulted from the amalgamation of the Amazonian, São Francisco-Congo and Paranapanema cratons and smaller allochthonous blocks (Fuck et al., 1994, 2017; Pimentel and Fuck, 1992a). The GMA trends NE-SW and its northern and southern limits are covered by the Phanerozoic Parnaíba and Parana sedimentary basins, respectively. It comprises two domains separated by the Goiás Archean Block (e.g., Pimentel, 2016). The northern domain is known as the Mara Rosa segment and the southern, which hosts the



Mangabal Complex, is called the Arenópolis arc (Pimentel et al., 2000). Both branches are suggested to have shared common evolution due to geological, geochemical, and geochronological similarities (Laux *et al.*, 2004, 2005a; Pimentel *et al.*, 2004; Matteini *et al.*, 2010). The GMA represents a composite arc terrain, formed by the accretion of intraoceanic island arcs. The igneous activity in the Goiás Magmatic Arc occurred in two main episodes: a first magmatic stage between ca. 900 and 750 Ma, characterized by the eruption of primitive tholeiitic to calc-alkaline volcanic rocks and intrusion of associated tonalites and granodiorites formed in an island arc setting, and a second magmatic stage in an active continental margin, dated around 670-600 Ma, in which calc-alkaline magmatism was accompanied by metamorphism and deformation, during the closure of the Goiás-Pharusian Ocean (Fuck et al., 2017; Laux et al., 2005, 2004; Matteini et al., 2010; Pimentel, 2016; Pimentel et al., 2004; Pimentel and Fuck, 1992).

The Arenópolis arc comprises N-S trending volcano-sedimentary sequences (e.g., Bom Jardim de Goiás, Arenópolis, Iporá, Jaupaci and Anicuns-Itaberaí, respectively from west to east), separated from each other by calcic- to calc-alkaline, diorite to granite orthogneisses (Fuck et al., 2017). The supracrustal and orthogneiss units of the Arenópolis arc are juxtaposed along regional NNE to NNW strike-slip fault systems, which are part of the continental-scale Transbrasiliano Lineament (Pimentel et al., 2000a). The eastern portion of the Arenópolis Arc is limited by the para- and orthogranulite rocks of the Anápolis-Itauçu Complex (Piuzana *et al.*, 2003; Baldwin *et al.*, 2005), which together host a cluster of several small-to-medium-sized mafic-ultramafic intrusions (Fig. 3.1B). The Mangabal Complex (Fig. 3.1C) is one of these, comprising two intrusions emplaced in the Arenópolis arc.

### 3.2.1. Previous work on the mafic-ultramafic intrusions in the region

The mafic-ultramafic intrusions in the Arenópolis arc were first recognized in 1969 (Danni *et al.*, 1973). The identified mafic-ultramafic bodies were called the Mangabal Massif which is currently called the Mangabal Complex, and the São João Massif which is currently known as the Americano do Brasil Complex (Danni *et al.*, 1973). Pfrimer *et al.* (1981) presented a geological map that contains more than 14 mafic and ultramafic intrusions that were metamorphosed in amphibolite (Arenópolis arc) to granulite facies (Anápolis-Itauçu Complex). Drago *et al.* (1981) used for the first time the term “Americano do Brasil-type mafic-ultramafic intrusions” to refer to those mafic and mafic-ultramafic intrusions that occur in the amphibolite-facies domains, whereas the ones in the granulite-facies terrane were called “Nerópolis/Damolândia Type” (e.g., Veiga *et al.*, 1986). The term “Americano do Brasil Plutonic Supersuite” was first used by Winge (1995) to describe several plutonic bodies hosted in the Arenópolis arc, divided into the Gabbro-Dioritic suite, and the Granitic-Tonalite Suite, encompassing intermediate to felsic intrusions in the region. The American do Brasil Plutonic Supersuite was later divided into two distinct sequences by Laux *et al.* (2004), who reserved the term “Americano do Brasil Suite” to describe the intrusions containing ultramafic rocks, whereas the intrusions including mafic-intermediate intrusions were then called Anicuns-Santa Barbara gabbro-diorite suite.

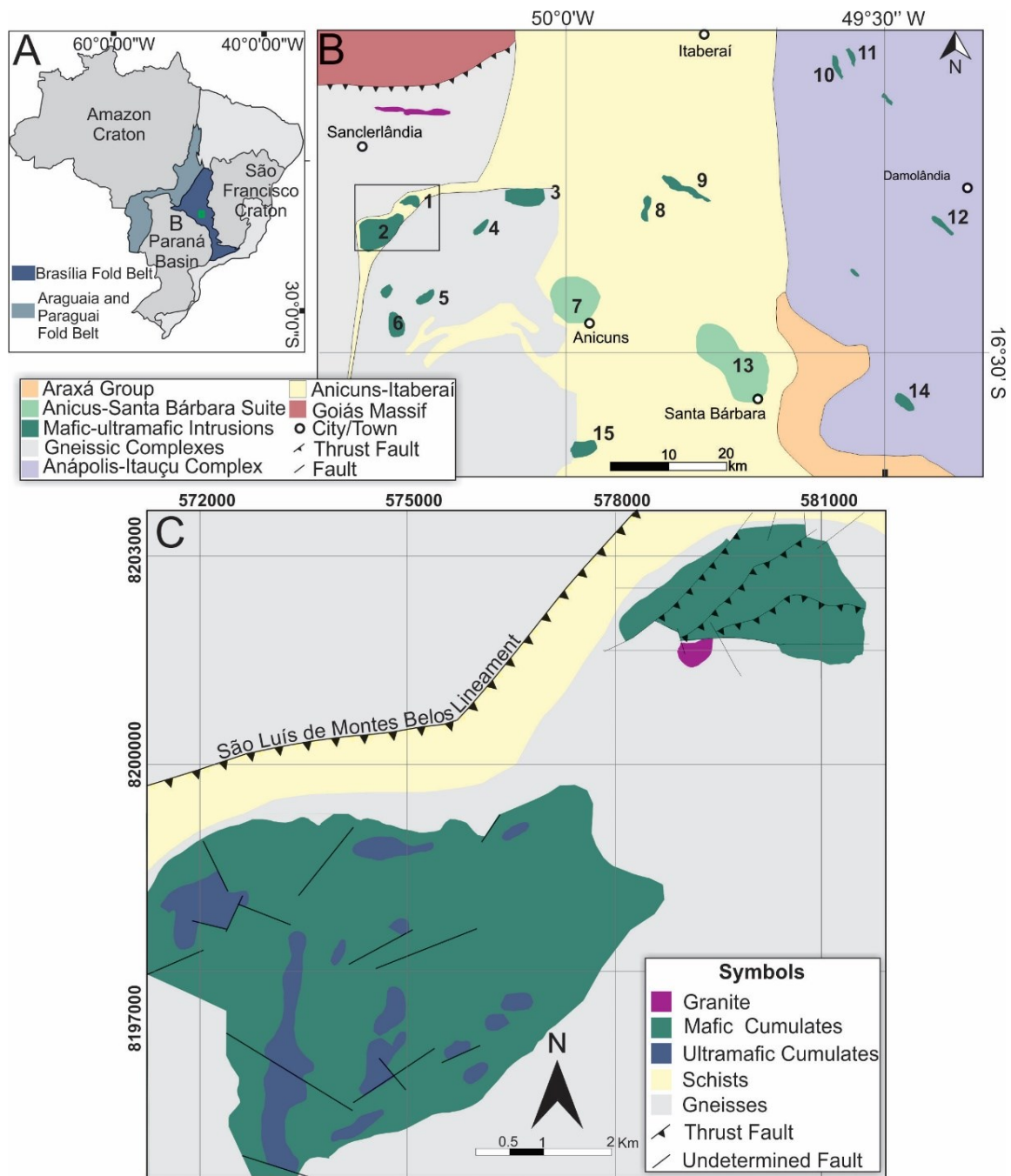


Figure 3.1 A) Location map of the Brasília Belt in Brazil. B) Simplified geological map of the Anicuns Region, showing the vicinities of the Anápolis-Itaçu Complex and the gneisses and volcano sedimentary sequence (Anicuns-Itaberaí) of the Arenópolis Arc hosting several Mafic-ultramafic intrusions. C) Simplified geological map of the Mangabal Complex.

Most studies have been performed on the Arenópolis mafic-ultramafic intrusions; however, each describes a single intrusion without making many comparisons between them. The Americano do Brasil Complex and Mangabal Complex are the ones with most

available data. The Americano do Brasil Complex is the best-known intrusion due to its record of exploration and mining; it was the object of detailed geological surveys and mineral exploration culminating in the operation of the Americano do Brasil underground Ni-Cu-Co mine by Prometalica Ltd and Votorantim Metals Ltd. Petrographic study of the mafic to ultramafic cumulates and associated Ni-Cu sulfide ore was published by Nilson (1984, 1981), Nilson and Santos(1982), Silva et al., (2011) and Chapter 2. Whole-rock Sm-Nd analysis of 6 samples indicated an  $\epsilon\text{Nd(T)} (+3.1)$ , and ID-TIMS U-Pb Concordia from zircons indicated an age of  $626 \pm 8$  Ma (Nilson *et al.*, 1997; Laux *et al.*, 2004).

The first detailed work on Mangabal was done by Ribeiro et al (1973), who described the northern body, formerly called Mangabal I. Augustin and Della Giustina (2019) and Candia (1983) worked on the petrology of the Mangabal Complex, focused on the petrography of both igneous and metamorphic rocks. These authors showed that it is composed of two tectonically deformed intrusions partially recrystallized in amphibolite-facies conditions with igneous relicts, comprising ultramafic rocks sitting below a sequence of mafic rocks (Candia, 1983; Augustin and Della Giustina, 2019).

### **3.3. Analytical Methods**

#### **3.3.1. Sampling and Petrography**

We collected 48 samples from three exploration drill cores, one from the northern part of the complex, and two from the south. The rocks were selected to represent the lithological associations and the stratigraphy of the Mangabal Complex. Sixty-five polished thin sections and eleven polished sections were examined using conventional transmitted and reflected light microscopy in combination with scanning electron microscopy (SEM). The SEM used was a JEOL JSM-IT500 Scanning Electron Microscope

equipped with Oxford ULTIM MAX SDD-EDS detector, located at the Earth Sciences Department, Carleton University.

### 3.3.2. Mineral Chemistry

The compositions of minerals from several polished thin sections were determined by electron probe microanalysis (EPMA). Analyses were performed using a JEOL JXA-8230 SuperProbe with five wavelength dispersive spectrometers (WDS) at the Electron Microprobe Lab (LME-IG) at the University of Brasília. Operating conditions for all silicate minerals were 15 kV accelerating voltage, a beam current of 10 nA, and probe diameters of 1  $\mu\text{m}$  for all minerals except plagioclase (5  $\mu\text{m}$ ). Counting time on peak and background were 10 s and 5 s, respectively.

### 3.3.3. Geochemistry

Forty samples were analyzed at the ALS Geochemistry laboratories in Vancouver, Canada. A package was selected for complete sample characterization (ALS method codes ME-ICP06, ME-IR08, ME-MS81<sup>TM</sup>, ME-MS42<sup>TM</sup>, ME-4ACD81). The whole rock was analyzed via inductively coupled plasma-atomic emission spectrometry (ICP-MS) and atomic emissions spectroscopy (ICP-AES). Major element oxides were analyzed via ICP-AES following a Lithium Metaborate Fusion plus Loss on Ignition (LOI) at 1000 °C to ensure complete dissolution of lithophile elements for major oxide results. Trace elements were analyzed using inductively coupled plasma-mass spectrometry (ICP-MS) with lithium borate fusion prior to acid dissolution. Total carbon and sulphur were determined by induction furnace using a Leco infrared sulfur analyzer. Platinum, palladium, and gold were determined by standard lead bead collection fire assay and ICP-MS finish. The

geochemical data can be found in the Appendix D. For comparison purposes, geochemical data used in this work were normalized to an anhydrous basis.

#### 3.3.4. U-Pb Geochronology

Polished petrographic thin-sections from Mangabal rocks and one from the Córrego Seco Intrusion were prepared at the Wyoming University, mapped, and imaged by backscattered electrons (BSE) to identify high-Zr domains, and the presence of baddeleyite was verified by a combination of BSE and EDS X-ray analysis. Domains containing microscopic baddeleyite crystals were trimmed to pieces that were mounted in epoxy disks along with pre-polished epoxy blocks of reference baddeleyite grains.

The U-Pb dates were obtained by performing in situ analyses of microscopic baddeleyite using a CAMECA-ims 1290 secondary ion mass spectrometry (SIMS) microscope at the University of California at Los Angeles (UCLA), USA. In-situ baddeleyite dating methods largely followed those described by Chamberlain *et al.* (2010) and Schmitt *et al.*, (2010). Micro-baddeleyite grains were analyzed *in-situ* from polished thin sections using a 3x3  $\mu\text{m}$  raster from a  $\sim 1 \mu\text{m}$  primary  $\text{O}^{2-}$  ion beam (Hyperion source). U/Pb relative sensitivity was calibrated by  $\text{UO}_2/\text{UO}$  for baddeleyite using the Phalaborwa standard with values that ranged from 0.286 to 0.317. U concentrations based on  $\text{U}^{94}\text{Zr}_2\text{O}$  measurements compared to those of zircon standard 91500 (80 ppm U) during the same session. Pb values were corrected for common Pb using the  $^{204}\text{Pb}$  method for baddeleyite. Data reduction used the in-house ZIPS program. Weighted mean and Concordia age calculations employed the ISOPLOT program (Ludwig, 1991, 1998). The decay constants used by ISOPLOT are those recommended by the I.U.G.S. Subcommittee on Geochronology (Steiger and Jäger, 1977):  $0.155125 \times 10^{-9}/\text{yr}$  for  $^{238}\text{U}$ ,  $0.98485 \times 10^{-9}/\text{yr}$

for  $^{235}\text{U}$  and present-day  $^{238}\text{U}/^{235}\text{U} = 137.88$ . As many of the samples exhibited alteration of baddeleyite to zircon, the data were filtered to remove the effects of alteration or the presence of zircon domains that were too small to detect in BSE. Analyses that were accepted for date calculations had high percentage (%) radiogenic  $^{206}\text{Pb}$  (>82%), low Th/U (<0.19), and  $\text{UO}_2/\text{UO}$  within the range of the standard analyses (Table 1).

### **3.4. Results**

#### **3.4.1. Geology of the Mangabal Complex**

The Mangabal Complex (Fig. 3.1C) is divided into two segments separated by 3 km of sheared hornblende gneiss at surface but inferred to be connected a depth, which we refer to henceforth as the Southern and Northern sequences. Some cumulate rocks of the Complex were recently described by (Augustin and Della Giustina, 2019) and the nomenclature here will follow the same of that work. Both sequences show similar igneous and metamorphic features, like mineralogy and textures. Each contains an ultramafic zone dominated by olivine cumulates at the bottom, and an overlying mafic zone marked by the appearance of plagioclase as a cumulus phase, dominated by pyroxene-plagioclase cumulates (i.e., gabbro). Since the intrusions have been affected by deformation and metamorphism, the contact between the zones is commonly sheared and/or juxtaposed by faulting, making it impossible to identify the detailed nature of the original contact, e.g., if gradual or abrupt. Despite the dominance of metamorphic rocks in the Complex, the description will focus on the few preserved igneous relicts for their significance for the emplacement of the complex.

##### **3.4.1.1. Northern Sequence**

The Northern sequence is faulted and the rocks close to these zones are intensely transformed into metamorphic assemblages. Despite this intense transformation in most of the rocks, some portions still preserve igneous relicts. A downhole log of a representative drill core is shown in Figure 3.2, with an ultramafic zone at the bottom. Outcrops are rare due to intense weathering alteration. The columns start at the base of the saprolite, around 50 m. Felsic veins occur within the complex and are strongly associated with shear zones and major hydrous alteration of the mafic and ultramafic rocks.

An ultramafic zone dominated by olivine orthocumulate (Fig. 3.3a) occurs at the bottom of the Northern sequence. It does not crop out and can only be found at depth in drill holes. It transitions upwards to a poikilitic harzburgite (Fig. 3.3b) by a gradual increase in the amount of intercumulus orthopyroxene; these poikilitic rocks are more prone to hydrous alteration than the others. Olivine forms euhedral to sub-rounded cumulate grains (up to 2 mm), locally with small (ca. 0.1 mm) euhedral to subhedral Cr-spinel as accessory included or cumulus grains. These rocks have a substantial volume of intercumulus material, reaching up to ca. 40 % in volume, composed of clinopyroxene, plagioclase, and orthopyroxene, from the most to least abundant. Accessory intercumulus phlogopite and sulfides occur locally.



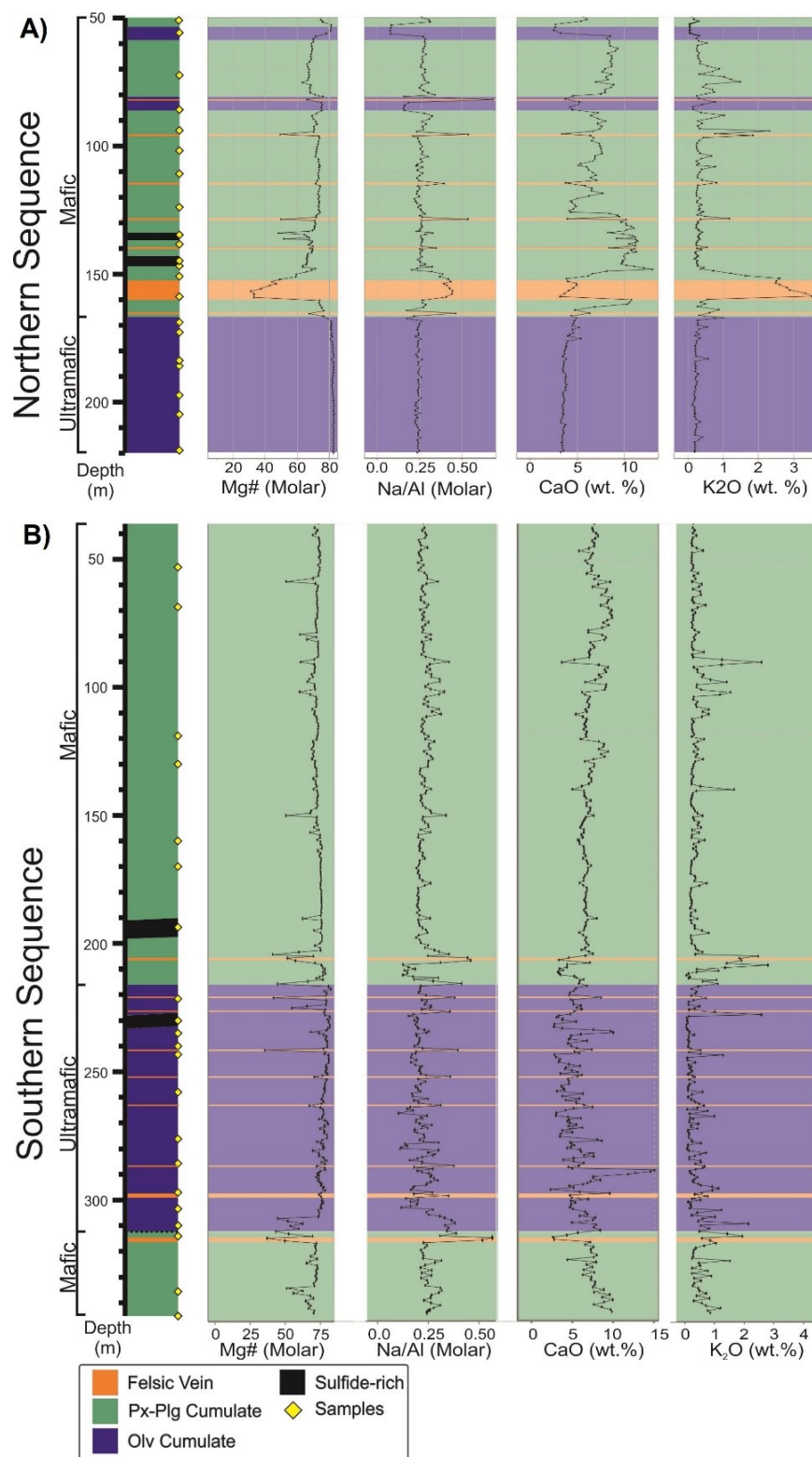


Figure 3.2 Downhole lithological and geochemical log of Mg#, Na/Al, CaO and K<sub>2</sub>O of representative drill holes of (A) the Northern sequence, and (B) the Southern sequence. Abbreviations: Px = pyroxene, Plg = plagioclase, Olv = olivine

Pyroxene-plagioclase cumulates (Fig. 3.3c) are the most voluminous rocks in the Northern sequence and represent the mafic zone. The form of transition from olivine cumulate to the first pyroxene-plagioclase cumulate is obscured because the contact is marked by meters of intensely deformed and altered rocks, accompanied by quartz-rich veins that are disposed concordant to the deformation fabric. Geochemical data indicate a sudden change. The cumulate phases are equidimensional fine- to medium-grained (up to 3 mm) orthopyroxene and plagioclase with parallel-oriented fabric. Coarse-grained (up to 1 cm) rounded to elongated clinopyroxene oikocrysts, enveloping both plagioclase and orthopyroxene, occur locally, often partially to completely transformed into green amphibole. Rare thin layers of two pyroxene-plagioclase cumulates occur within the mafic zone. These gabbronoritic layers are characterized by euhedral to subhedral plagioclase, ortho-, and clinopyroxene, the latter always partially to completely replaced by amphibole (Fig. 3.3d). The gabbronorites tend to be spatially close to the sulfide-rich portions, but the sulfide is concentrated in the most metamorphosed rocks. Apatite, Fe-Ti oxides, and sulfides are common accessory minerals.

Olivine cumulate layers up to 5 m thick appear among the mafic cumulates. These dunitic rocks are generally intensely metamorphosed, with metamorphic paragenesis that obliterates almost completely the original textures and mineralogy (Fig. 3.3e). Olivine-plagioclase cumulates (Fig. 3.3f) are the least common and most evolved rocks in the complex, occurring at the southern extremity of the intrusion and representing the uppermost stratigraphic unit.

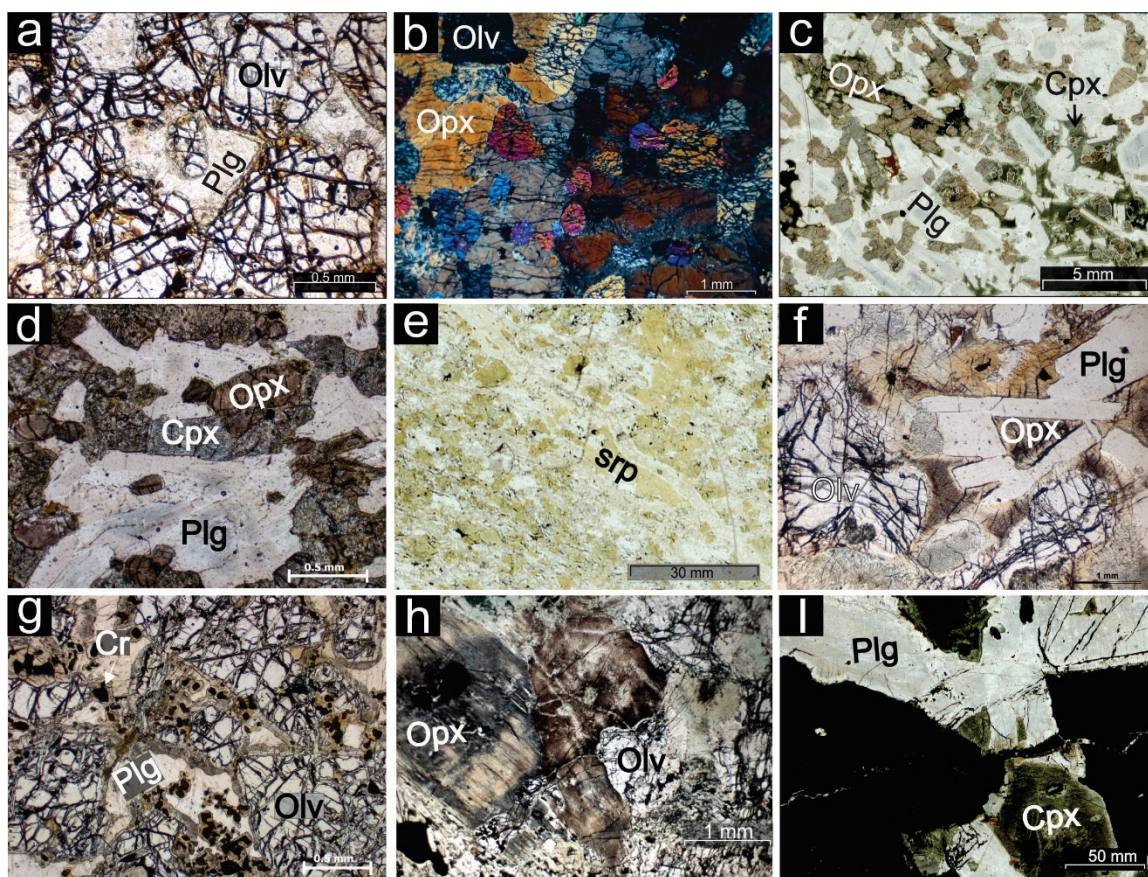


Figure 3.3 Photomicrographs of rocks from Mangabal Complex. (a) Under plane-polarized light, olivine-cumulate with plagioclase intercumulus (sample MNN01); (b) cross polarized light of poikilitic harzburgite with coarse grained orthopyroxene englobing cumulus olivine (sample MNN06); (c) Plane-polarized light of orthopyroxene-plagioclase cumulate, with some interstitial clinopyroxene; (d) two pyroxene-plagioclase cumulate (sample MNN12); (e) Chlorite-serpentine schist, with relict olivine in meta-olivine cumulate between mafic zone (sample MNN18); (f) Olivine-plagioclase cumulate that crops out in the south portion of Northern Mangabal. (g) olivine-cumulate rich in plagioclase and Cr-spinel in southern sequence (sample MNS20); (h) Meta granular harzburgite from Southern sequence (sample MNS18); (i) Coarse-grained gabbro from Southern sequence from Mangabal (sample MNS15).

#### 3.4.1.2. Southern Sequence

In the Southern sequence, the majority of samples show stronger effects of superimposed metamorphism compared to Northern sequence, leading to variable degrees of replacement of primary igneous minerals and textures. Identification of primary lithological layers is therefore difficult. The ultramafic rocks encountered at depth are the most strongly deformed and altered. The Southern sequence is a package of mafic orthopyroxene-plagioclase cumulates within which there is an ultramafic zone of

olivine/pyroxene cumulates fault-bounded both above and below. A downhole log of a representative drill core is shown in Figure 3.2B.

In the ultramafic zone, olivine cumulates are intercalated with minor layers of orthopyroxene cumulates. The former has an orthocumulate texture (Fig. 3.3g) and it is composed of fine to medium-grained, euhedral to subhedral olivine (ca. 3 mm) and minor euhedral to subhedral small grains of cumulate Cr-spinel (ca. 0.2 mm). Orthopyroxene and clinopyroxene locally occur, comprising less than modal 1 %; the former occasionally is seen to grow at the expense of the olivine with irregular and embayed contacts. However localized layers containing large euhedral oikocrysts of orthopyroxene contain euhedral olivine without any indication of replacement. Euhedral clinopyroxene grows close to olivine grains. In some examples, euhedral to subhedral grains of cumulus orthopyroxene occur with the cumulus olivine indicating simultaneous accumulation of both phases; however, these granular harzburgites (Fig. 3.3h) are prone to strong alteration that obscures modal proportions and primary mineral textures. Differently from the ultramafic zone of the Northern sequence, plagioclase is the majority intercumulus phase, reaching up to 35 %, and the Cr-spinel is in much higher volume than in Northern sequence, reaching locally as much as 3 modal % in this sequence (Fig. 3.3g), whereas in the north Cr-spinel is a trace accessory phase.

The orthopyroxene-plagioclase cumulates in this sequence are similar to the ones described in the Northern sequence but more metamorphosed. They are composed of fine- to medium-grained (up to 3 mm) equidimensional, euhedral to subhedral orthopyroxene and plagioclase, both commonly showing strong preferred orientation. Coarse-grained rounded to elongated clinopyroxene oikocrysts (ca. 1 cm), wrapping both plagioclase and

orthopyroxene, also occur locally, commonly transformed into amphibole. Sulfide-rich medium-grained two-pyroxene-plagioclase cumulate occurs close to the shear zone located near the upper contact of the mafic and ultramafic zones and is more sulfide-rich compared to the other rocks of the sequence.

Gabbro layers or intrusions that crosscut the pyroxene-plagioclase and olivine-cumulates are composed of coarse-grained but diabasic-textured plagioclase, clinopyroxene, and orthopyroxene (Fig. 3.3i). Plagioclase is the dominant mineral in all the variations. The abundance of orthopyroxene ranges from 4 to 25%, while the clinopyroxene mode ranges from 16 to 36%. Sulfide is a common phase, reaching up to 20% in the gabbro. Biotite, apatite, and quartz are the most common accessory minerals.

#### 3.4.2. Mineral Chemistry

Mineral chemistry is tabulated in Appendix E. The composition of analyzed olivine ranges from Fo<sub>78</sub> to Fo<sub>83</sub>. In all samples, the olivine is in part replaced by serpentine, but it still is possible to identify relicts large enough to analyse by EPMA. The nickel content varies from below detection limit to 3500 ppm. All mafic and ultramafic rocks contain low-Ca orthopyroxene varying from En<sub>62</sub> to En<sub>82</sub> in the Northern sequence and from En<sub>64</sub> to En<sub>85</sub> in the Southern sequence. Cumulus clinopyroxene is generally replaced by secondary amphibole in these intrusions, so no good analyses of preserved clinopyroxene were successfully obtained.

Plagioclase is a major mineral in mafic rocks of both Mangabal intrusions and also occurs as a common interstitial mineral in the ultramafic rocks. In both the Northern and Southern sequences, the plagioclase has a vast compositional range, ranging from An<sub>44</sub> to An<sub>58</sub> in the Northern and from An<sub>30</sub> to An<sub>78</sub> in the south. The intrusions were affected by

regional metamorphism and the plagioclase shows dynamic recrystallization to fine-grained aggregates, with the most sodic compositions most strongly affected by recrystallization.

#### 3.4.3. Geochemistry of the Intrusions

Variable amounts of loss on ignition reflect the degree of hydrous alteration for distinct rock types and lead to dilution of the non-volatile components of the rocks, so we have normalized all major and trace element data to 100% on an anhydrous basis.

The Mangabal Complex rocks range from 6.2 to 25.7 wt. % MgO in the gabbro-norites and 21 to 32.6 wt. % MgO in the olivine cumulates. The samples define a broadly linear trend in most bivariate major element plots. SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, CaO, and Na<sub>2</sub>O concentrations increase with decreasing MgO, whereas FeO (total) concentrations decrease as MgO decreases (Fig. 3.4). The correlations are more evident in the Northern sequence than in the Southern one. A systematic correlation between MgO and K<sub>2</sub>O is not evident, and the greatest concentrations of the latter are associated with the presence of abundant amphibole alteration.

In primitive mantle-normalized trace element plots compositions (McDonough and Sun, 1995; Fig. 3.5), sample patterns show considerable regularity, with the abundance of lithophile trace elements being slightly higher in the Southern sequence than in the Northern. Similarities include the presence of negative Nb anomalies and positive Sr anomalies, features that are the most pronounced in the most evolved rocks, i.e., pyroxene-plagioclase cumulates and amphibolite, relative to olivine cumulates. The light rare earth elements (LREEs) are relatively fractionated with mantle-normalized element ratios of La/Sm<sub>N</sub> ranging from 0.9 to 2.3 in the Northern sequence, and 0.9 to 4.5 in the Southern



sequence. In the majority, the Northern sequence is slightly more fractionated in LREE with a La/Sm<sub>N</sub> average of 2.3, whereas the Northern sequence has an average of 1.5. The heavy rare earth elements (HREEs) are slightly fractionated, with Gd/Yb ratios ranging from 1.0 to 1.4, with an average of 1.3 in the Northern sequence and ranging from 0.7 to 1.4 with an average of 1.1 in the southern. The large ion lithophile (LILE) elements Ba and K are enriched compared to LREE. A notable positive europium anomaly is identified in the pyroxene-plagioclase cumulates and amphibolite in the Southern sequence but is relatively weak in the Northern sequence.

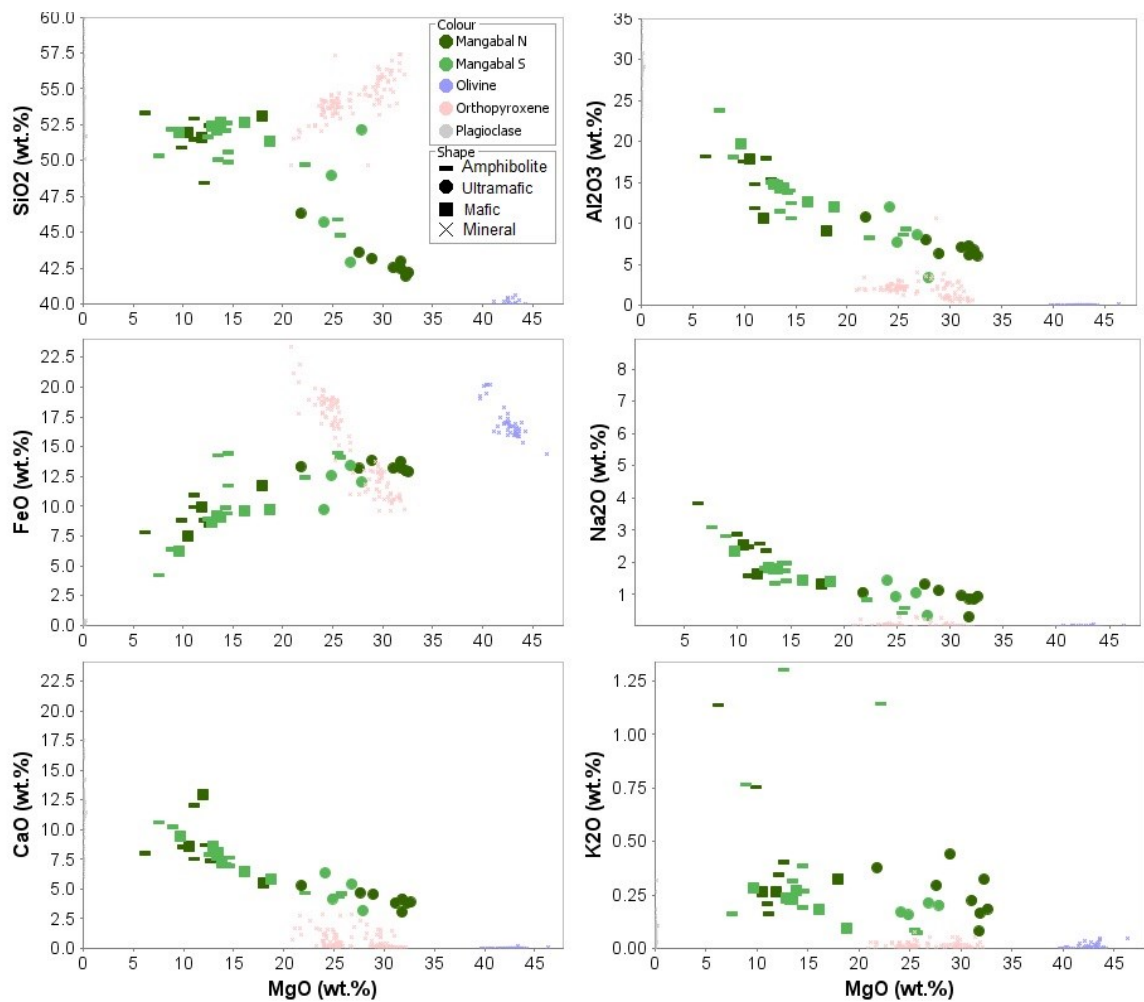


Figure 3.4. Whole-rock major element variation of lithologies intersected at the Mangabal Complex compared with the compositional ranges of minerals. SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, FeO, Na<sub>2</sub>O, CaO and K<sub>2</sub>O vs. MgO all in weight percent (wt %).

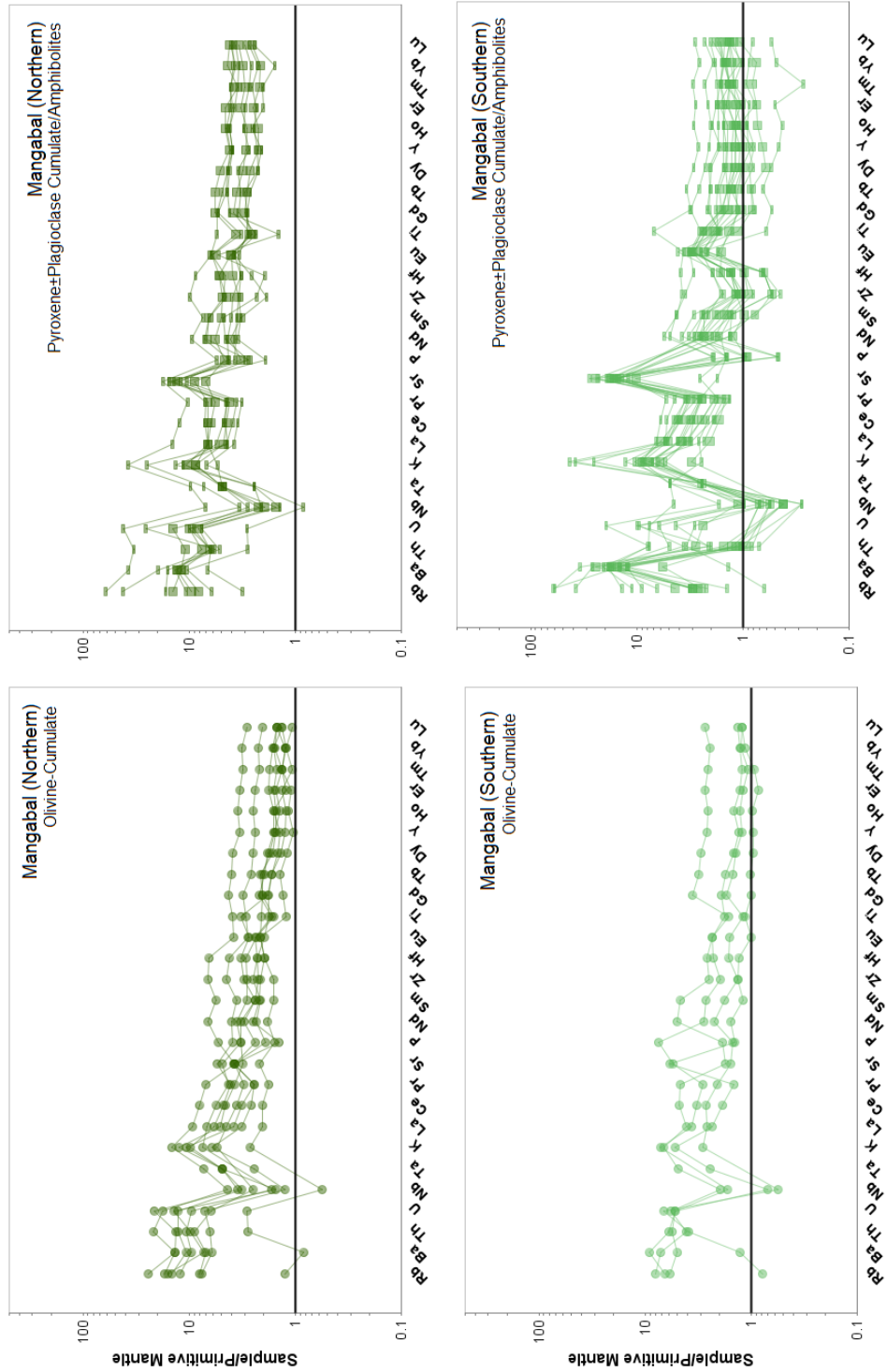


Figure 3.5 : Primitive mantle-normalized incompatible trace element diagrams for different rock types from the Mangabal Complex. Normalization values are taken from (McDonough and Sun, 1995).



#### 3.4.4. U-Pb in-situ SIMS data

Although some igneous textures remain intact at Mangabal, metamorphic recrystallization is widespread. The most pristine olivine cumulates from the ultramafic portion of the Mangabal Complex were selected to locate baddeleyite for U-Pb dating. Baddeleyite occurs in three samples of the Mangabal Complex, namely MNN-04, MNN-06 from the Northern sequence and MNS-14 from the Southern sequence. In-situ SIMS U-Pb results for these samples are shown in Table 1, BSE images for all grains analyzed are in Appendix F.

Sample MNN-04 is an olivine orthocumulate and it is the most pristine sample, with least alteration into secondary minerals. BSE imaging for this sample revealed a few baddeleyite grains with zircon rims (Fig. 3.6A) situated close to the boundaries of pyroxene crystals, but most of the grains were pure baddeleyite without any alteration to zircon (Fig. 3.6B-C); baddeleyite grain sizes ranges from 4 to ca. 30  $\mu\text{m}$  length. Both pure baddeleyite grains and those with large zircon rims were selected for SIMS analysis. In-situ baddeleyite analyses of sample MNN-04 (Fig. 3.6A-C) yielded a weighted mean  $^{206}\text{Pb}/^{238}\text{U}$  age of  $653 \pm 31$  Ma and a Concordia age (Ludwig, 1998) of  $^{206}\text{Pb}/^{238}\text{U}$   $637 \pm 24$  Ma (Fig. 3.7A-B). The baddeleyite grains are localized in the intercumulus portion, commonly close to the boundaries of pyroxene. The weighted mean  $^{206}\text{Pb}/^{238}\text{U}$  date of  $653 \pm 31$  Ma is interpreted as the best estimate of the magmatic age of MNN-04.

Sample MNN-06 is a poikilitic harzburgite with a higher degree of alteration compared to sample MNN04. BSE imaging for this sample revealed commonly fractured baddeleyite grains with rims or exsolutions of zircon (Fig. 3.6D-E), baddeleyite grain sizes

ranges from 3 to ca. 50  $\mu\text{m}$  length. The grains were found in the intercumulus portions, and mainly in secondary assemblages, such as between orthopyroxene-amphibole layers in the corona-textures and along fractures filled with serpentine, but some grains occurred in pyroxene oikocrysts. The data from this sample plot above concordia and yielded a  $^{206}\text{Pb}/^{238}\text{U}$  weighted mean date of  $720\pm54$  Ma (Fig. 3.7C-D). Due to the reverse discordance, the  $^{207}\text{Pb}/^{206}\text{Pb}$  weighted mean date of  $613\pm27$  Ma is favored as the best estimate of the magmatic age.

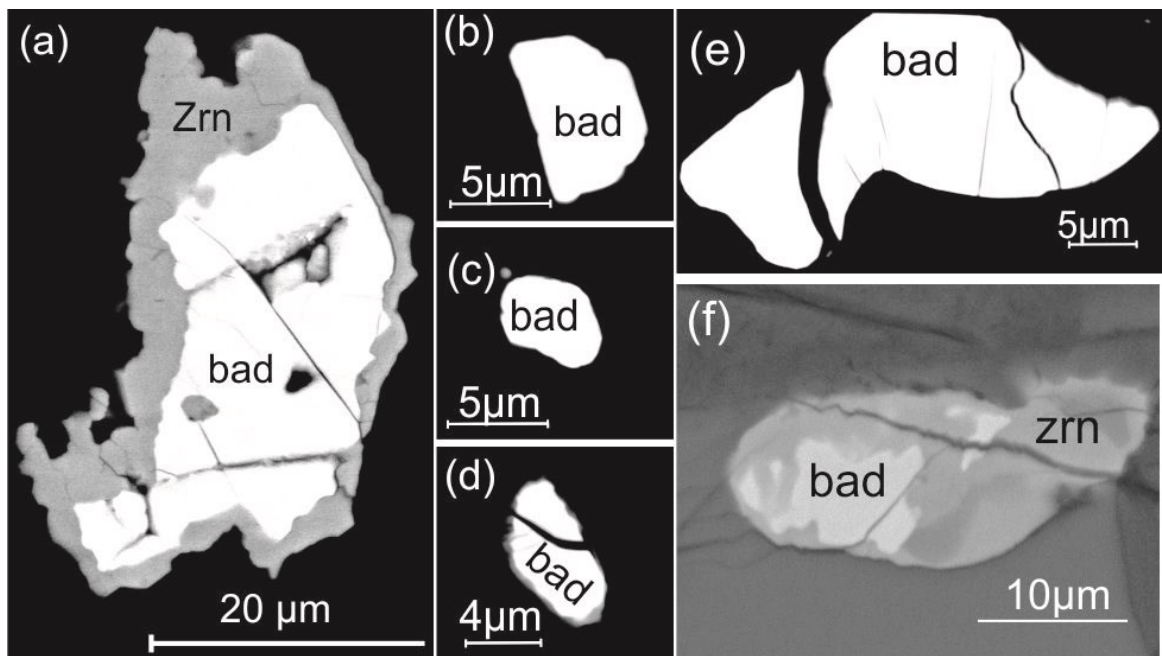


Figure 3.6 Backscatter electron (BSE) images of baddeleyite grains in the Mangabal Complex. (a-c) Baddeleyites from sample MNN-04, (d-e) baddeleyites from sample MNN-06, (f) baddeleyite from MNS-14.

Sample MNS-14 is a metamorphosed olivine-spinel cumulate, with well developed complex corona-textures around olivine and Cr-spinel, when in contact with plagioclase. BSE imaging for this sample revealed commonly fractured baddeleyite grains and alteration to zircon (Fig. 3.6F), baddeleyite grain sizes ranges from 3 to ca. 20  $\mu\text{m}$  length. The grains were found in intercumulus material, commonly along the plagioclase-olivine boundaries, more specifically in contact with the green spinel-amphibole symplectites

layer of corona-textures, but also associated with serpentine-filled fractures. In situ baddeleyite analyses of sample MNS-14 (Fig.3.6F) were reversely discordant and yielded an  $^{206}\text{Pb}/^{238}\text{U}$  weighted mean date of  $742\pm 87$  Ma (Fig. 3.7E-F).

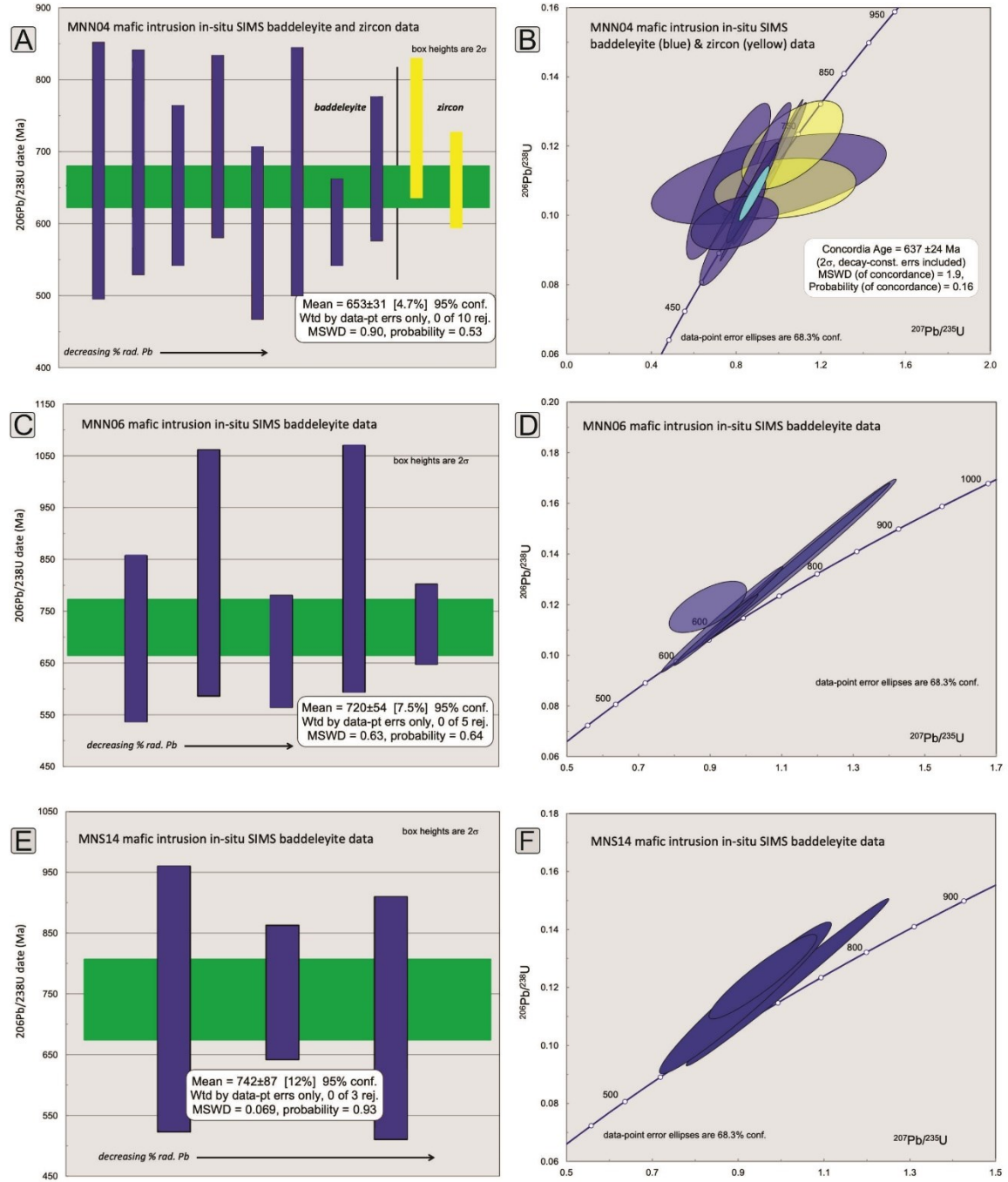


Figure 3.7. SIMS U-Pb baddeleyite (and zircon) results for samples MNN-04 (A-B), MNN-06 (C-D) and MNS-14 (E-F). Baddeleyite in blue, zircon in yellow.

Table 3-1 SIMS data from in-situ analyses of baddeleyite and zircon

| grain@<br>spot | grain size<br><br>(μm) | Dates (Ma)                                                                                                          |           |                    |           |                    |           |                     |       |                       |            | Ratios             |                     |                     |        |             |                  |
|----------------|------------------------|---------------------------------------------------------------------------------------------------------------------|-----------|--------------------|-----------|--------------------|-----------|---------------------|-------|-----------------------|------------|--------------------|---------------------|---------------------|--------|-------------|------------------|
|                |                        | <sup>206</sup> Pb/                                                                                                  |           | <sup>207</sup> Pb/ |           | <sup>207</sup> Pb/ |           | r <sup>206</sup> Pb | Th/   | U<br>O <sub>2</sub> / | U<br>conc. | <sup>206</sup> Pb/ | <sup>207</sup> Pb*/ | <sup>206</sup> Pb*/ | rho    |             |                  |
|                |                        | <sup>238</sup> U                                                                                                    | 1<br>s.e. | <sup>235</sup> U   | 1<br>s.e. | <sup>206</sup> Pb  | 1<br>s.e. |                     |       |                       |            |                    |                     |                     |        | 1 s.e.<br>% | <sup>238</sup> U |
| MNN04          |                        | 644±32 Ma, 95% conf., weighted mean <sup>206</sup> Pb/ <sup>238</sup> U date, MSWD 0.63, pof 0.75, 9 of 12 analyses |           |                    |           |                    |           |                     |       |                       |            |                    |                     |                     |        |             |                  |
| 34b@1          | 40x10                  | 674                                                                                                                 | 89        | 662                | 68        | 623                | 23        | 99.91               | 0.026 | 0.298                 | 2667       | 21200              | 0.9199              | 14.0                | 0.1102 | 14.0        | 0.997            |
| 8b@1           | 30x20                  | 685                                                                                                                 | 78        | 682                | 59        | 673                | 43        | 99.89               | 0.022 | 0.305                 | 938        | 17390              | 0.9582              | 11.9                | 0.1122 | 12.0        | 0.986            |
| 12b@1          | 8x5                    | 653                                                                                                                 | 56        | 640                | 44        | 592                | 53        | 99.62               | 0.035 | 0.323                 | 2801       | 4902               | 0.8774              | 9.2                 | 0.1066 | 9.0         | 0.964            |
| 33b@1          | 12x12                  | 707                                                                                                                 | 63        | 662                | 49        | 512                | 75        | 98.89               | 0.016 | 0.331                 | 468        | 1693               | 0.9197              | 10.0                | 0.1160 | 9.5         | 0.941            |
| 16b@1          | 15x15                  | 587                                                                                                                 | 60        | 588                | 58        | 592                | 127       | 96.85               | 0.027 | 0.320                 | 2726       | 598                | 0.7843              | 13.1                | 0.0953 | 10.7        | 0.897            |
| 30b@1          | 40x20                  | 672                                                                                                                 | 86        | 576                | 76        | 213                | 203       | 96.54               | 0.019 | 0.302                 | 979        | 545                | 0.7638              | 17.2                | 0.1099 | 13.5        | 0.864            |
| 32b@1          | 6x3                    | 602                                                                                                                 | 30        | 593                | 77        | 559                | 346       | 96.24               | 0.028 | 0.392                 | 5308       | 501                | 0.7935              | 17.2                | 0.0979 | 5.2         | 0.398            |
| 28b@1          | 10x6                   | 676                                                                                                                 | 50        | 680                | 190       | 694                | 740       | 94.24               | 0.014 | 0.373                 | 1334       | 328                | 0.9544              | 38.4                | 0.1106 | 7.8         | 0.548            |
| 3z@1           | 15x10                  | 661                                                                                                                 | 33        | 720                | 111       | 908                | 431       | 96.43               | 0.352 | 0.057                 | 312        | 529                | 1.0310              | 21.5                | 0.1079 | 5.3         | 0.217            |
| 26b@1†         | 25x20                  | 801                                                                                                                 | 131       | 738                | 92        | 552                | 33        | 99.08               | 0.010 | 0.286                 | 2253       | 2060               | 1.0690              | 17.5                | 0.1324 | 17.4        | 0.996            |
| 13b@1†         | 10x10                  | 968                                                                                                                 | 158       | 894                | 112       | 716                | 108       | 98.41               | 0.025 | 0.287                 | 1158       | 1184               | 1.4130              | 18.8                | 0.1621 | 17.6        | 0.963            |
| 10b@1†         | 15x4                   | 2228                                                                                                                | 805       | 1551               | 341       | 719                | 119       | 94.78               | 0.012 | 0.263                 | 4106       | 361                | 3.6050              | 42.9                | 0.4129 | 42.7        | 0.992            |
| MNN06          |                        | 613±27 Ma, 95% conf., weighted mean <sup>207</sup> Pb/ <sup>206</sup> Pb date, MSWD 0.65, pof 0.58, 4 of 4 analyses |           |                    |           |                    |           |                     |       |                       |            |                    |                     |                     |        |             |                  |
| 14b@1          | 50x30                  | 698                                                                                                                 | 80        | 670                | 59        | 576                | 31        | 99.94               | 0.004 | 0.304                 | 680        | 30600              | 0.9337              | 12.0                | 0.1143 | 12.1        | 0.993            |
| 12b@1          | 17x17                  | 825                                                                                                                 | 119       | 773                | 82        | 625                | 24        | 99.89               | 0.007 | 0.292                 | 1195       | 17700              | 1.1400              | 15.2                | 0.1364 | 15.3        | 0.997            |
| 26b@1          | 17x4                   | 673                                                                                                                 | 54        | 660                | 41        | 616                | 23        | 99.84               | 0.038 | 0.336                 | 3742       | 11990              | 0.9164              | 8.5                 | 0.1101 | 8.4         | 0.992            |
| 24bz@1         | 23x8                   | 833                                                                                                                 | 119       | 780                | 82        | 631                | 38        | 99.77               | 0.023 | 0.293                 | 2834       | 8182               | 1.1550              | 15.2                | 0.1379 | 15.2        | 0.993            |
| MNS14          |                        | 742±87 Ma, 95% conf., weighted mean <sup>206</sup> Pb/ <sup>238</sup> U date, MSWD 0.069, pof 0.93, 3 of 3 analyses |           |                    |           |                    |           |                     |       |                       |            |                    |                     |                     |        |             |                  |
| 16b@1          | 6x2                    | 753                                                                                                                 | 55        | 682                | 43        | 457                | 72        | 99.48               | 0.072 | 0.363                 | 3657       | 142500             | 0.9578              | 8.7                 | 0.1238 | 7.8         | 0.929            |
| 4b@1           | 20x10                  | 710                                                                                                                 | 100       | 661                | 70        | 496                | 83        | 98.90               | 0.026 | 0.297                 | 2543       | 3106               | 0.9170              | 14.4                | 0.1165 | 14.8        | 0.967            |
| 14b@1          | 5x5                    | 741                                                                                                                 | 109       | 711                | 79        | 617                | 41        | 99.78               | 0.032 | 0.326                 | 1398       | 8678               | 1.0150              | 15.4                | 0.1219 | 15.6        | 0.993            |
| CS11           |                        | 641±36 Ma, 95% conf., weighted mean <sup>206</sup> Pb/ <sup>238</sup> U date, MSWD 1.9, pof 0.08, 7 of 11 analyses  |           |                    |           |                    |           |                     |       |                       |            |                    |                     |                     |        |             |                  |
| 28b@1          | 37x5                   | 649                                                                                                                 | 23        | 665                | 33        | 718                | 87        | 99.88               | 0.021 | 0.895                 | 918        | 16200              | 0.9247              | 6.7                 | 0.1060 | 3.8         | 0.844            |

Table 3-1. Continuation.

|        |      |     |    |      |     |      |     |       |       |       |      |      |        |      |        |     |       |
|--------|------|-----|----|------|-----|------|-----|-------|-------|-------|------|------|--------|------|--------|-----|-------|
| 14b@1† | 15x2 | 398 | 27 | 426  | 28  | 581  | 47  | 99.79 | 0.008 | 0.516 | 269  | 8809 | 0.5213 | 8.0  | 0.0637 | 7.1 | 0.965 |
| 22b@1  | 15x4 | 616 | 21 | 611  | 22  | 590  | 94  | 99.78 | 0.031 | 0.952 | 318  | 8581 | 0.8246 | 4.8  | 0.1003 | 3.5 | 0.481 |
| 25b@1  | 15x2 | 619 | 28 | 623  | 23  | 637  | 47  | 99.63 | 0.058 | 0.527 | 2303 | 5127 | 0.8462 | 5.0  | 0.1007 | 4.8 | 0.904 |
| 23b@1  | 5x5  | 593 | 34 | 587  | 28  | 565  | 43  | 99.61 | 0.010 | 0.470 | 937  | 4883 | 0.7830 | 6.3  | 0.0964 | 6.0 | 0.948 |
| 26b@1  | 10x6 | 698 | 30 | 711  | 32  | 752  | 77  | 99.49 | 0.014 | 0.576 | 610  | 3714 | 1.0140 | 6.3  | 0.1144 | 4.5 | 0.824 |
| 24b@1† | 10x7 | 571 | 20 | 522  | 21  | 311  | 100 | 98.96 | 0.034 | 0.895 | 200  | 1815 | 0.6717 | 5.1  | 0.0927 | 3.6 | 0.545 |
| 16b@1† | 8x5  | 398 | 31 | 347  | 38  | 18   | 253 | 97.92 | 0.008 | 0.463 | 165  | 906  | 0.4075 | 13.0 | 0.0637 | 8.1 | 0.583 |
| 29b@1  | 6x4  | 674 | 35 | 609  | 78  | 376  | 345 | 97.27 | 0.054 | 0.760 | 151  | 691  | 0.8222 | 17.1 | 0.1102 | 5.5 | 0.464 |
| 10b@1  | 12x3 | 736 | 60 | 696  | 105 | 567  | 379 | 95.74 | 0.031 | 0.408 | 305  | 443  | 0.9843 | 20.8 | 0.1210 | 8.6 | 0.569 |
| 27b@1† | 12x7 | 777 | 42 | 1472 | 56  | 2696 | 106 | 96.88 | 0.063 | 1.132 | 91   | 605  | 3.2610 | 7.2  | 0.1280 | 5.7 | 0.521 |

Notes: values in parentheses are absolute errors at one sigma level for ages, percent for ratios.

b = baddeleyite, bz = baddeleyite rimmed with zircon, z = zircon. \_\_@\_\_ (grain number @ spot number)

$r^{206}\text{Pb}$ =radiogenic  $^{206}\text{Pb}$  in percent

\*=radiogenic Pb value corrected for initial Pb using  $^{204}\text{Pb}$  method for baddeleyite and zircon

rho=correlation coefficient of error ellipses

†=excluded from weighted mean

Data acquired Nov. 29<sup>th</sup> to Dec. 4<sup>th</sup>, 2021, and May 9<sup>th</sup> to 13<sup>th</sup>, 2022 on the CAMECA *ims* 1290 secondary ion microprobe (SIMS) at UCLA (University of California at Los Angeles), USA.

Micro-baddeleyite grains were analyzed in-situ from polished thin sections using a 3x3  $\mu\text{m}$  raster from an  $\sim 1 \mu\text{m}$  primary  $\text{O}^{2-}$  ion beam (Hyperion source) U/Pb relative sensitivity was calibrated by  $\text{UO}_2/\text{UO}$  for baddeleyite using Phalaborwa standard with values that ranged from 0.291 to 0.317 (Nov. 2021) and 0.332 to 0.383 (May 2022).

U concentrations based on  $\text{U}/^{94}\text{Zr}_2\text{O}$  measurements compared to those of zircon standard 91500 (80 ppm U) during the same session.

Pb values were corrected for common Pb using the  $^{204}\text{Pb}$  method for baddeleyite and zircon.

Sample CS-11 is a pyroxene-plagioclase cumulate from the Córrego Seco intrusion. Baddeleyite occurs close to ilmenite-magnetite grains, has little alteration to zircon and produced fairly consistent SIMS data. Weighted mean  $^{206}\text{Pb}/^{238}\text{U}$  date of  $641 \pm 36$  Ma is interpreted as the best estimate of the magmatic age of this sample, in agreement with previous date from the intrusion. The intrusion had been previously dated by ID-TIMS method (Laux *et al.*, 2004) with a date of  $622 \pm 9$  Ma.

### **3.5. Discussion**

#### **3.5.1. Modeling of cumulate formation and nature of the parental magma**

The characterization of hypothetical parental magmas in mafic-ultramafic intrusions is important to understanding the nature of their mantle sources and their composition is considered critical to the nature of the Ni-Cu sulfide mineralization associated with mafic-ultramafic rocks (e.g., Naldrett, 1981). The most common approaches to estimate the parental magma composition are the studies of chilled margins of the intrusions, fine-grained sills and dykes spatially associated with intrusions, comagmatic volcanic equivalents, or melt inclusions; but none of these could be applied to the Mangabal and Americano do Brasil intrusions. None preserved chilled margin was possible to identify in the Complex, whereas all the contacts are marked by intense shearing and alteration. None known volcanic rocks or any liquids in the area are inferred to be compositionally equivalent of a possible parental magma of the intrusion. Nevertheless, qualitative inferences concerning magma composition and evolution can be made.

The igneous rocks from the Mangabal Complex clearly show a sub-alkaline affinity, as indicated by their alkali and silica concentrations and their iron-enrichment trend, supporting a broadly tholeiitic affinity for the parental liquid composition, as suggested by Candia (1983). The forsterite content ranges from 78 to 83, which is

typical for mafic-ultramafic intrusions that originated from fairly primitive parental magmas. The most magnesian olivine (Fo<sub>83</sub>) is inferred to be crystallized from a liquid with a molar MgO/(MgO + FeO) value of 0.61, based on a distribution coefficient of 0.3 (Roeder and Emslie, 1970).

In order to address the composition and evolution of the parental melt associated with the cumulates of both the Northern and Southern portions of the Mangabal Complex, we have modeled crystallization using the alphaMELTS thermodynamic software (Ghiorso and Sack, 1995; Asimow, 1998; Smith and Asimow, 2005). Petrological studies of the mafic-ultramafic intrusions of the area are scarce, and commentary on the nature of parental magmas has been qualitative.

Candia (1983) suggested that the rocks of the complex were formed at low pressure, not exceeding 5 kbar. In addition, we estimated the pressure of equilibration of intercumulus pyroxenes at 2.2 to 2.5 kbar, using the empirical model described by Putirka (2008) for the most pristine clinopyroxene-orthopyroxene pair that we could identify with  $K_D(\text{Fe-Mg})^{\text{cpx-opx}}$  that lies in the equilibrium ranges for magmatic systems ( $1.09 \pm 0.14$ ). Chapter 2 proposed an iron-rich tholeiitic picrite as parental magma for Americano do Brasil Complex, therefore in an effort to find a reasonable starting liquid composition for modeling the evolution of the Mangabal Complex and test a co-magmatic affinity between the two complexes, we used a similar tholeiitic basalt. Both of the model compositions we have used were obtained from data for similar-aged Proterozoic Fe-rich tholeiites from the Mid-Continent Rift of North America (Lightfoot *et al.*, 1999; Rooney *et al.*, 2022). Cooling the parental basalt under isobaric conditions at 2.5 kbar and  $f_{\text{O}_2}$  0.5 log units above the fayalite–magnetite–quartz (FMQ) solid oxygen buffer produced a model sequence of crystallization and modal proportions of

solids similar to the observed bulk-rock and mineral compositions of most of the cumulate rocks of the complex.

Our model for Mangabal predicts the crystallization of olivine (Fo<sub>85</sub>) starting at a liquidus temperature of 1235 °C, followed by the appearance of spinel at 1225 °C, orthopyroxene (enstatite) at 1205 °C, and clinopyroxene at 1145°C. Between 1220 °C and 1085 °C the model predicts cumulate compositions corresponding to the entire range of the rocks observed in the Northern sequence. Modeled minerals and trend lines of solids and liquids are expressed in Figure 3.8 with the whole-rock geochemical data of Mangabal Complex. At 1220 °C, olivine (Fo<sub>83</sub>) and spinel crystallized as observed in the natural rocks. Assuming the collection of solids as predicted by the model along with 30-40 wt% of interstitial liquid as estimated in the petrographic observations, the model cumulates have compositions similar to the average of olivine cumulates of the Northern sequence as can be seen in Figure 3.9A. Model compositions and mineral modes similar to the ones described for the pyroxene-plagioclase cumulates can be produced if the system cools down to approximately 1085°C. Using the modeled cumulate minerals and reacting them with a small amount of trapped liquid (ca. 7%) results in model compositions similar to the rocks described and measured in the Northern complex (Fig. 3.9B). The natural rocks commonly show minor layering defined by variable proportions of the cumulate minerals, which could be explained by some mechanical sorting process and their average composition can be duplicated using the modeled cumulates.



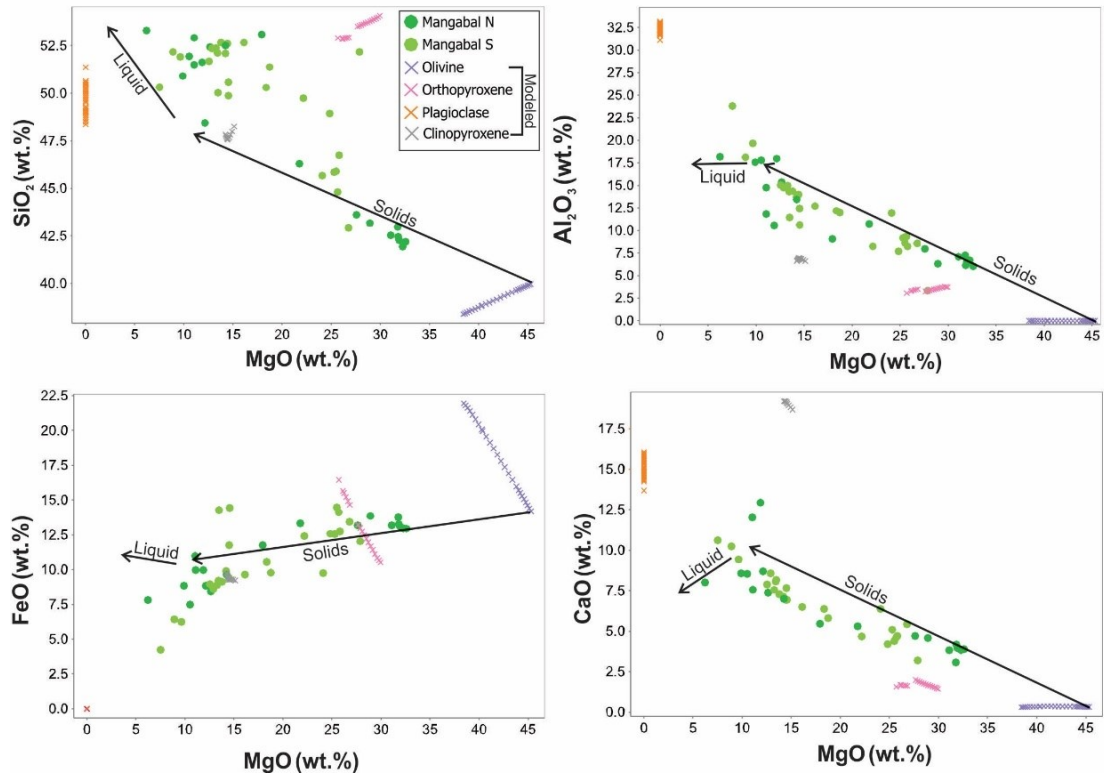


Figure 3.8. Whole-rock data compared with general trends (black lines) of modeled solids and liquids from 1240 to 1085 °C. The modeled minerals are also plotted.

The relict igneous olivine cumulates observed in the southern sequence can be modeled with the same conditions as the ones in the Northern ones. Also, at 1210°C, with the same conditions used to model the Northern sequence, olivine (Fo<sub>83</sub>) and spinel crystallized in a proportion of 98:2, as observed in the natural rocks, with a range from 20 to 30% of interstitial liquid as estimated in the petrographic observations. The model cumulates reached compositions similar to the average of olivine cumulates of the Southern sequence as can be seen in Figure 3.9C. Appearance of orthopyroxene occurs at 1195°C; at 1085°C clinopyroxene appears and olivine completely disappears. All the variations in pyroxene cumulates of the southern sequence can be explained between these temperatures, along with small variations in trapped liquid component (from 15 to 25%); an example is shown in Figure 3.9D. Few samples have stronger Eu anomaly, even in samples with small amounts of plagioclase. The alphaMELTS model does not

account for effects of different redox states on the behaviour of Eu in plagioclase, which could explain the difference only in this anomaly compared with the models.

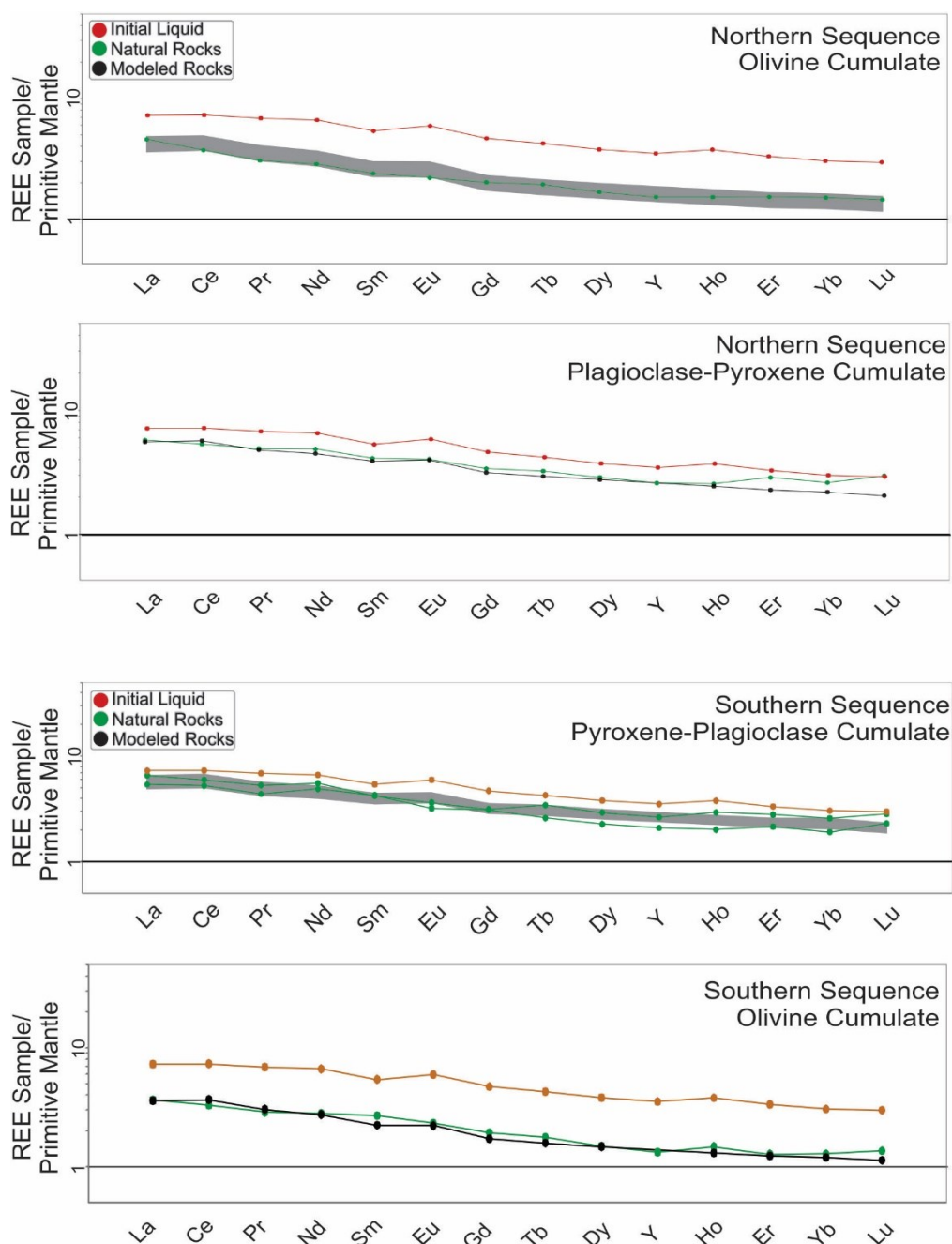


Figure 3.9 Trace element plots showing measured cumulate compositions by zone vs model cumulates from the alphaMELTS models discussed in the text. Also shown are the initial liquid (Sample #89; Lightfoot et al., 1999). Samples/model cumulates are normalized to primitive mantle (McDonough and Sun, 1995).

Overall, modeling indicates that the parental magma of the intrusion could have a similar composition to the tholeiitic basalt and the same liquid could be parental to rocks from both the Northern and Southern sequences. It appears that differences

between the Northern and Southern sequences resulted from different degrees of crystallization, temperature, and retention of different quantities of interstitial liquid.

### 3.5.2. Timing of Emplacement

Determining the timing of emplacement is important to constrain the origin of the intrusions. Baddeleyite ( $\text{ZrO}_2$ ) and zircon ( $\text{ZrSiO}_4$ ) are the most common minerals used for U-Pb geochronology in mafic-ultramafic rocks. However, these analyses and age interpretations are often difficult, particularly if the samples have experienced post-magmatic alteration and metamorphism as in the Mangabal Complex and other mafic-ultramafic intrusions in the area. In addition, baddeleyite geochronology by in-situ SIMS can be challenging due to analytical limitations for in-situ methods such as beam overlap on adjacent phases and possible bias in the U/Pb relative sensitivity calibration factor (RSF) (e.g., Pohlner et al., 2020; Schmitt et al., 2010).

In this work, micro baddeleyite from olivine orthocumulate was dated, trying to avoid the effects of the metamorphic event. The concordia age and weighted mean  $^{206}\text{Pb}/^{238}\text{U}$  dates in sample MNN-04 overlap, yielding results of  $637 \pm 24$  Ma and  $653 \pm 31$  Ma, respectively. In general, zircon from MNN-04 agrees with the baddeleyite dates, so there is not any evidence of metamorphic zircon in this sample. Sample MNN-06 rendered reversely discordant data and a weighted mean  $^{206}\text{Pb}/^{238}\text{U}$  date of  $720 \pm 54$  Ma. The weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  date ( $613 \pm 27$  Ma) overlaps the date from MNN-04, however. Similarly, sample MNS-14 produced a reversely discordant data and older  $742 \pm 87$  Ma weighted mean ( $^{206}\text{Pb}/^{238}\text{U}$  date) from 3 out of 16 analyses; the  $^{207}\text{Pb}/^{206}\text{Pb}$  dates do not overlap within error. This sample had a lot of variation, and the excluded analyses had  $\text{UO}_2/\text{UO}$  values that were outside of the range of the standard, both too high and too low. The most robust three analyses plot slightly reversely discordant and so as with MNN06, the calculated  $^{206}\text{Pb}/^{238}\text{U}$  date is likely too old. The alteration could

compromise the data and lead to reverse discordance, as is observed for samples MNN-06 and MNS-14. The intense alteration could explain the poor quality of the data from MNN06 and MNS14. In addition, the effect of potential intergrowths of zircon that are too small to detect by BSE and EDS could affect the interaction with the ion beam and therefore the U-Pb calibration. Thus, since the most pristine sample with the most robust data is the sample MNN-04, and since the Concordia age and weighted mean for it agree at ca. 650 Ma it is interpreted as the most reliable age identified for the Mangabal Complex.

Zircon ID-TIMS data were previously obtained from a norite sample of the Americano do Brasil Complex, indicating an age of  $626 \pm 8$  Ma (Laux *et al.*, 2004). The Americano do Brasil Complex rocks have undergone intense amphibolitization altered and crosscut by younger dykes (Chapter 2). The dated sample was first cited as hornblende-norite (Gioia, 1997), and the absence of published lithogeochemistry or a detailed description and zircon imaging prevent the characterization of the degree of alteration. As the zircons were neither chemically nor mechanically abraded, the data could reflect some Pb loss. The possibility of occurrence of metamorphic zircon rims in the analyzed crystals can not be discounted either, so the reported date may be slightly younger than the magmatic age of the intrusion. Our sample CS-11 is from the sample complex and although its date overlaps with the reported ID-TIMS date at its younger limit, the CS-11 date also overlaps with those from the Mangabal complex. Within uncertainties, the obtained age could be interpreted as a minimum age for the Americano do Brasil complex and, therefore, it could be coeval to the Mangabal Complex. The possibility of such a cogenetic nature between the two complexes cannot be discarded, contrariwise it is plausible that they are related to the same event due to the affinity of the parental magma.



Figure 3.10 Previous U-Pb zircon age data from the Goiás magmatic arc. (Araújo, 2012; Giustina et al., 2011; Guimaraes et al., 2012; Hollanda et al., 2003; Joseneusa Brilhante Rodrigues et al., 1999; Laux et al., 2005, 2004; Macedo et al., 2018; Marques, 2017; Pimentel et al., 1991)

The Damolândia and Taquaral intrusions, located in the high-grade Anápolis-Itaçu Complex, show a wide range of concordant LA-ICPMS zircon dates spreading

from 670 Ma down to 590 Ma, with the oldest zircon at  $670 \pm 20$  Ma interpreted as the crystallization age of the intrusions (Giustina *et al.*, 2011). This age (within errors) overlaps the ages we have found for the Mangabal Complex, indicating that the intrusions in both the Arenópolis Arc and in the Anápolis-Itauçu domain could be coeval. In addition to the cited intrusions, the ultrahigh-temperature (UHT) metamorphism in the Anápolis-Itauçu complex was interpreted as a short-lived episode, with a maximum duration of c. 15 Myr, starting at 649 Ma and ending around 634 Ma (Baldwin *et al.*, 2005). This overlap in dates could indicate that the Damolândia and Taquaral intrusions are coeval with or slightly older than the UHT event, a similar relationship that was suggested by Giustina *et al.* (2011) due to the close spatial association of those intrusions with UHT sites in the Anápolis-Itauçu Complex. Based on similar ages, we suggest this correlation also applies to the western intrusions, located in the Arenópolis arc.

Piauilino *et al.* (2021) described OIB-like basaltic magmatism at  $651 \pm 6$  Ma represented by an amphibolite located closely between the Araxá Group and Anápolis-Itauçu Complex. These chemical characteristics (OIB-like) for parental liquid are similar to those suggested for Americano do Brasil Complex, and its age overlaps those of the Mangabal Complex.

### 3.5.3. Emplacement of the Intrusions

Combining the results described above, the existing geological data available about the area, and the timing of emplacement, we are able to formulate and test hypotheses for the geodynamic setting of the intrusive bodies. Figure 3.8 summarizes a compilation of zircon and baddeleyite ages for a variety of rocks of the Arenópolis-Arc and intrusions dated in the Anápolis-Itauçu Complex, including our own work. Two groupings of ages, corresponding to major magmatic events, can be observed in

data from the Arenópolis Arc, as described by previous works (e.g., Laux et al., 2005; Pimentel, 2016). The first volcanic and plutonic cycle ranges from 923 to 748 Ma, represented by orthogneisses, granitoid and volcano-sedimentary sequences. It was followed by an apparent period of magmatic quiescence that lasted ca. 80 Myr, with no ages recorded so far for this period. The second magmatic event starts around 670 Ma, with the crystallization of granodioritic and tonalitic gneiss, as such Turvânia and Firminópolis, as well as crystallization of mafic-ultramafic layered intrusions. Despite the large extent of the Goiás Magmatic Arc, the mafic-ultramafic intrusions are localized only in the vicinities of the Anicuns region, lying near to the boundary of the domain of the Arenópolis arc and the Anápolis-Itauçu Complex.

The Americano do Brasil and Mangabal Complexes could have originated from parental magmas compositionally similar to the liquids we have chosen as starting points in our forward models. The magmas we used were sampled from the North American Mid-Continent Rift large igneous province ; (groups 2 and 7; Lightfoot et al., 1999) which are representative of Neoproterozoic Fe-enriched tholeiite. We do not imply any direct correlation between the Americano do Brasil and Mangabal Complexes and the Mid-Continent Rift; rather, we used it only to infer the chemical characteristics and suggest that the rocks of the complex could have formed by some processes similar to the ones that generate that liquid. Hence, Americano do Brasil could have been formed from a primitive melt similar to iron-rich picrite with an OIB-like trace signature (Chapter 1), which corresponds well to the OIB-like signature documented in 650 Ma amphibolite found in the vicinity of Anápolis-Itauçu (Piauilino *et al.*, 2021), coeval to our preferred age for the Mangabal Complex.

OIB-like magmatism is often regarded as anorogenic nature and its source has commonly been associated with mantle plumes, upper asthenosphere, and/or

subcontinental lithosphere mantle, frequently triggered by extension events or any other mechanisms that allow asthenosphere upwelling from considerable depths, leading to adiabatic decompression melting (e.g., Gao et al., 2021; Kheirkhah et al., 2015; Niu and O'Hara, 2003; and references therein). Deeper lithospheric or asthenospheric processes are required to form the highly magnesian magmas inferred for the intrusions.

The Brasiliano orogeny has been described as active until ca. 630 Ma (e.g., Fuck et al., 2017; Pimentel, 2016), which is evident in the arc-typical signature rocks that have been dated such as Matrinxã, Firmópolis, and Turvânia gneisses (Laux *et al.*, 2005a), thus there is ample evidence for subduction simultaneous with the emplacement of the mafic-ultramafic intrusions. Considering the localized area of the intrusions (i.e., they do not occur in all extensions of the Goiás Magmatic Arc), the coeval UHT event, the geochronology, geochemical signature, the adiabatic decompression melting of the asthenosphere required for the magmatism could have been triggered by some major tectonic disturbance of the subducted slab. Roll-back of the subducting oceanic plate could have taken place during magma generation, causing localized back-arc extension, and inducing the melting of the asthenosphere, thus explaining the enriched signature of the basic magmatism, the thermal anomaly in the area and the simultaneous occurrence of voluminous arc magmatism. In a review about the Brasília Belt, Pimentel et al (2003) suggested a model in which in the period between approximately 660 and 620 Ma the evolution of the Arenópolis Arc was the result of alternating distension events, associated with short episodes of slab steepening, perhaps leading to pulses of back-arc extension and the generation of decompression melts within the arc.

On the other hand, the mantle plume model could also explain the generation of mafic magmatism and can not be discarded merely because no such suggestion has previously been raised for the Neoproterozoic Brasília Belt. Mantle plume events are



of short duration (e.g., Ernst, 2014), and more high-precision dating should be done in the intrusions to further test this hypothesis. In addition, one hypothesis does not exclude the other, in fact, there is the possibility of both influencing the formation of the magmatism. Despite mantle plumes being widely associated with intraplate magmatism, they can also be spatially associated with plate boundaries with some widely known examples. Ernst (2014) suggested that the Keweenaw LIP, associated with the MCR and therefore the liquid used for the thermodynamic modeling here, could be an example of a mantle plume arising randomly into a region that was experiencing regional compression in a back-arc setting with respect to the Grenville Orogen. Contemporaneous analogs are also possible to find, as in the case of the Tonga-Kermadec subduction system, which is a well known intra-oceanic convergent plate boundary (Smith and Price, 2006), which has magmatism in the back-arc with the influence of OIB material derived from the Samoan plume leaking into the Lau Basin asthenosphere (Falloon *et al.*, 2007; Karrei, 2008).

### **3.6. Conclusion**

The Mangabal Complex is composed of mafic-ultramafic cumulates and has been affected by metamorphism and deformation, but it keeps relicts of its primary magmatic textural features because deformation and hydrothermal alteration tends to have been restricted to discrete shear zones, veins and/or the margins of the intrusion.

Modeling indicates that the parental magma of the intrusion could be a composition similar to a tholeiitic basalt composition and that the same liquid could be parental to rocks from both the Northern and Southern sequences. Differences between the Northern and Southern sequences have mainly resulted from different degrees of crystallization and different interstitial liquid, likely representing different portions of

the same magmatic system. The parental magma could be genetically associated with the parental magma for Americano do Brasil Complex.

U-Pb *in situ* SIMS in micro baddeleyite indicates a minimum age of 650 Ma for the Complex, suggesting the intrusions of the Arenópolis-Arc segment are a little bit older than previously thought and coeval with the intrusions in the Anápolis-Itaçu Complex.

Considering the temporal and spatial correlations, we propose that decompression melting of upwelling asthenosphere triggered by rollback subduction and/or influence of a mantle plume are plausible sources to explain the petrogenesis of the mafic-ultramafic intrusions in the vicinities of the eastern Arenópolis arc and westernmost Anápolis-Itaçu belt.

## **Chapter 4**

# **Characteristics of the Amphibolite Facies Metamorphism Overprinted in Mafic- Ultramafic Cumulates in the Mangabal and Americano do Brasil Complexes**

## **4. Characteristics of the Amphibolite Facies Metamorphism Overprinted in Mafic-Ultramafic Cumulates in the Mangabal and Americano do Brasil Complexes**

### **Abstract**

The Americano do Brasil and Mangabal Complexes belong to a cluster of Neoproterozoic mafic-ultramafic intrusions in the southern Goiás Magmatic Arc in Brazil. Both complexes were highly deformed and metamorphosed under amphibolite facies conditions, leaving few igneous relict domains. We have documented mineralogy and texture to constrain the secondary alteration processes recorded in the rocks of both complexes. The rocks of both complexes show intense amphibolitization associated with the most metamorphosed rocks. Construction of pseudosections suggests temperature between 670 to 710 °C and pressure between 4.4 to 7.5 kbar, at amphibolite facies conditions. In some samples of amphibolite, we note the presence of unusual minerals such as kyanite, sillimanite, muscovite, silvialite (sulfate-rich member of calcic scapolite), and anhydrite. We attribute these unusual assemblages to open system behavior during metamorphism, most likely related to metasomatism surrounding diorite veins that are inferred to have released fluids rich in CO<sub>2</sub>, Ca, and SO<sub>3</sub>. Pseudosections could not be calculated for rocks with unusual mineralogy.

### **4.1. Introduction**

The occurrence of Ni-Cu sulfide systems in orogenic settings has received increased attention in the last few years, despite earlier expectations that these settings were less prospective (Le Vaillant *et al.*, 2020). Some notable examples are Aguablanca in Spain (Piña, 2019); the Savannah Ni-Cu-Co Camp in East Kimberley, Australia (Le Vaillant *et al.*, 2020); the Limoeiro and Mirabela Intrusions in Brazil (Barnes *et al.*, 2011; Mota-e-Silva *et al.*, 2013); and the Ntaka Hill in Tanzania (Barnes *et al.*, 2019).

Intrusions located in orogenic settings could have registered a complex metamorphic evolutionary history, due to the complexity of their regional tectonic evolution. Documentation of the effects of metamorphism on mafic-ultramafic intrusions has been scanty, although some studies have examined the effects of hydrothermal and metamorphic processes on the mineralogy and textures of the sulfide ores (e.g., Hoatson *et al.*, 2006; Holwell *et al.*, 2017; Wu *et al.*, 2018)

The Americano do Brasil suite is a cluster of mafic-ultramafic intrusions emplaced within the Brasília Belt, a complex Neoproterozoic orogen in western Gondwana. The intrusions are affected by metamorphism (e.g., Chapter 1, Chapter 2; Augustin and Della Giustina, 2019a; Cândia and Girardi, 1991; Nilson and Dos Santos, 1981), but details of the metamorphic assemblage are poorly constrained. The rocks of the complexes went through intense amphibolitization, with typical coarse-grained poikiloblastic hornblende overprinting in different intensity the igneous textures and mineralogy of the complex, most strongly associated with the margins of the complex. This article focuses on the nature of the metamorphic assemblages developed in the mafic and ultramafic rocks of the Mangabal and Americano do Brasil complexes. The igneous features of both intrusions were the focus of previous studies (Nilson, 1981; Candia, 1983; Mota-e-Silva *et al.*, 2011; Augustin and Della Giustina, 2019), and here we focus on the effects of post-magmatic events that both complexes underwent and try to draw links to the regional geological history.

#### **4.2. Geological Setting**

Several small to medium-sized mafic-ultramafic intrusions occur near the boundary between the Goiás Magmatic Arc, most specifically its southern portion called the Arenópolis, arc and the granulite-facies Anápolis-Itauçu metamorphic complex, both belonging to the Internal Zone of the Brasília belt (Fig. 4.1A-B). The

Mangabal (Fig. 4.1C) and Americano do Brasil (Fig. 4.1D) mafic-ultramafic complexes are enclosed by tonalitic gneisses of the Arenópolis segment of the Goiás Magmatic Arc and their emplacement is temporally associated with the same magmatic event (Chapter 3).

The Brasília Belt is one of the Neoproterozoic orogenic belts that formed due to the final amalgamation of the Amazonian, São Francisco/Congo, and Paranapanema cratons (e.g., Fuck *et al.*, 2017 and references therein). The Goiás Magmatic arc can be described as a composite arc terrain, which was formed by the accretion of arcs of different ages and nature (Pimentel, 2016). The evolution took place during two magmatic episodes, the first with ages between 900 and 800 Ma formed by calc-alkaline rocks generated in island arcs, followed by the second episode of arc activity, possibly in an active continental margin setting ca. 660-600 (e.g., Laux *et al.*, 2005; Pimentel, 2016). The Anápolis-Itauçu metamorphic complex is composed of granulite, and it is exposed between the Goiás Magmatic Arc and occurrences of metasedimentary rocks of the Araxá Group to the east. It has been interpreted as the metamorphic core of the Brasília Belt and it consists of ortho- and paragranelites, locally presenting ultra-high temperature (UHT) metamorphism. The metamorphism in the internal zone took place between 650 and 630 Ma, concurrent with the final closure of the Goiás Ocean and resulting continental collision (Pimentel *et al.*, 2000b; Piuzana *et al.*, 2003; Baldwin *et al.*, 2005; Pimentel, 2016).

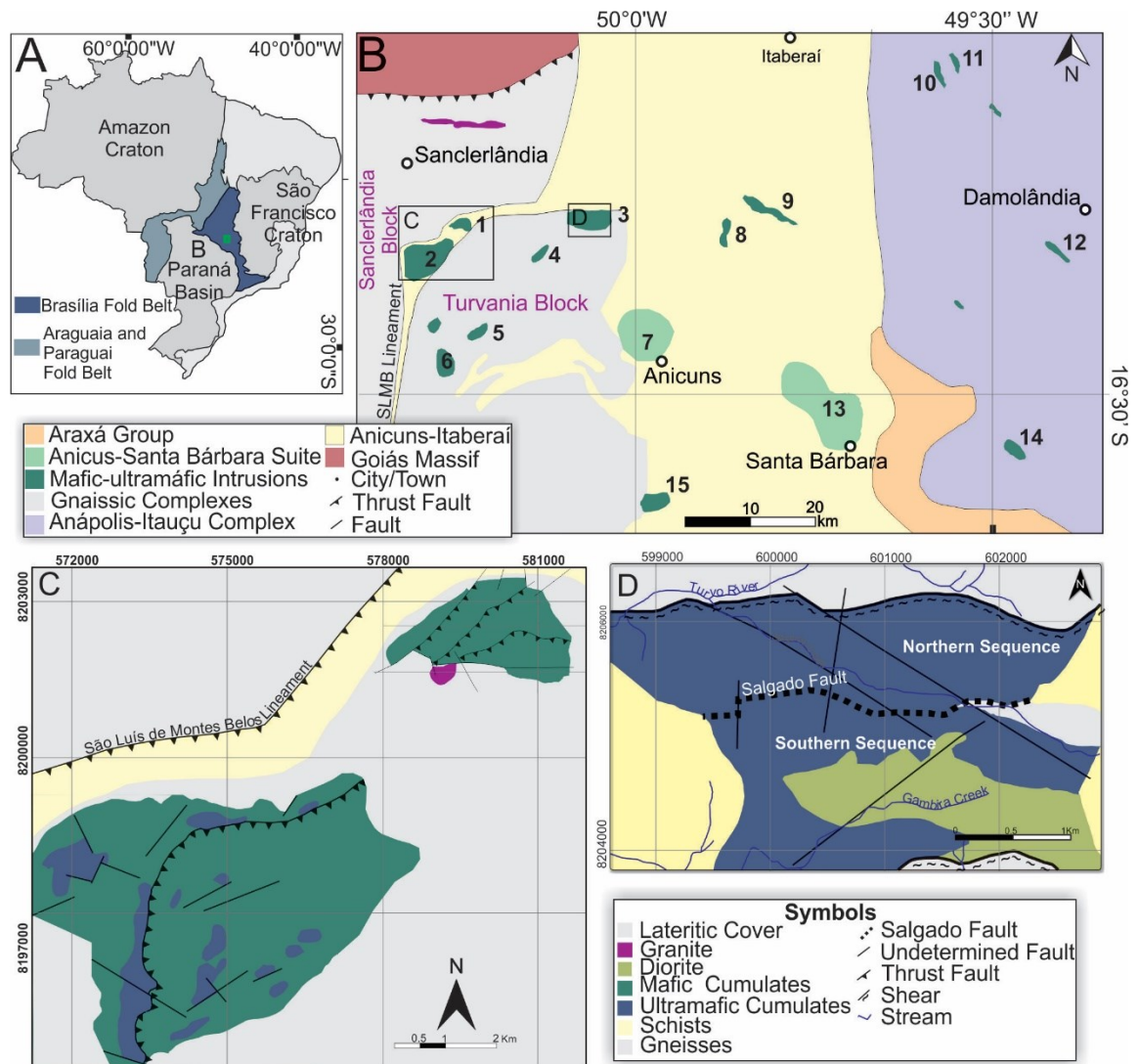


Figure 4.1 A) Spatial location of Brasília Belt in Brazil. B) Simplified geological map of the Anicuns-Region, showing the locations of Anápolis-Itaúçu Complex and Arenópolis Arc hosting several mafic-ultramafic intrusions. C) Simplified geological map of the Mangabal Complex (chapter 3). D) Simplified geological map of the Americano do Brasil Complex (modified from chapter 2).

Considering the temporal, spatial, and geochemical characteristics, the intrusions possibly were formed due to decompression melting of upwelling asthenosphere triggered either by rollback subduction and/or the influence of a mantle thermal anomaly or plume (Chapters 2, 3).

### 4.3. Sampling and Methods

The rocks of the Americano do Brasil and Mangabal complexes are poorly exposed, so all the work in this study focused on drill core. The 145 samples collected were chosen to represent the main structural, lithological, and mineralogical variations in

both complexes. Mineralogical and textural studies were performed using conventional transmitted and reflected light microscopy in combination with scanning electron microscopy (SEM). The SEM used was a JEOL JSM-IT500 Scanning Electron Microscope equipped with Oxford ULTIM MAX SDD-EDS detector, located at the Earth Sciences Department, Carleton University.

In addition to SEM analysis, the compositions of some plagioclase and amphibole crystals were determined. The mineral analyses were performed using a JEOL JXA-8230 SuperProbe with five wavelength-dispersive spectrometers (WDS) at the University of Brasília. Operating conditions for all silicate minerals were 15 kV accelerating voltage, a beam current of 10 nA, and probe diameters of 1  $\mu\text{m}$  for all minerals except plagioclase (5  $\mu\text{m}$ ). Counting time in peak and background were 10 s and 5 s, respectively.

Phase equilibrium modeling was performed in the  $\text{Na}_2\text{O}\text{--}\text{CaO}\text{--}\text{K}_2\text{O}\text{--}\text{FeO}\text{--}\text{MgO}\text{--}\text{Al}_2\text{O}_3\text{--}\text{SiO}_2\text{--}\text{H}_2\text{O}\text{--}\text{TiO}_2\text{--}\text{O}_2$  (NCKFMASHTO) compositional system using Theriak–Domino software (de Capitani and Petrakakis, 2010), and the internally consistent thermodynamic data set of Holland and Powell (2011). Mixing models for solid solutions were amphibole, biotite, chlorite, clinopyroxene, epidote, feldspar, garnet, orthopyroxene, spinel, and white mica (Holland and Powell, 2003, 2011; White *et al.*, 2007, 2014; Green *et al.*, 2016). Pressure-temperature pseudosections were calculated for representative mafic samples of known bulk compositions (Chapters 2 and 3). To help constrain the conditions, the plagioclase-amphibole pair of Holland and Blundy (1994) was calibrated for amphibole ( $\text{Na}_A > 0.02$  pfu,  $\text{Al}_{(\text{IV})} < 1.8$  pfu, and Si between 6.0 and 7.7 pfu) and plagioclase ( $X_{\text{an}} < 0.90$ ), considering edenite-richterite reaction: edenite + albite = richterite + anorthite. This thermometry was combined with the Al-in-hornblende barometry described by Anderson and Smith (1995).



#### **4.4. Metamorphic Rocks of Mangabal Complex**

The Mangabal Complex shows a large range of degrees of alteration, from nearly pristine igneous relicts to entirely overprinted metamorphic assemblages and textures. The complex is faulted, and the most altered rocks are spatially linked with sheared or faulted zones marked by a notable increase in the replacement of igneous minerals by hydrous metamorphic mineral assemblages. Description of igneous rocks was the focus of previous studies (Chapter 3; Augustin and Della Giustina, 2019; Candia, 1983) and will not be repeated in this work. Here we describe the metamorphic assemblages found in the complex corresponding to the zones previously described in Chapter 3.

##### **4.4.1. Ultramafic Zone**

The ultramafic Zone in Mangabal Complex is composed of olivine orthocumulates and rare olivine-orthopyroxene orthocumulates (i.e., granular harzburgites) that transition to poikilitic harzburgites. The interstitial minerals are mainly clinopyroxene, orthopyroxene, and plagioclase, the latter occurring in all olivine cumulates and sometimes occupying the majority of the intercumulus volume. A common feature of the olivine cumulates in the Mangabal Complex is the presence of reaction coronas variably developed between olivine and plagioclase grains, as previously cited in older studies (Candia, 1983; Augustin and Della Giustina, 2019). Corona textures between olivine and plagioclase are especially well developed in the olivine orthocumulate rich in plagioclase, and the size and degree of development are closely associated with alteration zones. Distal to shear zones, coronas are either simple or completely absent whereas the more well-developed corona textures occur close to shear zones (Fig. 4.2a). In general, the coronas are composed of two layers, an inner shell composed of radially oriented orthopyroxene, and an outer shell that is mostly

expressed as calcic amphibole or even amphibole-spinel symplectites (Fig. 4.2 b-c). Biotite locally occurs outside the orthopyroxene layer, closely associated with fine (1-2 mm) veinlets rich in very-fine grained biotite, andesine, and very fine-grained hydrous phyllosilicates that crosscut all minerals in the rocks. In addition, when Cr-spinel is present as a cumulate mineral, it also has a corona texture against plagioclase, composed of biotite and amphibole. Overall, the shape of each described layer is parallel to the shape of the olivine or chromite.

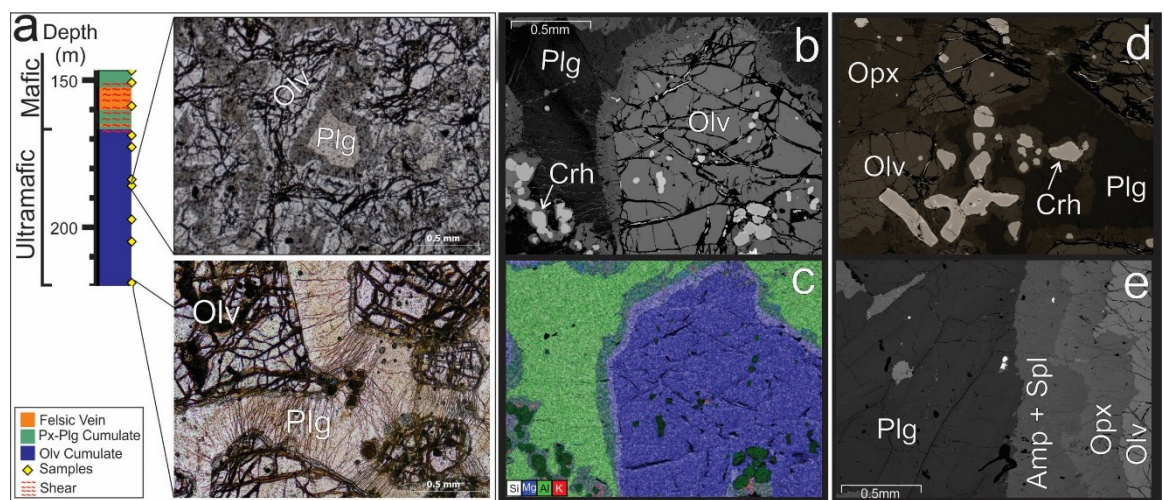


Figure 4.2 a) Photomicrographs in plane-polarized light showing the different degrees of development of corona textures between plagioclase and olivine in olivine cumulates from the Northern sequence of the Mangabal Complex, compared spatially to proximity with the shear zone in the schematic section at left. b-c) BSE image and phase map from the same section in olivine-cumulate in a sample from the Northern Sequence of Mangabal showing the multilayer corona. Note corona developed also around Cr-spinel at left, whereas the spinel included in olivine (middle-right) lack coronas. D) BSE image showing in detail Cr-rich spinel with corona in contact with plagioclase. E) BSE image of well-developed multilayer corona between olivine and plagioclase in mafic cumulate from Mangabal Complex.

The samples with higher amounts of intercumulus or poikilitic pyroxene have more hydrous secondary minerals and commonly show more alteration. The igneous textures in these meta-ultramafic cumulates can be completely overprinted by metamorphic minerals concurrent with the development of mineral foliation, usually defined by nematoblastic amphiboles and minor phyllosilicates. The most dominant minerals are hornblende, orthoamphibole, biotite, chlorite, and relicts of mesh-textured

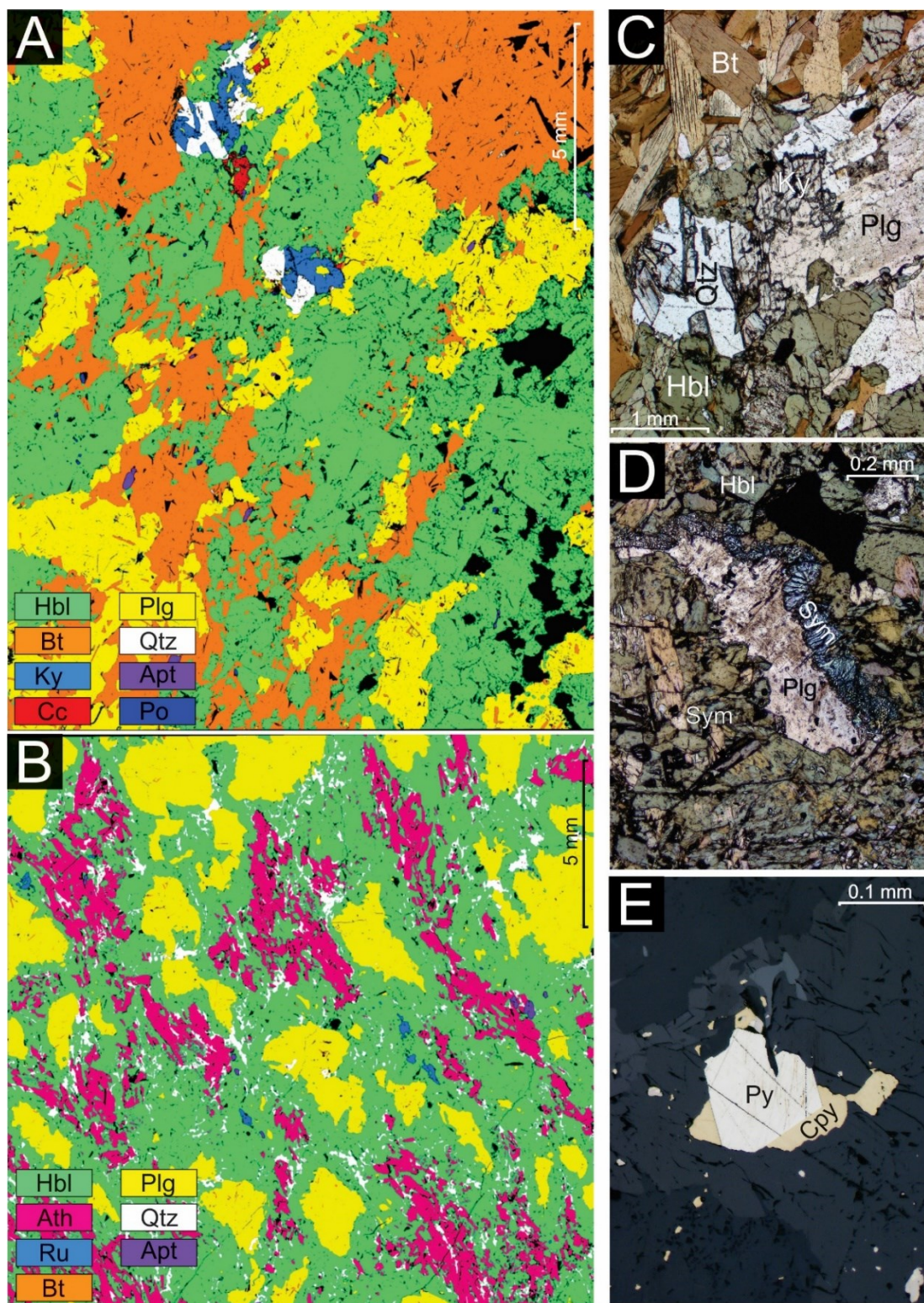
serpentinized olivine. Apatite, carbonates, and needle-like iron-oxides are common metamorphic minerals.

#### 4.4.2. Mafic Zone

The mafic zone was originally mostly composed of pyroxene-plagioclase cumulates, including norite and gabbro-norite. These rocks were commonly transformed into amphibolite, spanning a range of mineral modes and textures. The textures vary from primary igneous textures with some shape preferred orientation to strongly foliated. In all metamorphosed samples, the dominant minerals are hornblende followed by plagioclase, commonly with variable amounts of orthoamphibole and biotite. Titanite, rutile, quartz, epidote, apatite, kyanite, sillimanite, carbonate, calcic myrmekite, silvialite, epidote, and allanite have been observed as minor or accessory metamorphic phases. Despite these local variations in mineral assemblage, we will describe the most common amphibolites found in the complex that we will call here hornblende amphibolite (Fig. 4.3A) and hornblende-orthoamphibole amphibolite (Fig. 4.3B).

The most common mineral assemblage in the hornblende amphibolite involves medium-grained equigranular hornblende + plagioclase  $\pm$  biotite with accessory quartz, apatite, titanite, rutile, zircon, kyanite, carbonate, and/or epidote. Hornblende ranges from idioblastic to xenoblastic texture, variable color to pale green to bluish dark green in thin sections. It commonly has inclusions of rounded quartz. The plagioclase is commonly fractured, with deformation twinning and/or showing dynamic recrystallization to a fine granular texture. Biotite is typically found in clusters, with





colors ranging from pale brown to medium brown. Minor idiomorphic fine-grained

Figure 4.3 Detailed textures from metamorphic rocks in the Mangabal Complex. A) Phase map of a hornblende amphibolite from Northern sequence. It shows a paragenesis of hornblende, plagioclase, and biotite. Kyanite, quartz, and carbonate also appear in this sample. B) Phase map of an orthoamphibole-bearing amphibolite from Northern sequence, showing the oriented fabric in the rock. C) Detail from kyanite grain (same sample from picture in A). d) Plane-polarized light photograph of detail in epidote-quartz symplectite in an amphibolite sample. E) Idiomorphic pyrite in symplectite-bearing amphibolite.

sub-idiomorphic kyanite occurs with quartz and carbonate, in contact with plagioclase and hornblende (Fig. 4.3C). Locally, symplectites of quartz and epidote (Fig. 4.3D) occur in the contact of amphibole and plagioclase. Sulfides can occur as minor or accessory phases, chalcopyrite, pentlandite, pyrrhotite, and idiomorphic pyrite (Fig. 4.3E).

Hornblende-orthoamphibole amphibolite is a strongly foliated rock, marked by idioblastic elongated grains of orthoamphibole, netamoblastic hornblende, and elongated plagioclase clusters (Fig. 4.3B). The hornblende usually forms coronas with quartz around the orthoamphibole. Biotite, rutile, apatite, kyanite, and carbonate are common accessory minerals. Where kyanite is observed, its textural relationship with quartz and carbonate is similar in all amphibolites. Sulfides occur as the minor or accessory phases chalcopyrite, pentlandite, pyrrhotite, and idiomorphic pyrite.



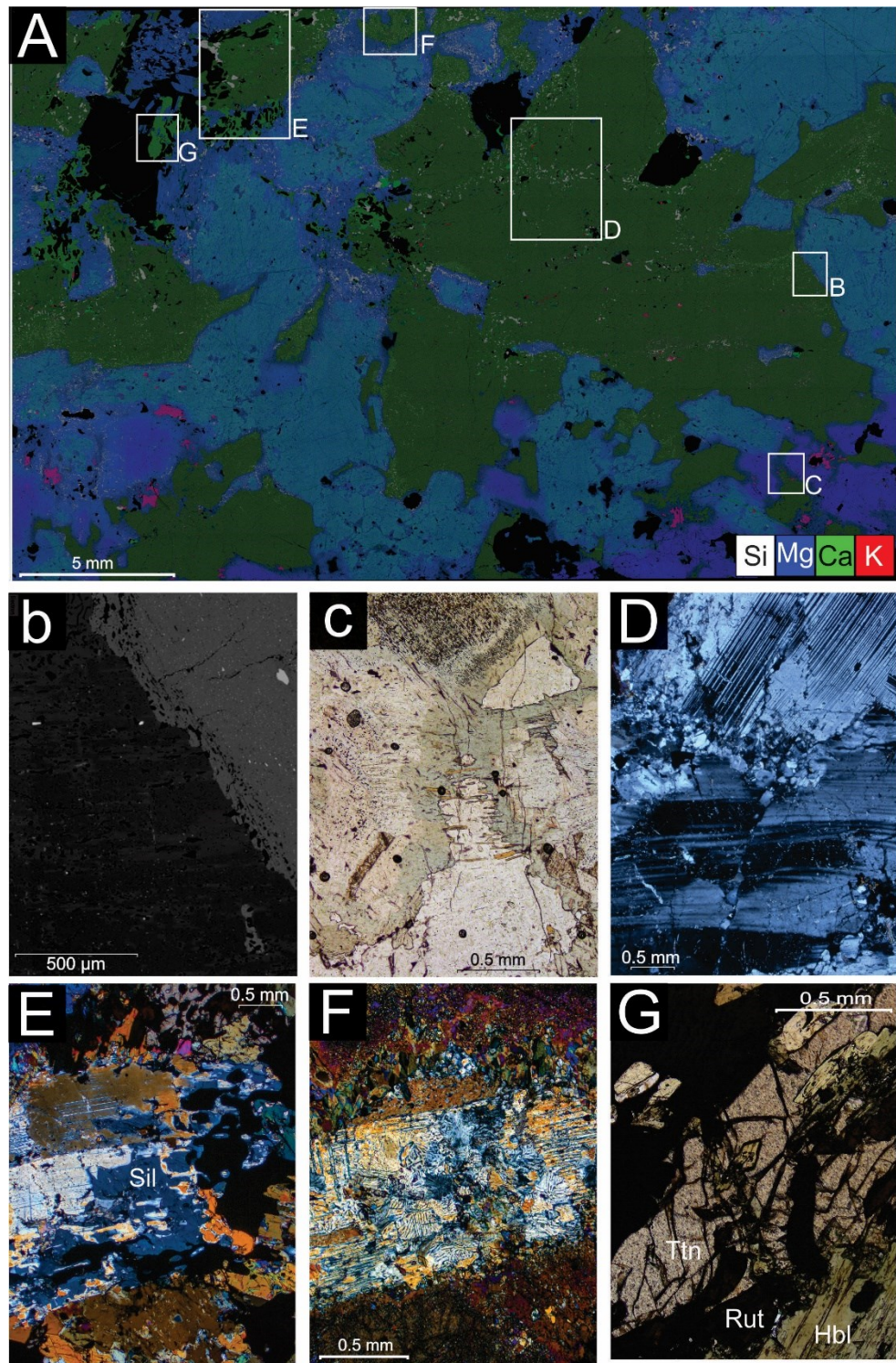


Figure 4.4 A) Phase map in a whole thin section of coarse-grained metagabbro from the Southern Sequence. B) Backscattered electron image showing the breakdown of labradorite into quartz+bytownite, as well as quartz+amphibole symplectite along contact. C) details of biotite and hornblende intergrowth in rim around pyroxene relict. D) Cross-polarized microphotograph of fractured plagioclase grain with sub grains along fractures and grain boundaries. E) Photomicrograph in cross-polarized light with silvialite replacing plagioclase. F) Photo in cross-polarized light showing a grain of labradorite completely replaced by quartz-bytownite symplectite. G) Plane-polarized light photomicrograph of titanite and rutile in metagabbro.

Rare olivine-norite, which only crops out close to the sheared southern limit of the complex, also shows well-developed coronas, similar to the ones in the ultramafic zone (Fig. 4.2D). Very well-developed multilayer corona texture is observed at the contact between plagioclase and olivine and locally the corona preserves a euhedral/subhedral shape of the original grain. Usually, it is composed of two layers, an internal one composed of orthopyroxene and an external one composed of amphibole-green spinel symplectites. Some grains have coronas so well-developed that olivine was completely replaced by orthopyroxene in granoblastic texture preserving the pseudomorph of the original olivine, or pyroxene-magnetite symplectites, surrounded by amphibole-spinel symplectites. Some coronas have magnetite between the orthopyroxene and amphibole layers.

Some coarse-grained gabbro (Fig. 4.4A) in the Mangabal Complex shows better preservation of igneous texture and minerals, but with some interesting secondary mineralogy. Clinopyroxene is commonly altered to amphibole, and its contacts with plagioclase are mantled by amphibole-quartz symplectites (Fig. 4.4B). Locally, biotite growing orthogonal to pyroxene faces forms intergrowths with amphibole (Fig. 4.4C). Plagioclase shows several deformation features like fractures, undulose extinction, deformation twinning, and dynamic recrystallization leading to sub grains (Fig. 4.4D). Silicalite, the sulfate-rich member of scapolite, occurs in alteration zones close to contacts between sulfide minerals and plagioclase (Fig. 4.4E). Along borders and oriented fractures in deformed plagioclase (labradorite), symplectites of quartz and bytownite (calcic myrmekite) replace portions of the original plagioclase; in more altered zones it pseudomorphs entire grains (Fig. 4.4F). In these more altered areas, it is common to find rutile with coronas of titanite (Fig. 4.4G), silicalite (sulfur-calcic member scapolite), and sulfides. Sulfides are pyrrhotite, pentlandite, chalcopyrite and

euhedral pyrite. Around euhedral pyrite grains, when enclosed by other sulfide minerals, a very fine rim of carbonate is commonly present. Inclusions of rutile, euhedral amphibole, and chalcopyrite can also occur in the pyrite.

#### 4.4.3. Semi-massive Sulfides

Semi-massive sulfides are associated with amphibolite, commonly occurring as veins in fault zones (ex. Fig. 4.5A-C). The sulfide is composed of pyrrhotite, pentlandite, chalcopyrite, and pyrite. Foliated amphibolite in discordant contact with sulfides commonly comprises hornblende and plagioclase, with minor or accessory rutile, titanite, quartz, carbonate, muscovite, chlorite, and scapolite. Directly along the contact it is common to observe chlorite oriented parallel to the interface, epidote (with some inclusions of idiomorphic allanite), and very fine-grained intergrowths of sillimanite + quartz (fibrolite, Fig. 4.5D). Carbonate, chlorite, plagioclase, idiomorphic epidote, and hornblende are the most common minerals enclosed within in the sulfide matrix. Pyrite occurs as idiomorphic grains when included in carbonates, but also commonly alters the pentlandite (Fig. 4.5E).

Large garnet grains occur immersed in sulfide, with inclusions of quartz, biotite, chlorite, carbonate, and amphibole. When garnet is present, the contact between amphibolite and sulfides is marked by a contact zone dominated by plagioclase, with some interstitial sulfide. The contacts between plagioclase sub grains are marked by a zonation of needles of epidote intergrown with quartz, followed by sillimanite intergrown with quartz, and then muscovite intergrown with quartz. The acicular minerals grow in between grains of plagioclase, marking foliation. In garnet-rich sulfides, the most common mineral is pyrite, followed by chalcopyrite, pyrrhotite, and pentlandite.



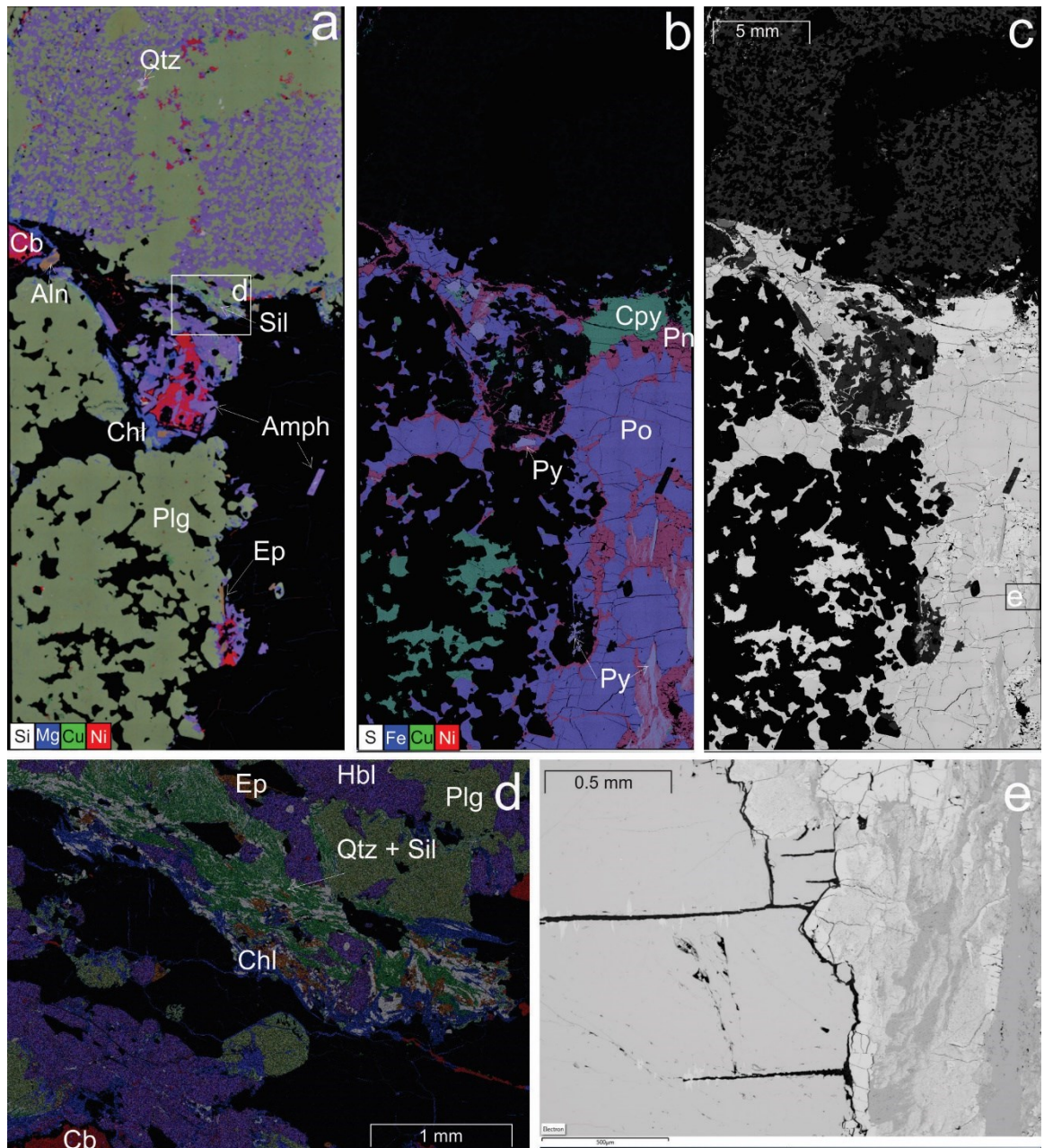


Figure 4.5 A-C Compositional EDS map from sulfide-amphibolite contact (sample MNS-04) from Southern Mangabal (a-b) and backscattered electron image (c) of amphibolite in contact with sulfide-rich fault. d) detail of area marked in panel a, showing intergrowth of sillimanite and quartz close to the contact. e) detail from the area in e showing replacement of pyrite along pentlandite.

#### 4.5. Metamorphic Rocks of Americano do Brasil Complex

The margin of the Americano do Brasil is marked by intense deformation, as also is the Salgado's Fault separating the Northern and Southern sequences of the complex in the E-W direction. Even though the degree of alteration in these rocks varies, it is greater closer to the bounding shear zones, and closely associated with the

diorite veins that cut the complex. Description of igneous rocks was the focus of previous studies (Chapter 2; Nilson, 1981), and this work will focus on the post-magmatic mineralogy and textures.

#### 4.5.1. Ultramafic Zone

Olivine cumulates still preserve igneous texture and the outline of olivine grains even though they are almost entirely replaced by pseudomorphs of serpentine and magnetite in a mesh texture (Fig. 4.6a). The few intercumulus materials are replaced by chlorite intergrown with carbonate, pale-green amphibole, and/or talc. The olivine-pyroxene cumulate differs in having higher amounts of amphibole, that commonly preserve the texture or core relicts of clinopyroxene. The amphibole (pargasite) replacing clinopyroxene in these rocks shows very fine needle-shaped grain exsolutions of oxide minerals, giving a cloudy appearance. Commonly, besides the pargasite, tremolite also occurs in these rocks. Around chromite not included in olivine a rim of green chlorite occurring with serpentine is commonly found. In addition, several thin veins of diorite, and some smaller veins composed of carbonate, chlorite, and/or amphibole, crosscut the rocks of the complex. Close to the veins the olivine is transformed into yellow serpentine and amphibole-iron oxide symplectites occur at the margins of the vein.

#### 4.5.2. Mafic Zone

The mafic rocks are in the Southern Sequence, and consequently are much more altered than the Northern Sequence due to the greater degree of deformation in the



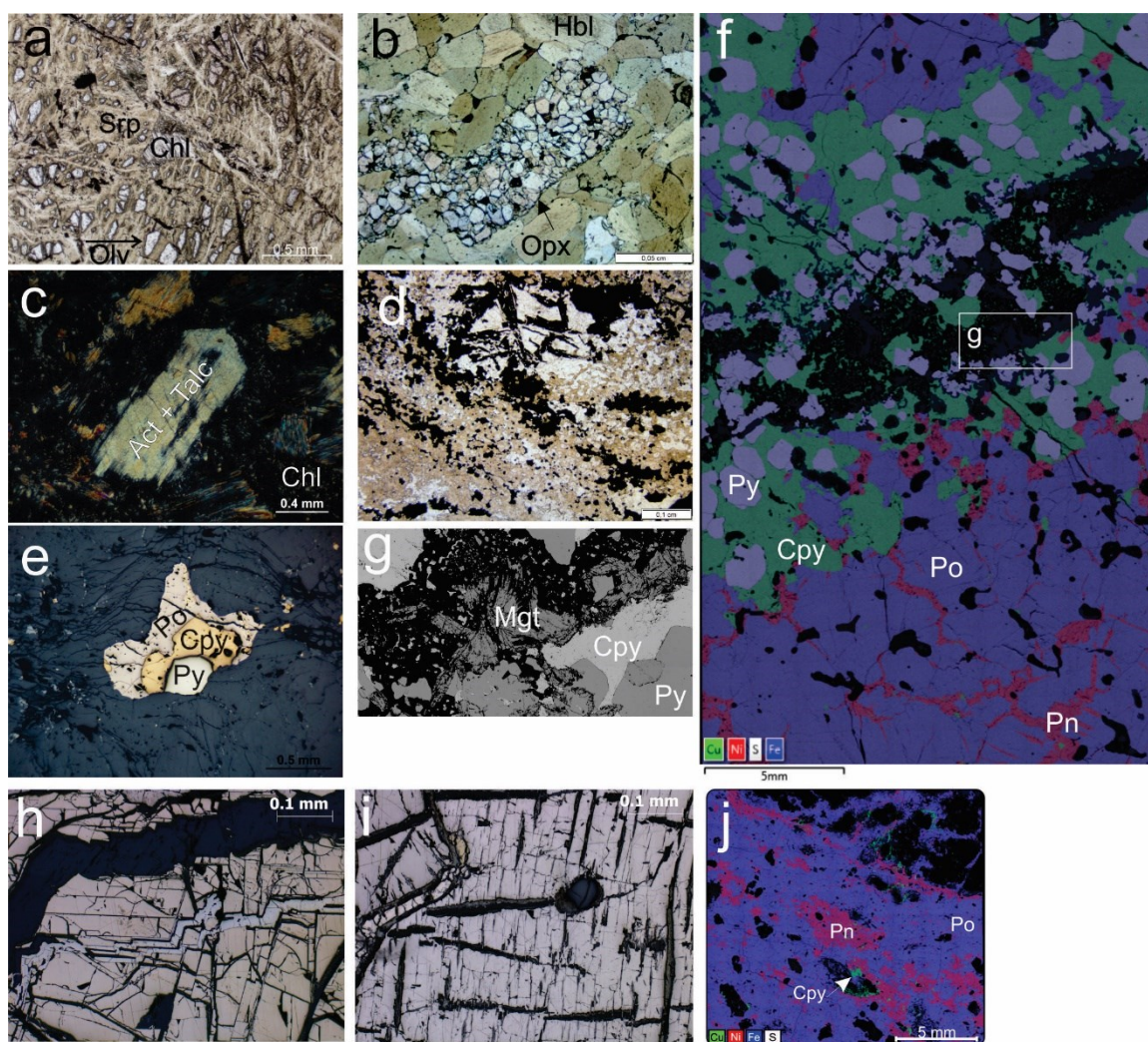


Figure 4.6 Different textures from metamorphosed samples from Americano do Brasil Complex. A-D) Plane-polarized light photomicrographs of A) serpentinite (after olivine adcumulate) from Northern sequence (Sample AMB314-04). Olivine is almost completely replaced by serpentine, with intercumulus material replaced by an intergrowth of chlorite and carbonate. B) Granoblastic orthopyroxene in amphibolite after olivine from Southern sequence (AMB366-19). C) Actinolite after orthopyroxene, and chlorite pseudomorphs of intercumulus plagioclase. D) Carbonate- and talc-rich vein that crosscuts meta-pyroxenite cumulates. Opaques are skeletal magnetite and sulfides (chalcopyrite rich). E) Reflected light photomicrograph showing the texture of pyrite, which is usually rimmed by chalcopyrite. F) Phase map of massive sulfide sample showing quartz-carbonate veinlet cutting the sulfide and the alteration of pentlandite+pyrrhotite assemblage into chalcopyrite + pyrite. G) Backscattered electron image showing the formation of magnetite in the contact of veinlet and massive sulfide. H) Photomicrographs of the S2 ore under reflected light showing secondary pyrite in veins along cleavage planes in pentlandite. I) Microphotographs of the S2 ore under reflected light showing serpentine-filled fractures in pyrrhotite, and replacement by magnetite. J) Compositional EDS map of massive ore from G2 orebody with tectonically mobilized and recrystallized massive ore, showing granoblastic textures and foliation defined by flattened pentlandite aggregates.

south. Most of the rocks are highly transformed into amphibole-rich assemblages.

Rocks that retain some of their primary mineral assemblages and textures are pyroxene cumulates with interstitial plagioclase. The pyroxene is commonly rimmed and replaced by hornblende in contact with plagioclase. Closer to alteration zones the hornblende grows in poikiloblastic texture, with few relicts of pyroxene or plagioclase.

The amphibole commonly has a core with thin acicular exsolutions of oxide giving the amphibole a “dusty” look, but these oxides are absent from the outer portions of the crystals. The amphibole poikiloblasts locally retain inclusions of absorbed plagioclase and orthopyroxene, the latter sometimes partially or fully replaced by orthoamphibole. Along grain boundaries, the hornblende can show recrystallization to fine-grained granoblastic aggregates.

Rocks that are completely altered to metamorphic textures and mineral assemblages are referred to here as amphibolite. Amphibolite is composed mostly of green amphibole, but plagioclase and pyroxene may also appear. The amphibole ranges from poikiloblastic to granoblastic texture. The granoblastic amphibole has iron-oxide in the contacts of the grains, and the poikiloblastic texture contains thin acicular inclusions of oxide. Clinopyroxene, when present, forms irregular and highly altered and resorbed remnant inclusions in poikiloblastic hornblende and is altered to amphibole along cleavages. Orthopyroxene, when present, appears in aggregates with granoblastic texture (Fig. 4.6b) in relict cores resembling corona textures. Occasionally the core is formed by a core of yellow serpentine, rimmed by orthopyroxene-magnetite symplectites, with an outer rim of granoblastic orthopyroxene (Fig.4.6b). Plagioclase can be present in smaller portions as non absorbed relicts between amphiboles.

In some rocks the primary mineralogy has been completely overprinted by pseudomorphs that partially preserve the original igneous textures, with euhedral pyroxene crystals transformed to pseudomorphs of actinolite and talc enveloped in a groundmass of chlorite (Fig. 4.6c) and resembling an original pyroxene-orthocumulate texture. In some portions it is possible to identify relicts of poikiloblastic hornblende partially replaced by chlorite. The rocks are commonly crosscut by veins with highly hydrous alteration zones with a matrix of fine-grained carbonate, chlorite, talc, with

granoblastic amphibole, epidote, and skeletal magnetite (Fig. 4.7d), generally accompanied by the presence of sulfides such as pyrite, chalcopyrite, and pyrrhotite. Quartz, anhydrite, apatite, saussurite can also be present in most altered areas.

#### 4.5.3. Sulfide-Rich Rocks

The Americano do Brasil Complex has three main orebodies, known as S1, S2, and G2. The S1 orebody is localized just south of the Salgado fault, and it consists of disseminated sulfide containing several sulfide-rich lenses. It is hosted by pyroxene cumulates and the equivalent metamorphic rocks, most of them highly affected by amphibolitization. The sulfide minerals in the disseminated to massive portions are composed mainly of pyrrhotite, chalcopyrite, pentlandite, and pyrite. Pyrrhotite is the dominant groundmass phase in massive sulfides, with pentlandite occurring in loop texture around pyrrhotite grain boundaries. Chalcopyrite predominates over pentlandite, and it is usually concentrated closer to boundaries against silicate material. An unusual and highly distinctive texture is commonly observed within massive pyrrhotite at Americano do Brasil in which concentric equant masses of chalcopyrite hosted by pyrrhotite, surround nuclei of subhedral to anhedral pyrite (Fig. 4.6e); always associated closely to hydrous phases. Some bodies of massive sulfide are crosscut by veins of amphibole, quartz, carbonate, and/or fine phyllosilicates. In such cases the outer margins of the sulfides are lined by fan-like clusters of elongated magnetite crystals whereas pyrrhotite and pentlandite are replaced by patches of chalcopyrite surrounding euhedral pyrite (Fig. 4.6f-g). The few clots of silicate included in the sulfide groundmass are composed mainly of biotite, plagioclase, quartz, and amphibole.

The S2 orebody is composed of olivine cumulate enclosed in a net-textured sulfide matrix. The sulfide minerals of the primary magmatic assemblage consist of pyrrhotite, chalcopyrite, and pentlandite, in descending order of abundance. Some

pentlandite occurs as flame exsolutions within pyrrhotite, but most pentlandite occurs as polycrystalline aggregates with pyrrhotite crystals. Chalcopyrite occurs in anhedral agglomerates. The sulfides are highly fractured, and veins of serpentine, magnetite, carbonate, and/or pyrite crosscut the primary sulfides and fill along the partition planes. Pyrite also occurs along cleavage planes within pentlandite (Fig. 4.6h). The sulfides are commonly replaced by secondary phases along with the fractures, magnetite in the case of pyrrhotite (Fig. 4.6i), and cubanite in the case of chalcopyrite.

The G2 orebody occurs in the southwestern portion of the Southern sequence and is hosted by olivine-pyroxene cumulates. The ore textures range from net-textured to massive breccia, with localized deformed *durchbewegung* breccias. The massive ore comprises a matrix of sulfide with floating or imbricated inclusions of meta-ultramafic clasts and/or minerals, within which individual silicate crystals are commonly replaced by sulfides. The sulfide mineralization has the typical magmatic sulfide assemblage of pyrrhotite, pentlandite, and chalcopyrite, but is intensely recrystallized, evidenced by granoblastic textures and foliation defined by flattened pentlandite aggregates (Fig. 4.6j). Portions richer in phyllosilicates such as serpentine can show strong, commonly folded, foliations. These highly recrystallized domains are also characterized by common development of pentlandite exsolution in pyrrhotite. In these foliated portions, silicate inclusions are strongly replaced by hydrous phases including serpentine, amphiboles, and talc. Some inclusions of silicate minerals were replaced by pseudomorphs of sulfide. Disseminated portions of the G2 orebody close to a major fault are commonly hosted by talc schist, displaying fracturing, and folding of the interlaminated sulfide and silicate texture along with replacement of chalcopyrite by lamellae of cubanite and pentlandite by violarite.

## 4.6. Mineral Chemistry

### 4.6.1. Plagioclase

In the Mangabal Complex, both northern and southern, the plagioclase has a broad compositional range, from An<sub>44</sub> to An<sub>58</sub> in the northern and An<sub>30</sub> to An<sub>78</sub> in the south since both were affected by regional metamorphism and the plagioclase shows intense recrystallization. The most calcic compositions are associated with igneous textures, and the more sodic compositions are associated with metamorphic textures. In the southern part of the Americano do Brasil Complex the plagioclase composition ranges from An<sub>60</sub> to An<sub>82</sub>.

### 4.6.2. Amphiboles

Amphibole compositions have been recast into ideal stoichiometry, using stoichiometric proportions to estimate the amount of Fe<sup>3+</sup>. Using the classification of Leake et al. (1997), the amphiboles present in the mafic and ultramafic rocks of the intrusions are mainly identified as calcic amphiboles (Ca-amphiboles, Fig. 4.7). Some of these Ca-amphiboles are members of the subgroup defined by (Na+K)<sub>B</sub> ≥ 0.50 and (Ti)<sub>B</sub> > 0.50; others belong to the subgroup characterized by (Na+K)<sub>B</sub> < 0.50 atoms per formula unit (a.p.f.u.). The first sub-group is the most abundant, comprising compositions ranging from tschermakite to actinolite/tremolite, with the greatest number showing intermediate compositions corresponding to magnesium-hornblende. In the second sub-group, the amphiboles are essentially pargasite or magnesio-hastingsite (Fig. 4.7), depending on their VI<sub>Al</sub> and Fe<sup>3+</sup> contents. Pargasite is mainly found in the outer rim of the corona texture around olivine in contact with plagioclase in the Mangabal Complex; Magnesio-hastingsite occurs as veins crosscutting the intrusions and as intercumulus material in dunite and peridotite. A few amphiboles belonging to the Mg–Fe–Mn–Li group, as defined by Leake et al. (1997), occur locally in some metamorphic rocks of the Mangabal complex and in the southern portion of Americano do Brasil, mainly gedrite and anthophyllite. All mineral data for amphiboles can be seen in Appendix G.

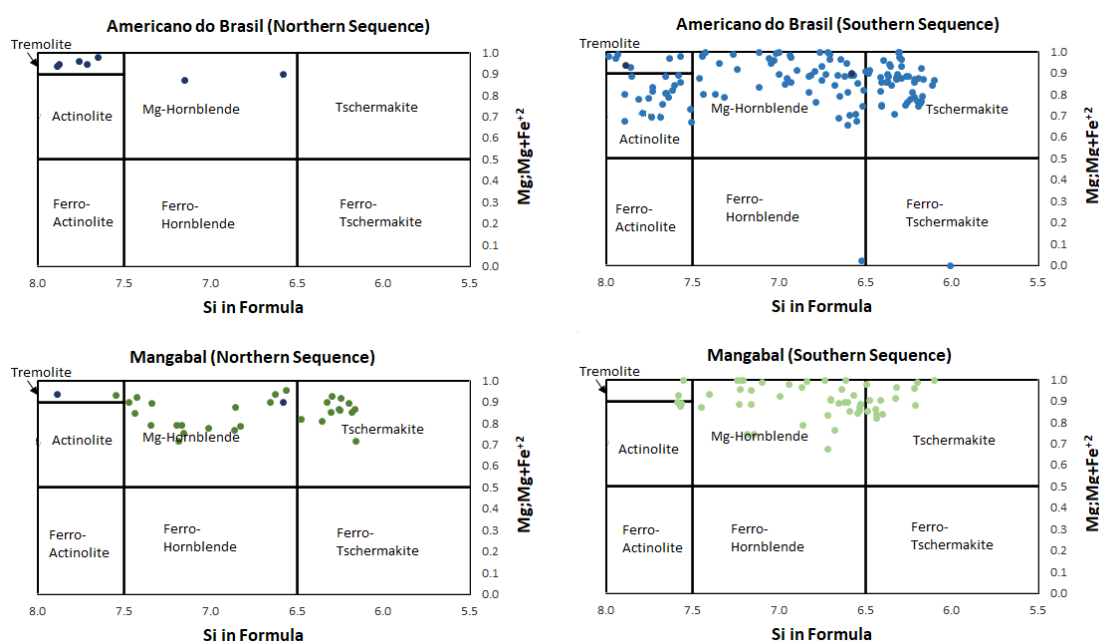


Figure 4.7 Classification of the calcic amphiboles analyzed. Diagram parameters: ( $CaB \geq 1.5$ ; ( $Na + K)A < 0.5$ ), according to Leake *et al.* (1997).

## 4.7. Discussion

### 4.7.1. Regional Metamorphism

#### 4.7.1.1. Mangabal Complex

Using thermodynamic modeling allows the estimation of the P-T stability field of assemblages for a given rock composition. The approach permits us to establish limits to the PT conditions at which a given mineral assemblage might have last reached chemical equilibrium. Various rock types in the Mangabal Complex have distinctive mineral assemblages, and we tried to identify the P-T conditions for these distinct assemblages. Many rocks contain relatively unusual mineral assemblages that cannot be accommodated by our models, presumably due to open system behaviour during metamorphism, but we have chosen three samples with simple mineral assemblages that are amenable to the calculation of pseudosections.

Sample MNN-03 is a metamorphosed olivine cumulate, composed of orthoamphibole, calcic amphibole, biotite, large poikiloblastic pale green chlorite, and



olivine. Some biotite is locally replaced along cleavages by a dark-green chlorite indicating a second generation and olivine by serpentine. The P-T pseudosection for the sample is shown in Figure 4.8, which shows an amphibolite-facies condition for the coexistence of orthoamphibole and calcic amphibole for that given composition with temperatures between 655 to 795°C and pressures up to 7.5 kbar. The formation of serpentine and chlorite from the breakdown of biotite is an indication of retrograde metamorphism.

Pseudosections of two mafic amphibolites with distinct parageneses were calculated. The sample MNN-21 paragenesis was formed by Fe-Mg amphibole, hornblende, biotite, plagioclase, and quartz. The assemblage orthoamphibole + hornblende + biotite + plagioclase + quartz is stable at conditions of amphibolite facies, as can be seen in the calculated pseudo-section (Fig.4.8). The paragenesis is an indication of conditions between 540 to 750°C and up to ca. 7.8 kbar. It agrees with the results for the amphibole-plagioclase thermobarometer (Anderson, 1996).

Sample MNN19 is an amphibolite with hornblende, plagioclase, biotite, and minor quartz. Apatite, carbonate, and kyanite occurs locally in these rocks. The paragenesis indicates amphibolite facies (Fig. 4.8), with a wide possible range of pressure from 5.5 to up to 11.5 kbar, and a range of temperature from ca. 640 to 860 °C.

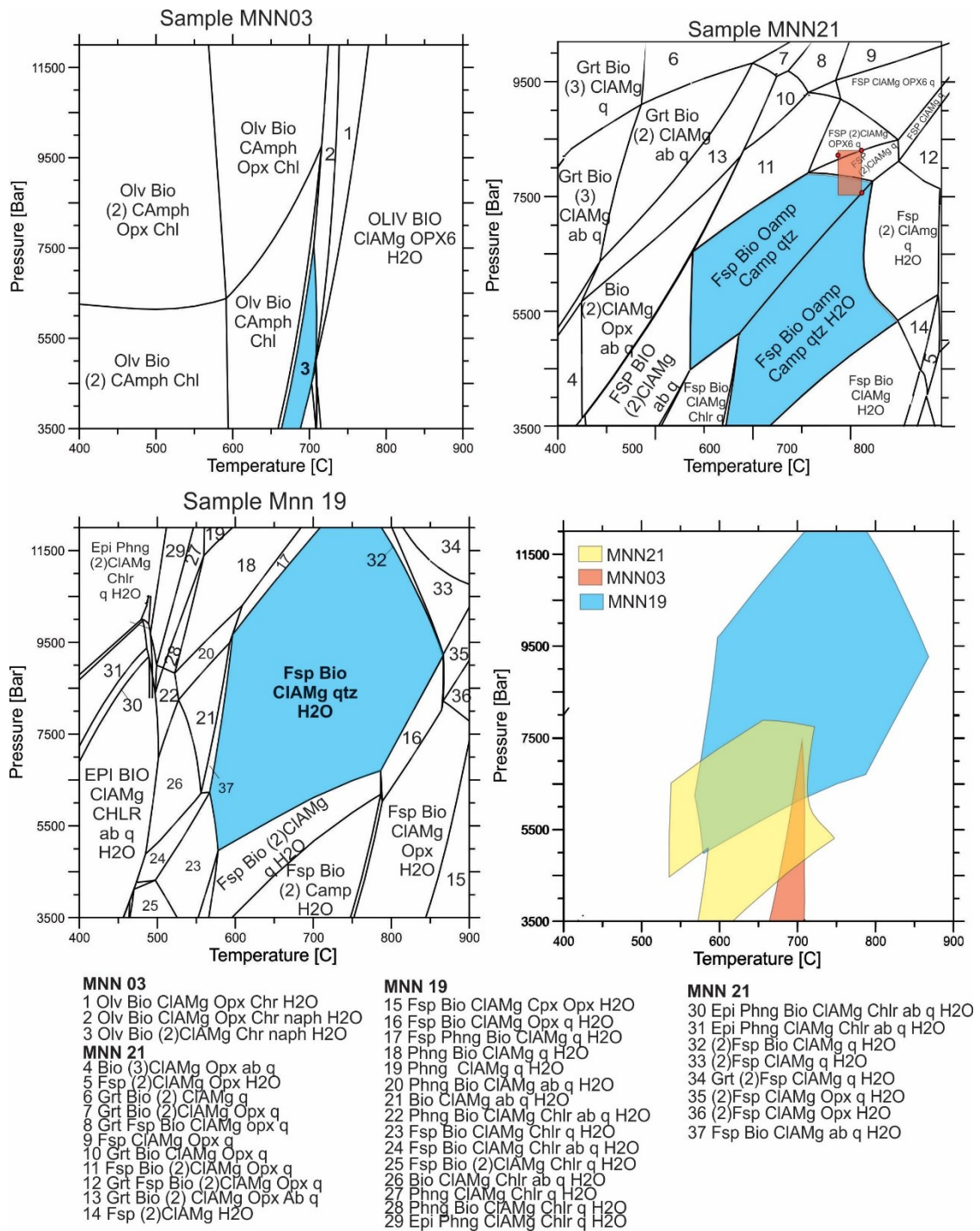


Figure 4.8 Calculated P–T pseudosection phase diagrams for Mangabal Complex samples. Sample MNN03 is an olivine orthocumulate, MNN21 is orthoamphibole-bearing amphibolite and MNN19 is hornblende-biotite amphibolite. The last section shows the paragenesis field for all samples in one diagram, showing the overlap.

On the assumption that all three samples reached equilibrium under the same conditions of temperature and pressure, which seems plausible considering their proximity, then we can use the field of overlap of all three individual fields of stability

to define a much narrower range of conditions. This overlapping condition is met at pressures between 6.0 and 7.5 kbar and temperatures from 680 to 710 °C.

It was not possible to stabilize kyanite in the pseudosections at equilibrium with any of the mineral assemblages found in the samples. Kyanite is only expected to occur at conditions of the blueschist facies with garnet and glaucophane for rocks with the stated bulk compositions, neither of which has been identified. Kyanite occurs as an accessory phase, with very restricted distribution and always in textural equilibrium with quartz and carbonate, apparently resulting from a breakdown of plagioclase. It may have been formed due to locally distinct conditions, accompanying metasomatism driven by fluid percolation and may have formed at a metastable equilibrium condition. Kyanite is the aluminosilicate phase that would be expected to form under the identified metamorphic conditions if aluminosilicates were stabilized by local metasomatic changes in composition.

#### 4.7.1.2. Americano do Brasil Complex

Metamorphism of ultramafic rocks in general is considered well constrained, mainly because they can be fairly well represented by the simple system  $\text{SiO}_2\text{-MgO-CaO-H}_2\text{O-CO}_2$  (e.g., Will *et al.*, 1990; Baker *et al.*, 1991; Spear, 1995; Bucher and Grapes, 2011). Metamorphic equivalents of olivine adcumulates show a paragenesis composed of serpentine + chlorite + carbonate + hornblende (magnesio-hastingsite); whereas olivine-pyroxene cumulates develop a secondary assemblage of serpentine + chlorite + carbonate + hornblende + tremolite. However, it was not possible to form pseudosections for the Americano do Brasil Complex, where the hornblende-rich rocks are closely associated with faults, lithological contacts, and proximity to crosscutting diorite veins. The rocks present a highly heterogeneous aspect reflecting open system metamorphic effects associated with ubiquitous crosscutting alteration zones. The

presence of amphibole indicates amphibolite facies in the system, delimiting a temperature ca. 500-600°C, but does not limit pressure in the system.

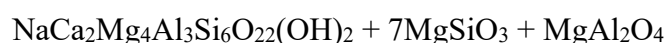
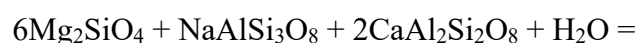
The mafic rocks in the Southern sequence at Americano do Brasil are highly altered to amphibole where they are crosscut by abundant veins with varied compositions. Hornblende was apparently formed due to the reaction of plagioclase, clinopyroxene, and orthopyroxene, commonly forming rocks almost entirely composed of hornblende (i.e., hornblendites). Locally, it is possible to identify pseudomorphic alteration of orthopyroxene into talc and/or actinolite. There is local textural evidence for retrograde development of chlorite after poikiloblastic hornblende.

The evidence for Americano do Brasil indicates, in the broadest terms, achievement of amphibolite facies assemblages followed by some retrograde metamorphism, in agreement with the previous suggestion of Nilson (1981). Different from Mangabal Complex, Americano do Brasil rocks do not show intense foliation and even though deformation in plagioclase is common, it is less intense.

#### 4.7.2. Corona Textures

Reaction coronas developed between olivine and plagioclase are common features that have been reported in several mafic intrusions around the world. There has been a long debate over magmatic versus metamorphic origin (e.g., Joesten, 1986; de Haas *et al.*, 2002; Gallien *et al.*, 2012; Torres-Rodriguez *et al.*, 2021). It has been shown that the multi-layer coronas texture around olivine can be formed by magmatic processes, post-magmatic sub-solidus reactions and/or metamorphic processes, or even a continuum from magmatic to metamorphic conditions (e.g., Ambler and Ashley, 1977; Zeck *et al.*, 1982; Candia *et al.*, 1989; de Haas *et al.*, 2002; Malaspina *et al.*, 2006; Gallien *et al.*, 2012; Jašarová *et al.*, 2016; Banerjee *et al.*, 2019; Torres-Rodriguez *et al.*, 2021).

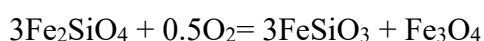
Corona textures have been identified in both the Mangabal and Americano do Brasil complexes, but mostly in the Mangabal Complex, due to the presence there of more evolved rocks compared to Americano do Brasil (Chapter 02) and consequently the higher abundance of coexisting olivine and plagioclase. Since coronas could be developed by either magmatic or metamorphic reaction, some phenomena need to be considered to interpret their formation in the context of the studied intrusions. Olivine can react with melt and be replaced by orthopyroxene in a well-known peritectic reaction. On the other hand, the structure of metamorphic coronas can simply be explained by a solid-state reaction in the presence of volatiles:



The products of the olivine-orthopyroxene peritectic reaction have been identified in both complexes, where either cumulus-textured or poikilitic orthopyroxene can be seen to have grown at the expense of olivine (Chapter 01, 02). In samples that contain both peritectic orthopyroxene replacement of olivine and olivine-plagioclase reaction coronas, the orthopyroxene in these two manifestations has different compositions. The peritectic orthopyroxene presents a slightly higher calcium and aluminum concentration compared to the examples that have formed in coronas. The formation of the outer shell of the corona, composed of amphibole  $\pm$  spinel required the addition of water, which could be explained by hydration during metamorphism, which agrees with the fact that the development of the coronas is spatially associated with shear zones and highly hydrous rocks. Most of the studies that exclude metamorphic origin for the corona point to the absence of evidence for deformation in nearby rocks, or an absence of pyroxene replacement by amphibole. These objections to metamorphic

origins of coronas cannot be raised at Mangabal, where deformation and addition of metamorphic amphibole are widespread. Our observations and reasoning are in agreement with the suggestion by Candia *et al.* (1991) that the coronas from Mangabal Complex were metamorphic in origin, and the same reasoning applies also to corona textures at Americano do Brasil.

Where amphibole replacement has not occurred, aggregates of granoblastic orthopyroxene are a common feature and locally display a core composed of serpentine, rimmed by symplectites of magnetite and orthopyroxene, followed by the last shell of granoblastic orthopyroxene and external amphibole. We attribute the formation of orthopyroxene-magnetite symplectites in the inner shell of the corona to oxidation of the fayalitic component of olivine through the following reaction:

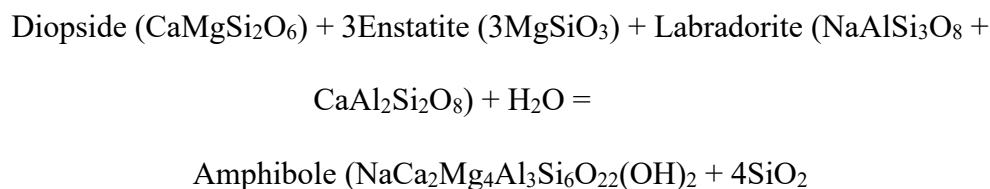


with the remainder of the corona assemblage forming as described above. We discuss the origins and significance of symplectites further below.

#### 4.7.3. Amphibolitization

Both complexes have in common the presence of coarse-grained amphiboles, mainly near the contacts of the intrusions and associated with veins. There are two possibilities for the formation of the amphiboles: hydration and reaction of pyroxenes and plagioclase during metamorphism (1) or crystallization of percolating or trapped residual melts (2). Both scenarios are not mutually exclusive, and the origin could be some combination of the two. A metamorphic origin is supported by the association of hornblende with structural controls like contacts and faults, and by the textural observations of sub-solidus reactions between pyroxene and plagioclase and the occurrence of apparent metamorphic foliation or lineation in the amphibolites. The amphiboles in Americano do Brasil and Mangabal complexes have a wide range of

compositions from tschermakite to actinolite-tremolite compositions. The textures occurring in poikiloblastic hornblende-rich rocks indicate the formation of amphibole due to the reaction of pyroxene and plagioclase with fluid as the following:



Primary anhydrous igneous minerals at Americano do Brasil were largely replaced by amphibole, commonly associated with later varitextured diorite veins that crosscut the complex, mainly in the Southern Sequence. The primary mineralogy and textures of the cumulates in contact with these posterior veins were completely substituted by hydrous phases, with amphibole the dominant mineral. These altered rocks are composed mostly of calcic amphiboles and are usually called hornblendites in the literature about the area. These amphiboles are commonly recrystallized or commonly replaced by other, possibly retrograde, amphiboles and chlorite, making it difficult to constrain the order and compositions of stable metamorphic assemblages.

The southern sequences for both Americano do Brasil and Mangabal Complexes show higher degrees of alteration compared to the northern sequences. The more extensive alteration obliterates the igneous textures and mineralogy almost completely, making it difficult to identify adequately the stratigraphic relations among the primary igneous rock types which are all now replaced by amphibolite (Chapters 2, 3). Granoblastic hornblendite is common in the southern sequences of both complexes, apparently formed by the replacement of earlier granoblastic aggregates of orthopyroxene some of which retain evidence for the former presence of orthopyroxene-magnetite symplectites after olivine. Remnants of both orthopyroxene and clinopyroxene are preserved within these granoblastic amphibolites. The granoblastic replacement of olivine

and accompanying formation of olivine by orthopyroxene-magnetite symplectites therefore may have slightly predated the amphibolite overprint that completely replaced the primary pyroxene-plagioclase assemblage.

#### 4.7.4. Symplectites

Symplectites are interesting microstructures characterized by the vermicular intergrowth of at least two minerals that replace a coarser-grained reactant phase at a sharp reaction interface, commonly associated with high-grade metamorphic rocks (e.g., Passchier and Trouw, 2005; Spruzeniec *et al.*, 2017; Gaidies, 2021). Symplectites are supposed to be formed by the fast breakdown of a mineral(s) or by the combination of dispersed reactants. Even though some common symplectites are present in dehydrated rocks, some studies suggest that symplectite growth is facilitated by interaction with fluids (e.g., Claeson, 1998; Efimov *et al.*, 2010; Spruzeniec *et al.*, 2017). Americano do Brasil and Mangabal Complexes shows some symplectic textures, that will be discussed below.

##### 4.7.4.1. Mangabal Complex

Amphibolite in the complex can locally show some fine-grained intergrowth or symplectites. Some epidote-quartz symplectite locally appear along amphibole-plagioclase boundaries. It does not occur as a corona in all contacts, but it is occurring in an oriented way. When this kind of symplectites occurs, the plagioclase usually has a dusty appearance, due to sericitization. Disseminated sulfide can occur, with euhedral pyrite overgrowing chalcopyrite and altering pentlandite.

The calculated pseudosections for amphibolite do not predict the amphibole-plagioclase breakdown to epidote-quartz. The epidote would be stable in a very specific conditions always with garnet and/or glaucophane at low temperature-high pressure conditions, and neither of these minerals occur. There is no evidence to infer that



Mangabal Complex reaches garnet-omphacite equilibrium, and since the symplectites occur in elongated strips and are oriented when compared between the point of symplectites, it could be associated with deformation and highly localized changes in conditions, like fluid-mediated breakdown into the symplectites. The breakdown of plagioclase into quartz and symplectites releases Na into the system, which seems to be lost from the system. Very-fine grained intergrowth with epidote and quartz also occurs in the faulted contact of amphibolite with the sulfide-carbonate-rich veins. In the same context with sulfide-rich veins, also sillimanite-quartz and muscovite-quartz intergrowths occur close to contacts with amphibolite-sulfide-rich portions. The three occur in the boundaries of plagioclase and mark a foliation. Sillimanite always occurs in intergrowth with quartz in contact with sulfide.

In the Mangabal Complex, the aluminosilicates are closely associated with metamorphosed rocks and faults. Kyanite, or intergrowth of sillimanite and quartz, occur in the contact with sulfide-calcic rich veins or boundaries of plagioclase defining a foliation. Kyanite, quartz, and carbonate in equilibrium cannot be reproduced in the pseudo-sections for the amphibolite, indicating a distinct condition, like fluid percolation and locally changing composition. Kyanite and sillimanite-quartz intergrowth can occur in the same sample. Whereas the kyanite occurs with more idiomorphic form and in contact with amphibole, the sillimanite-quartz intergrowth (fibrolite) is associated as rims around sulfide in contact with plagioclase. The ubiquitous occurrence of carbonates with kyanite may indicate that a CO<sub>2</sub>-bearing fluid was inserted into the system and drove the crystallization of kyanite. Kyanite-bearing amphibolite was identified in some metabasalt in Mara Rosa Arc, the northern segment of the Goiás Magmatic Arc, and the presence of kyanite was previously associated with metasomatism (Kuyumjian, 1998).

Quartz-bytownite symplectites (also called calcic-myrmekite) replace labradorite in coarse-grained gabbro along boundaries, fractures, or along whole grain. Measuring the composition of a whole grain of myrmekite and comparing it with the relict labradorite in the samples, reveals a notable difference in composition of calcium and sodium. Bytownite could not replace labradorite without the introduction of Ca from an external source or the removal of Na. Calcic myrmekite is not as common as the classical myrmekite, occurring usually in gabbroic rocks with just a few observed occurrences. Similar textures have been identified in gabbro and anorthosites, where it was explained by metasomatic infiltration (Dymek and Schiffries, 1987; Deer *et al.*, 2004; Efimov *et al.*, 2010).

#### 4.7.4.2. *Americano do Brasil*

Apart from the symplectites caused in the development of corona textures around olivine, the complex also presents biotite-quartz symplectites in a few silicate inclusions within massive-sulfide of the S1 orebody, close to alteration zones. The biotite-quartz symplectite occurs with chlorite, amphibole, and plagioclase, but since occurrences are minor and included in sulfide, the characteristics or equilibrium assemblages are difficult to constrain.

#### 4.7.5. Late Retrograde Assemblages

All the metamorphic assemblages documented here and attributed to equilibration with fluids at amphibolite facies are locally overprinted by assemblages consistent with the greenschist facies. The amphibolite and primary igneous rocks both display locally intense alteration to chlorite, bastite, talc, and tremolite. The serpentinization overprint in the rocks of the northern sequence of Americano do Brasil postdated the complete crystallization of the rocks and formation of the mineralization, as evidenced by the presence of serpentine veins crosscutting the sulfide minerals and

the de-sulfidation of the sulfide-bearing minerals along fractures, transforming them to oxides.

The crosscutting diorites throughout the complexes show a secondary mineral assemblage composed mainly of saussurite and tremolite. The plagioclase is intensely transformed into saussurite, and the amphibole shows a substitution in the boundaries to a secondary tremolite-actinolite amphibole. This re-equilibrium indicates that a low-temperature alteration reached the dioritic rocks, and no evidence of a higher degree has been identified, which indicates that a second lower-temperature alteration postdated the emplacement of the diorites.

#### 4.7.6. Open System, Reactive Fluids, and Sulfides

Post-magmatic processes, such as metamorphism, may result in considerable changes in the original geochemistry of the affected rocks. Some degree of alteration can be monitored using the loss on ignition (LOI). The samples of Americano do Brasil and Mangabal have significant LOI values, mainly in the ultramafic rocks, reaching up to 12 wt. %, mainly due to serpentinization. Also, the LILE elements (e.g., Ba, Rb, Th, and U) are typically mobilized during metamorphism and/or hydrothermal alteration (e.g., Lahaye et al., 1995). The LILE elements are highly variable in the rocks, falling well off the compositions predicted by forward models of magmatic evolution (Chapters 2, 3). In the southern portion of Mangabal and Americano, inconsistent and widely scattered patterns are evident for LILE in the multi-element diagrams, more so than observed in the northern portions.

Both Americano do Brasil and Mangabal have been cut by sulfide- and carbonate-rich veins that contain and are associated with selvages of hydrous silicate mineral assemblages. These veins alter the composition of the rocks nearby, forming a very distinct mineralogy. Sylvialite and anhydrite are two minerals inconsistent with

igneous origins that occur in Mangabal, and Americano do Brasil complex respectively. Both minerals are common sulfur-bearing minerals in hydrothermal veins, and together with the common pyritization spatially associated with these veins, we see evidence for the introduction of sulfur, CO<sub>2</sub>, H<sub>2</sub>O, and calcium to form these hydrothermal assemblages close to the sulfide veins.

Americano do Brasil has intense amphibolitization, linked to diorite that cuts the intrusion, as well as along the deformed contacts with country rocks and along the Salgado Fault. The complexes are highly faulted, but Mangabal has evidence of higher deformation due to the intense fabric development in metamorphic equivalents of the original igneous rocks. The Mangabal Complex is spatially closer to the Sao Luis de Montes Belos Lineament, which is a major regional deformation zone that marks the contact between two accreted blocks of the Goiás Magmatic Arc.

In both complexes, the sulfide-bearing rocks associated with metamorphosed or metasomatic rocks show higher amounts of pyrite, compared to the most pristine rocks. It could indicate why the S1 orebody in Americano do Brasil has the lowest Ni and Cu tenors, due simply to dilution of the ore metals in the increased amount of sulfide material due to sulfur addition (Chapter 2; Mota-e-Silva *et al.*, 2011).

The nickel potential seems to be negatively affected due to the metamorphic/metasomatism overprint as can be seen with the S1 orebody in Americano, and the pyrite replacing the pentlandite in Mangabal, but different associations could further be investigated. The Mara-Rosa arc in the northern portion of the Goiás Magmatic Arc contains an example of a Cu-Au deposit which has been affected by metasomatism and metamorphism (Oliveira *et al.*, 2016). It is a porphyry deposit, that could be associated with an orogenic Cu-Au mineralization, dated with the metamorphic event in the Arc between 630 and 580 Ma (Oliveira *et al.*, 2016). The

Mara Rosa arc also has kyanite-orthoamphibole bearing amphibolite (Kuyumjian, 1998), which could indicate similar conditions for both branches. Further details about the fluid characteristics and regional structural control are needed for a better understanding and ascertainment of economic aspects in the area.

#### **4.8. Conclusion**

The Americano do Brasil and Mangabal complexes have experienced a protracted metamorphic evolution. Pseudosections obtained for the Mangabal Complex suggest regional metamorphic temperatures between 680 to 710 °C and pressures between 6.0 to 7.5 kbar for the overlapping conditions for the three assemblages calculated, which are well within the amphibolite facies. The localized presence of kyanite + quartz + carbonate, epidote + quartz, sillimanite + quartz, and muscovite + quartz with the previously cited parageneses in local domains did not yield a unique solution and no T-P conditions could be determined. Similarly, pseudosections for the rocks from Americano do Brasil also did not yield a unique solution for the paragenesis. The assemblages recorded by the ultramafic rocks indicate that they reached temperatures between 500 and 600°C, but do not constrain pressures of equilibration. The failure to retain equilibrium mineral assemblages in the Southern Sequence of Americano do Brasil could have been caused by open system behavior and alteration associated with metasomatism by CO<sub>2</sub>-Ca-S fluids, forming carbonate + chalcopyrite + pyrite (± chlorite, talc, epidote, amphibole) veining, suggested by the formation of Ca-rich phases such as epidote and scapolite (silvialite) and secondary pyrite within the sulfide-rich mineralization/domains.

The association of veins with metasomatic alterations identified and described here is indicative of open system behavior and fluid circulation, which could lead to new economic exploration models. Although the nickel mineralization seems to be

negatively affected with regard to economic potential due to these metamorphic overprints, the study of metasomatism could lead to a different economic view. Further details about the fluid characteristics and regional structural control are needed for a better understanding of further economic potential.

## **CHAPTER 5**

### **450 Ma Mafic Dyke Linked to NW Dykes in the Sanclerlândia-Anicuns Region**

## **5. 450 Ma Mafic Dyke Linked to NW Dykes in the Sanclerlândia-Anicuns Region**

### **Abstract**

We report a U-Pb radiometric age of  $453 \pm 29$  Ma for a sample of dolerite from a regional-scale NW-oriented mafic dyke. The dyke crosscuts the mineralized Americano do Brasil Complex and has not been the focus of detailed work before. The dyke is associated with the Azimuth 125° Lineament, which is a large structural feature located in Brazil that is spatially associated with several mineral deposits. Previous workers have suggested that the dykes are related to events dating from a possible time during the Brasiliano event, while others suggest being as young as the 130 Ma Paraná-Etendeka LIP. The obtained age of  $453 \pm 29$  Ma is the first record of an Ordovician age for a regional-scale dyke in Brazil.

### **5.1. Introduction**

The Azimuth 125° Lineament is an important structural feature located in Brazil. It is 1800 km long and extends from Minas Gerais to Rondônia states. Distinct types of mineralization are associated with it, such as carbonatite and kimberlite complexes. The associated intrusions host important deposits of phosphate, niobium, barium, titanium, and rare earth elements (REE) (e.g., Moraes Rocha et al., 2014, 2019). The dyke swarm has a different name in each state/region and the origin of the Lineament, and its related dykes are widely discussed. It has a prominent magnetic signature in the southern portion of the Goiás Magmatic Arc in the Brasília Belt (Fig. 5.1), and it is easily identified on geophysical maps. However, it rarely crops out and does not appear on any geological maps at a regional scale. Since the outcrops are sporadic and highly weathered, no petrographic, geochemical, or geochronological data was available. Rocha et al (2014) associated the dyke in the study area with the first



event associated with the Lineament, comprising the Brasiliano Orogeny (950-520 Ma), and with an estimated age younger than 622 Ma, due to crosscutting relations with an intrusion of known age. Pessano et al. (2021) published an updated map of the mafic dyke swarms of Brazil, based on geophysical data. They associated this Azimuth 125° Lineament dyke with the 130 Ma Parana-Etendeka Large Igneous Province. The main aim of our study was to obtain the age of the dyke, which was only previously estimated by crosscutting relationships identified in geophysical images.

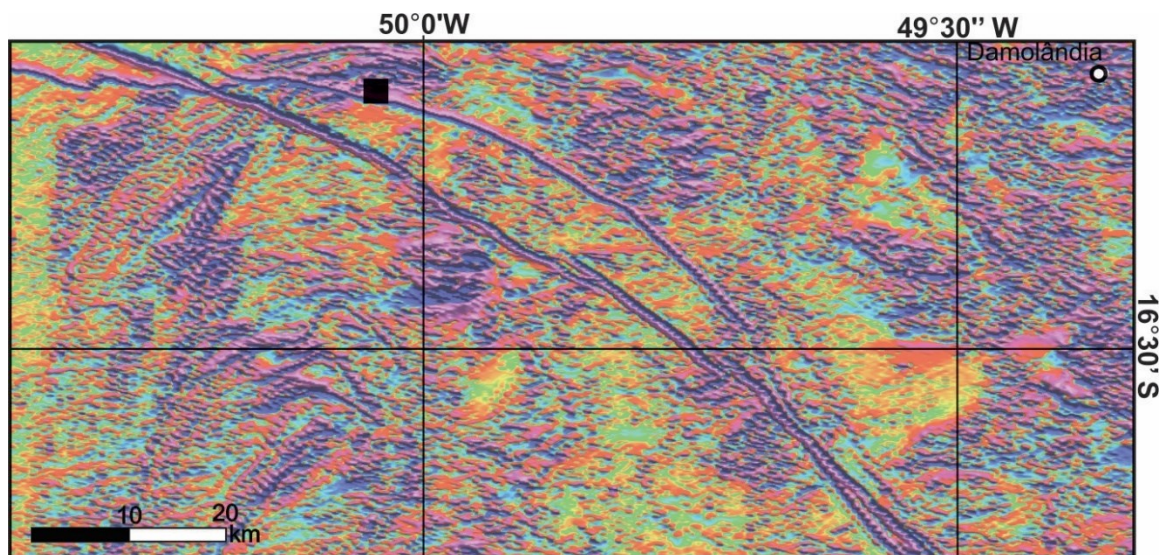


Figure 5.1 Map of the first vertical derivative of the magnetic field. The black square indicates the approximate sample location. Image downloaded from Brazilian Geological Survey – CPRM (Project 3009) (LASA Engenharia e Prospecções S.A., 2004.).

## 5.2. Methods

Polished thin sections were prepared of dolerite samples. The thin sections were examined under petrological transmitted/reflected light polarizing microscopes. In addition, back-scattered electron (BSE) imaging and qualitative energy-dispersive spectrometry (EDS) were carried out with a scanning electron microscope (SEM) to help identify mineralogy.

The U-Pb date was obtained by performing in-situ analyses of micro-baddeleyite using a CAMECA-ims 1290 secondary ion microprobe (SIMS) at UCLA

(the University of California at Los Angeles), USA. Micro-baddeleyite grains were analyzed in-situ from polished thin sections using a 3x3  $\mu\text{m}$  raster from an  $\sim 1\ \mu\text{m}$  primary  $\text{O}^{2-}$  ion beam (Hyperion source). U/Pb relative sensitivity was calibrated by  $\text{UO}_2/\text{UO}$  for baddeleyite using the Phalaborwa standard with values that ranged from 0.286 to 0.317. U concentrations based on  $\text{U}/^{94}\text{Zr}_2\text{O}$  measurements compared to those of the zircon standard 91500 (80 ppm U) during the same session. Pb values were corrected for common Pb using the  $^{204}\text{Pb}$  method for baddeleyite. The methodology used was identical to the one described in Chapter 3.

### **5.3. Characteristics of the Sampled Dyke**

The dyke swarm is a regional feature that extends throughout the studied area and has an NW orientation. It rarely crops out due to intense weathering and soil formation. We used preserved drill core samples to characterize the dyke's petrography. The dolerite crosscuts all the different rocks of the Americano do Brasil Complex and the gneisses that host the complex. It appears as numerous dykes that range from 1 cm to up to 5 m. The rock is dark grey in color, highly magnetic, and holocrystalline with relict porphyritic texture. It has a very fine-grained matrix, recrystallized to granoblastic texture. It preserves relict porphyritic texture, where it is possible to identify the shape of former plagioclase phenocrysts (fig. 5.2) that have undergone dynamic recrystallization. Minerals include clinopyroxene, plagioclase, orthopyroxene, ilmenite, and magnetite. The Fe-Ti oxides are major constituents of the sample, occurring both as relict phenocrysts and in the matrix. Sulfide minerals, including pyrite, chalcopyrite, and pyrrhotite, are present in trace amounts.

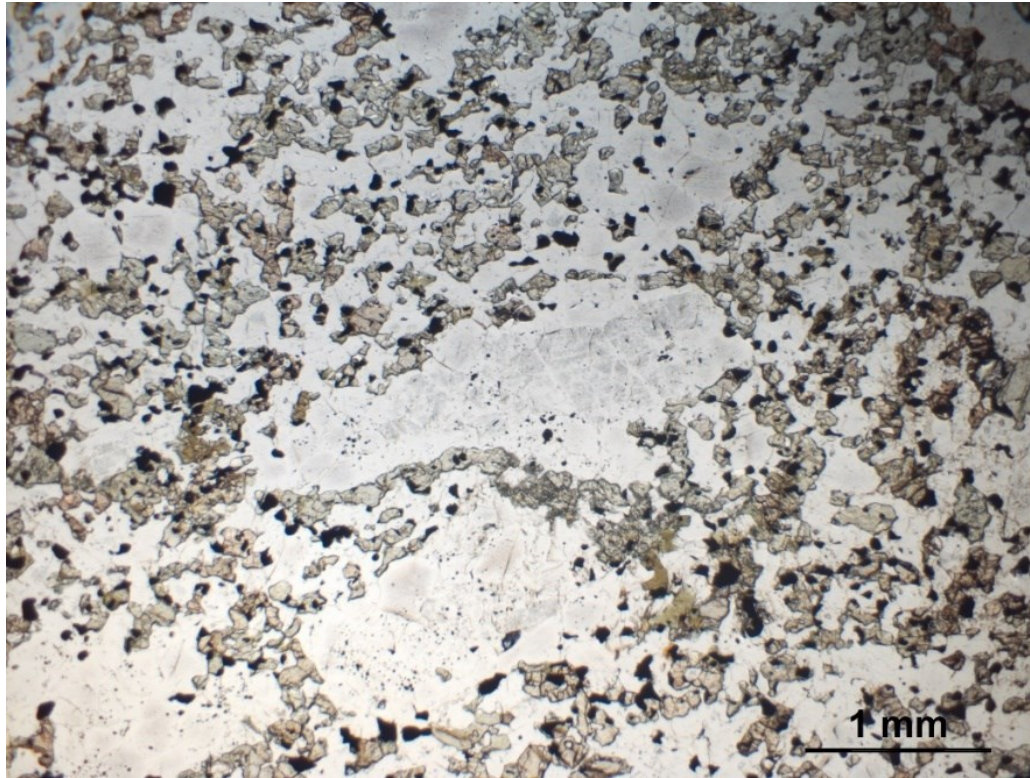


*Figure 5.2. Photomicrograph in plane-polarized light of the dolerite. Relicts of plagioclase phenocryst, and recrystallized matrix.*

#### **5.4. U-Pb in-situ SIMS Data**

The grains identified and selected for analysis were pure baddeleyite without any alteration to zircon; baddeleyite grain sizes ranged from 4 to ca. 11  $\mu\text{m}$  in length (fig. 5.3). In-situ baddeleyite analyses of sample AMB366-102 (Fig. 5.4A) yielded a weighted mean  $^{206}\text{Pb}/^{238}\text{U}$  age of  $459 \pm 42$  Ma and a Concordia Age (Ludwig, 1998) of  $^{206}\text{Pb}/^{238}\text{U}$   $453 \pm 26$  Ma (Fig. 5.4B). In-situ SIMS U-Pb results for these samples are shown in Table 5.1.

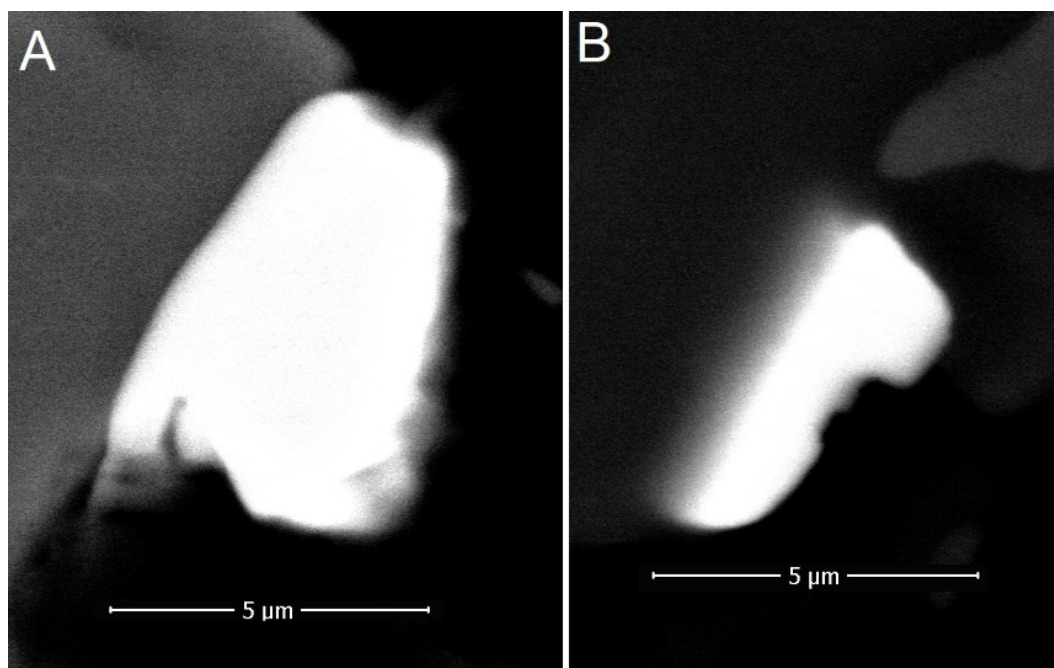


Figure 5.3 Backscatter electron (BSE) images of baddeleyite grains in dolerite that cuts Americano do Brasil, Sample AMB366-102.

Table 5-1. SIMS data from in-situ analyses of baddeleyite from sample AMB366-102.

| #   | Size<br>(µm) | Dates (Ma)     |     |                |     |                 |      |        |          |          |                | Ratios          |                 |      |                 |      |       | rho |
|-----|--------------|----------------|-----|----------------|-----|-----------------|------|--------|----------|----------|----------------|-----------------|-----------------|------|-----------------|------|-------|-----|
|     |              | 206Pb/<br>238U |     | 207Pb/<br>235U |     | 207Pb/<br>206Pb |      | r206Pb | Th/<br>U | O2/<br>O | U conc.<br>ppm | 206Pb/<br>204Pb | 207Pb*/<br>235U |      | 206Pb*/<br>238U |      |       |     |
| 2b  | 5x5          | 424            | 37  | 426            | 114 | 435             | 676  | 91.20  | 0.087    | 0.690    | 300            | 214             | 0.5214          | 32.9 | 0.0681          | 9.0  | 0.406 |     |
| 5b  | 6x3          | 507            | 38  | 610            | 265 | 1013            | 1099 | 89.08  | 0.055    | 0.993    | 229            | 173             | 0.8237          | 57.7 | 0.0819          | 7.9  | 0.501 |     |
| 27b | 6x1          | 495            | 50  | 613            | 234 | 1075            | 924  | 85.67  | 0.087    | 0.521    | 545            | 132             | 0.8280          | 50.9 | 0.0798          | 10.5 | 0.551 |     |
| 27b | 11x2         | 516            | 37  | 573            | 139 | 804             | 612  | 85.09  | 0.056    | 0.875    | 128            | 127             | 0.7575          | 31.8 | 0.0833          | 7.5  | 0.445 |     |
| 27b | 6x2          | 553            | 174 | 470            | 294 | 83              | 1444 | 84.86  | 0.182    | 0.972    | 150            | 125             | 0.5884          | 78.1 | 0.0895          | 32.9 | 0.677 |     |
| 27b | 10x4         | 435            | 19  | 681            | 200 | 1610            | 719  | 82.40  | 0.040    | 1.423    | 116            | 107             | 0.9553          | 40.3 | 0.0698          | 4.5  | 0.430 |     |

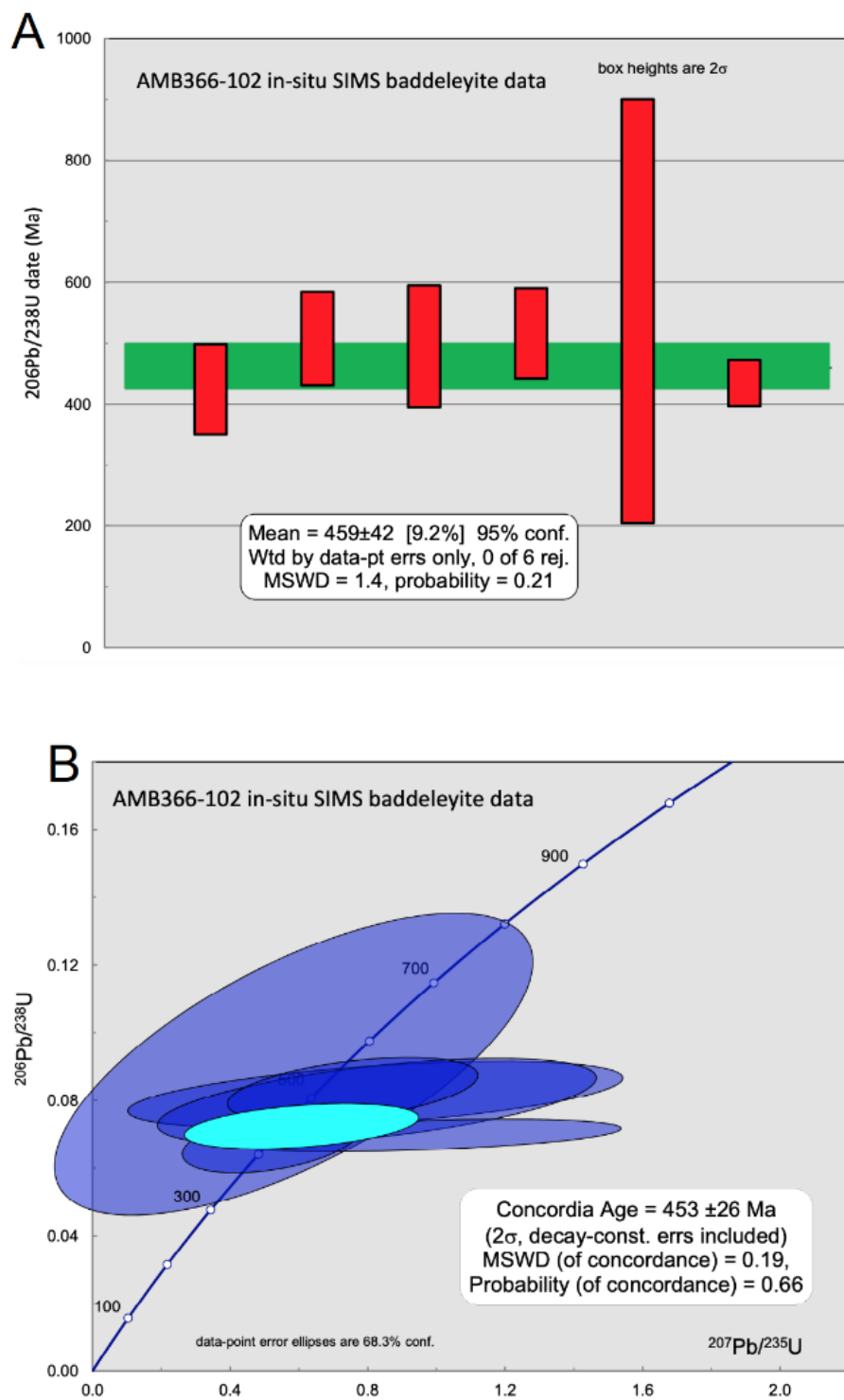


Figure 5.4 SIMS U-Pb baddeleyite results for sample AMB366-102.

## 5.5. Discussion

The age obtained for the dyke is  $453\pm 29$  Ma. It indicates that the dyke is younger than the Brasiliano Orogeny but older than the main magmatism of the Paraná-Etendeka LIP. The gabbroic rocks related to the dyke are unrelated to the mineralized emplacement of host Americano do Brasil intrusion.

This age was not previously identified for the Azimuth 125° Lineament. The most recent review of mafic dykes in Brazil shows a gap of ages between 201 and 485 Ma (Pessano *et al.*, 2021). This is the first record of the Ordovician age in a regional mafic dyke located in Brazil. The age is in accordance with the estimated age of the opening of the Paraná Basin, for which magmatic U-Pb ages have not previously been registered.



## Chapter 6

### 6. Summary and Conclusions

This work has focused on the two biggest mafic-ultramafic complexes in the Arenópolis Arc to try to answer some questions. A combination of field work, petrography, geochemistry, geochronology, and petrological modeling was used to evaluate the petrogenesis of the Americano do Brasil and Mangabal Complexes.

More than 150 samples were collected and analyzed under petrological transmitted/reflected light polarizing microscopes for the identification of mineralogy and textures. SEM and electron microprobe were used to help with petrography and the identification of minerals. The Americano do Brasil Complex is dominated by ultramafic cumulates; the northern sequence has olivine and olivine-pyroxene-cumulates, while the Southern one has more evolved compositions dominated by pyroxene and pyroxene-plagioclase cumulates. The Mangabal Complex most common rocks are olivine cumulates and pyroxene-plagioclase cumulates. The rocks of the Complex have been affected by metamorphism to the amphibolite facies, resulting in intense amphibolitization and recrystallization.

Whole-rock geochemistry from 65 samples was determined. The concentration of the major elements in rocks of both complexes is inferred to be mainly controlled largely by variation in the proportions of the cumulus minerals (olivine, clinopyroxene, orthopyroxene, and plagioclase), but the quantity of intercumulus material has some influence, mainly in the Mangabal Complex, where the orthocumulate is common.

U-Pb in-situ baddeleyite SIMS data showed that Mangabal Complex revealed an age ca. 650 Ma. This age could indicate that the intrusions in the Arenópolis Arc are coeval with the intrusions in the Anápolis-Itaçu complex, and not different events as

previously suggested. Despite efforts with several samples, neither baddeleyite nor zircon was found in any igneous rocks from the Americano do Brasil Complex. Baddeleyite from the large regional dyke that cut Americano do Brasil and its host rocks were dated, indicating ca. 450 Ma.

Modeling indicates that the parental magma for the Americano do Brasil Complex had an OIB-like Fe-rich picrite composition and that the same primary liquid could be parental to rocks from both the Northern and Southern sequences, indicating that both sequences are likely comagmatic and coeval. The differences between the Northern and Southern sequences resulting from different degrees of crustal assimilation could represent different portions of the same system. Modeling indicates that the parental magma of the Mangabal Complex could have been tholeiitic basalt composition and that the same liquid could be parental to rocks from both the Northern and Southern sequences, likely representing different portions of the same magmatic system. The parental magma could be genetically associated with the parental magma for Americano do Brasil Complex, therefore are evidence that the intrusions could be associated with the same origin.

Considering the temporal and spatial correlations, decompression melting of upwelling asthenosphere triggered by rollback subduction and/or influence of a mantle plume are plausible mechanisms to explain the petrogenesis of these mafic-ultramafic intrusions in the vicinities of the eastern Arenópolis arc and westernmost Anápolis-Itaçu belt.

The complexes have experienced a protracted metamorphic evolution despite the persistence of minor igneous relicts. Pseudosections obtained for the Mangabal complex suggest regional metamorphic temperatures between 680 to 710 °C and pressures between 6.0 to 7.5 kbar. The failure to retain equilibrium mineral assemblages



in rocks of both complexes could have been due to open system behavior and alteration associated with metasomatism.

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## Appendices

### Appendix A: Whole-Rock geochemistry of the Americano do Brasil rocks.

| Drillcore#                         | AMB317 | AMB317 | AMB317 | AMB317 | AMB317 | AMB317 | AMB317 | AMB317 | AMB317 | AMB317 | AMB317 | AMB317 | AMB317 |
|------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Sample                             | 102    | 4      | 7      | 9      | 101    | 103    | 12     | 13     | 17     | 19     | 24     | 25     | 27     |
| Sequence                           | N      | N      | N      | N      | N      | N      | N      | N      | N      | N      | N      | N      | N      |
| Lithology                          | PD     | DU     | DU     | DU     | DU     | PD     | DU     | PD     | PD     | PD     | PD     | PD     | DU     |
| SiO <sub>2</sub> (%)               | 33.40  | 33.10  | 33.90  | 34.70  | 33.80  | 40.20  | 35.40  | 38.90  | 39.30  | 41.50  | 39.40  | 47.40  | 35.70  |
| TiO <sub>2</sub> (%)               | 0.09   | 0.04   | 0.04   | 0.04   | 0.04   | 0.18   | 0.06   | 0.20   | 0.21   | 0.84   | 0.16   | 0.34   | 0.05   |
| Al <sub>2</sub> O <sub>3</sub> (%) | 1.26   | 0.67   | 0.69   | 0.63   | 0.62   | 1.93   | 0.97   | 1.89   | 2.61   | 6.59   | 1.73   | 3.47   | 0.87   |
| Fe <sub>2</sub> O <sub>3</sub> (%) | 20.00  | 15.65  | 15.95  | 16.45  | 15.95  | 15.00  | 17.15  | 13.95  | 15.90  | 13.45  | 15.40  | 13.45  | 16.80  |
| MnO (%)                            | 0.19   | 0.18   | 0.19   | 0.18   | 0.17   | 0.19   | 0.20   | 0.18   | 0.20   | 0.16   | 0.19   | 0.20   | 0.19   |
| MgO (%)                            | 35.70  | 37.20  | 38.10  | 38.70  | 38.50  | 32.00  | 38.10  | 31.20  | 32.50  | 24.00  | 33.00  | 24.10  | 36.50  |
| CaO (%)                            | 0.51   | 0.28   | 0.45   | 0.36   | 0.28   | 6.20   | 0.99   | 6.54   | 4.83   | 8.91   | 5.72   | 9.79   | 0.92   |
| Na <sub>2</sub> O (%)              | 0.07   | 0.02   | 0.03   | 0.03   | 0.03   | 0.23   | 0.06   | 0.27   | 0.32   | 1.05   | 0.20   | 0.28   | 0.06   |
| K <sub>2</sub> O (%)               | 0.02   | 0.01   | 0.01   | 0.02   | 0.02   | 0.02   | 0.02   | 0.02   | 0.05   | 0.09   | 0.02   | 0.02   | 0.02   |
| P <sub>2</sub> O <sub>5</sub> (%)  | 0.01   | b.d.l. | 0.03   | 0.03   | b.d.l. | 0.01   | 0.01   | b.d.l. | 0.04   | b.d.l. | b.d.l. | b.d.l. | 0.02   |
| Cr <sub>2</sub> O <sub>3</sub> (%) | 0.31   | 0.34   | 0.32   | 0.33   | 0.35   | 0.22   | 0.31   | 0.19   | 0.18   | 0.16   | 0.19   | 0.19   | 0.25   |
| SrO (%)                            | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | 0.01   | b.d.l. | b.d.l. | b.d.l. |
| BaO (%)                            | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. | b.d.l. |
| LOI (%)                            | 8.18   | 13.65  | 11.10  | 8.99   | 11.30  | 5.01   | 8.15   | 6.76   | 5.69   | 4.47   | 5.24   | 2.49   | 9.71   |
| Sum                                | 99.74  | 101.14 | 100.81 | 100.46 | 101.06 | 101.19 | 101.42 | 100.10 | 101.83 | 101.23 | 101.25 | 101.73 | 101.09 |
| S (%)                              | 1.92   | 0.02   | 0.14   | 0.23   | 0.06   | 0.10   | 0.04   | 0.05   | 0.04   | 0.27   | 0.04   | 0.03   | 0.17   |
| Ni (ppm)                           | 4560   | 1440   | 1690   | 1540   | 1630   | 1200   | 1420   | 1030   | 1200   | 733    | 1040   | 678    | 1460   |
| Cu (ppm)                           | 2580   | 15     | 518    | 11     | 14     | 477    | 16     | 22     | 41     | 151    | 32     | 13     | 40     |
| Co (ppm)                           | 247    | 163    | 174    | 179    | 180    | 145    | 173    | 142    | 149    | 111    | 145    | 121    | 183    |
| Cr (ppm)                           | 2290   | 2570   | 2440   | 2530   | 2610   | 1620   | 2300   | 1420   | 1360   | 1180   | 1420   | 1400   | 1910   |
| Ba (ppm)                           | 4.30   | 2.90   | 2.90   | 3.20   | 2.40   | 5.60   | 5.90   | 5.60   | 17.10  | 18.10  | 4.50   | 6.60   | 7.20   |
| Sc (ppm)                           | 4      | 3      | 4      | 4      | 4      | 27     | 6      | 28     | 21     | 46     | 26     | 53     | 5      |
| Sr (ppm)                           | 18.4   | 7.6    | 10.2   | 12.6   | 8.2    | 33.4   | 22.3   | 44.7   | 75.7   | 142.0  | 35.1   | 42.7   | 30.3   |
| V (ppm)                            | 41     | 27     | 32     | 33     | 27     | 99     | 39     | 96     | 91     | 283    | 84     | 185    | 43     |
| Zn (ppm)                           | 115    | 97     | 100    | 105    | 106    | 81     | 106    | 78     | 96     | 69     | 81     | 82     | 111    |
| Zr (ppm)                           | 2      | <2     | <2     | <2     | <2     | 5      | 2      | 5      | 7      | 9      | 4      | 8      | 3      |
| U (ppm)                            | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | 0.05   |
| Th (ppm)                           | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  | 0.06   | <0.05  | <0.05  | <0.05  | 0.08   |
| Rb (ppm)                           | 0.30   | 0.20   | 0.20   | <0.2   | <0.2   | 0.20   | 0.20   | 0.20   | 0.70   | 0.70   | <0.2   | 1.20   | 0.60   |
| Nb (ppm)                           | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.40   | 0.50   | 0.10   | 0.10   | 0.10   |
| Cs (ppm)                           | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | <0.01  | 0.01   | 0.02   |
| Hf (ppm)                           | 0.10   | <0.1   | <0.1   | <0.1   | <0.1   | 0.20   | <0.1   | 0.20   | 0.30   | 0.40   | 0.20   | 0.40   | 0.10   |
| Ta (ppm)                           | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   |
| Y (ppm)                            | 0.60   | 0.20   | 0.30   | 0.20   | 0.20   | 2.50   | 0.50   | 2.60   | 3.50   | 6.40   | 2.30   | 5.00   | 0.40   |
| La (ppm)                           | <0.1   | <0.1   | <0.1   | <0.1   | <0.1   | 0.10   | <0.1   | 0.20   | 0.60   | 0.30   | <0.1   | 0.30   | 0.30   |
| Ce (ppm)                           | 0.40   | 0.20   | 0.20   | 0.30   | 0.20   | 1.10   | 0.40   | 1.30   | 2.40   | 2.20   | 1.00   | 1.80   | 0.90   |
| Pr (ppm)                           | 0.14   | <0.02  | 0.03   | 0.03   | 0.03   | 0.47   | 0.07   | 0.27   | 0.43   | 0.58   | 0.38   | 0.42   | 0.09   |
| Nd (ppm)                           | 0.60   | 0.20   | 0.20   | 0.20   | 0.20   | 1.90   | 0.40   | 1.60   | 2.70   | 3.40   | 1.60   | 2.50   | 0.60   |
| Sm (ppm)                           | 0.15   | 0.04   | 0.04   | 0.04   | 0.07   | 0.51   | 0.13   | 0.44   | 0.69   | 1.28   | 0.44   | 1.03   | 0.16   |
| Eu (ppm)                           | 0.05   | <0.02  | 0.02   | <0.02  | <0.02  | 0.18   | 0.04   | 0.17   | 0.21   | 0.44   | 0.15   | 0.29   | 0.02   |
| Gd (ppm)                           | 0.13   | 0.06   | 0.08   | 0.10   | b.d.l. | 0.59   | 0.15   | 0.65   | 0.78   | 1.48   | 0.45   | 1.22   | 0.07   |
| Tb (ppm)                           | 0.02   | 0.01   | 0.02   | 0.01   | 0.01   | 0.09   | 0.02   | 0.08   | 0.11   | 0.20   | 0.07   | 0.16   | 0.02   |
| Dy (ppm)                           | 0.11   | b.d.l. | 0.08   | b.d.l. | b.d.l. | 0.53   | 0.09   | 0.64   | 0.80   | 1.27   | 0.48   | 1.02   | 0.08   |
| Ho (ppm)                           | 0.02   | 0.01   | 0.01   | b.d.l. | 0.01   | 0.11   | 0.02   | 0.12   | 0.13   | 0.30   | 0.09   | 0.22   | 0.02   |
| Er (ppm)                           | 0.07   | b.d.l. | b.d.l. | b.d.l. | b.d.l. | 0.25   | 0.07   | 0.35   | 0.37   | 0.71   | 0.24   | 0.59   | 0.04   |
| Tm (ppm)                           | 0.01   | b.d.l. | 0.01   | 0.01   | b.d.l. | 0.04   | 0.01   | 0.03   | 0.05   | 0.09   | 0.04   | 0.09   | 0.01   |
| Yb (ppm)                           | 0.10   | b.d.l. | b.d.l. | b.d.l. | b.d.l. | 0.18   | 0.03   | 0.22   | 0.35   | 0.54   | 0.21   | 0.52   | 0.03   |
| Lu (ppm)                           | b.d.l. | 0.01   | 0.01   | 0.01   | b.d.l. | 0.04   | 0.01   | 0.03   | 0.07   | 0.08   | 0.03   | 0.07   | 0.01   |
| Pt (ppb)                           | 91.4   | 2.1    | 14.2   | 1.5    | 1.9    | 15.4   | 4.2    | 4.8    | 7.6    | 15.1   | 7.9    | 3.9    | 9.6    |
| Pd (ppb)                           | 94.5   | 2.0    | 18.3   | 1.3    | 1.2    | 20.4   | 5.3    | 4.4    | 6.8    | 15.7   | 8.6    | 4.5    | 5.2    |
| Au (ppb)                           | 43     | 1      | 16     | 1      | 1      | 10     | 4      | 3      | 2      | 3      | 3      | 1      | 1      |

ane cumulate; PX - pyroxene cumulate; DB - diabase  
thern; N - Northern

| Drillcore# | AMB366 | AMB366 | AMB366 | AMB366 | AMB366 | AMB366 | AMB366 | AMB366 | AMB366 | AMB366 | AMB366 | AMB366 |
|------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Sample     | 1      | 7      | 9      | 102    | 103    | 104    | 12     | 14     | 16     | 18     | 22     | 29     |
| Sequence   | S      | S      | S      | S      | S      | S      | S      | S      | S      | S      | S      | S      |
| Lithology  | DB     | GN     | DB     | DB     | PX     | PX     | DB     | PX     | PX     | DB     | PX     | PX     |
| SiO2 (%)   | 43.80  | 64.90  | 48.60  | 48.50  | 49.20  | 50.60  | 51.20  | 48.50  | 47.40  | 40.70  | 46.10  | 47.70  |
| TiO2 (%)   | 0.79   | 0.51   | 0.85   | 0.86   | 0.32   | 0.32   | 0.91   | 0.55   | 0.49   | 1.62   | 0.24   | 0.44   |
| Al2O3 (%)  | 19.75  | 17.30  | 17.75  | 17.70  | 8.09   | 8.13   | 19.15  | 8.94   | 15.85  | 18.65  | 13.80  | 10.10  |
| Fe2O3 (%)  | 12.95  | 2.06   | 11.50  | 11.65  | 12.40  | 11.80  | 10.50  | 10.35  | 10.55  | 17.70  | 12.70  | 14.95  |
| MnO (%)    | 0.13   | 0.06   | 0.20   | 0.21   | 0.19   | 0.21   | 0.15   | 0.18   | 0.19   | 0.16   | 0.14   | 0.22   |
| MgO (%)    | 5.33   | 3.09   | 5.18   | 5.16   | 18.00  | 18.40  | 5.43   | 14.70  | 13.70  | 6.72   | 12.40  | 17.90  |
| CaO (%)    | 10.95  | 7.28   | 10.80  | 11.30  | 8.74   | 9.11   | 9.22   | 13.15  | 8.53   | 10.90  | 10.65  | 7.29   |
| Na2O (%)   | 2.69   | 4.91   | 3.07   | 3.16   | 0.77   | 0.77   | 3.68   | 1.12   | 1.43   | 2.69   | 1.03   | 0.98   |
| K2O (%)    | 0.74   | 0.19   | 0.16   | 0.16   | 0.07   | 0.07   | 0.15   | 0.14   | 0.22   | 0.24   | 0.06   | 0.10   |
| P2O5 (%)   | 0.02   | 0.17   | 0.23   | 0.24   | 0.01   | 0.01   | 0.06   | 0.02   | b.d.l. | 0.10   | b.d.l. | 0.03   |
| Cr2O3 (%)  | 0.01   | 0.02   | 0.01   | 0.01   | 0.04   | 0.04   | 0.01   | 0.05   | 0.03   | 0.00   | 0.03   | 0.04   |
| SrO (%)    | 0.10   | 0.06   | 0.07   | 0.07   | 0.02   | 0.02   | 0.09   | 0.03   | 0.06   | 0.08   | 0.05   | 0.03   |
| BaO (%)    | 0.01   | 0.02   | 0.01   | 0.02   | b.d.l. | b.d.l. | 0.01   | b.d.l. | 0.01   | 0.01   | b.d.l. | b.d.l. |
| LOI (%)    | 2.92   | 0.70   | 0.93   | 0.23   | 0.93   | 0.43   | 0.82   | 1.16   | 1.91   | 0.63   | 1.44   | 1.16   |
| Sum        | 100.19 | 101.27 | 99.36  | 99.27  | 98.78  | 99.91  | 101.38 | 98.89  | 100.37 | 100.20 | 98.64  | 100.94 |
| S (%)      | 0.54   | 0.15   | 0.12   | 0.18   | 0.84   | 0.22   | 0.50   | 0.46   | 0.06   | 0.30   | 2.67   | 1.34   |
| Ni (ppm)   | 10     | 12     | 29     | 27     | 916    | 346    | 17     | 556    | 184    | 18     | 3160   | 530    |
| Cu (ppm)   | 77     | 25     | 66     | 233    | 867    | 221    | 97     | 530    | 80     | 143    | 2150   | 709    |
| Co (ppm)   | 48     | 4      | 24     | 25     | 103    | 74     | 29     | 72     | 49     | 50     | 167    | 98     |
| Cr (ppm)   | 40     | 120    | 100    | 70     | 310    | 330    | 50     | 370    | 200    | 30     | 190    | 270    |
| Ba (ppm)   | 93.90  | 140.00 | 113.00 | 161.00 | 18.90  | 18.90  | 77.50  | 33.30  | 47.40  | 63.40  | 26.30  | 24.90  |
| Sc (ppm)   | 16     | 12     | 30     | 36     | 44     | 44     | 17     | 55     | 16     | 28     | 33     | 42     |
| Sr (ppm)   | 938.0  | 593.0  | 673.0  | 683.0  | 228.0  | 239.0  | 861.0  | 268.0  | 606.0  | 762.0  | 474.0  | 279.0  |
| V (ppm)    | 538    | 165    | 407    | 431    | 188    | 188    | 373    | 239    | 168    | 431    | 145    | 199    |
| Zn (ppm)   | 76     | 22     | 77     | 88     | 71     | 77     | 74     | 70     | 83     | 100    | 50     | 80     |
| Zr (ppm)   | 15     | 97     | 22     | 22     | 11     | 11     | 12     | 17     | 8      | 22     | 8      | 11     |
| U (ppm)    | 0.05   | 0.17   | <0.05  | <0.05  | <0.05  | <0.05  | 0.06   | <0.05  | <0.05  | <0.05  | <0.05  | <0.05  |
| Th (ppm)   | 0.11   | 0.23   | 0.12   | 0.24   | <0.05  | 0.05   | 0.13   | 0.09   | 0.05   | 0.05   | <0.05  | 0.05   |
| Rb (ppm)   | 8.80   | 0.40   | 0.60   | 0.40   | 0.70   | 1.00   | 1.20   | 1.10   | 2.00   | 1.20   | 0.80   | 0.60   |
| Nb (ppm)   | 0.90   | 5.40   | 1.20   | 1.20   | 0.40   | 0.40   | 1.30   | 0.80   | 0.50   | 1.50   | 0.30   | 0.70   |
| Cs (ppm)   | 0.26   | 0.02   | 0.09   | 0.01   | 0.05   | 0.04   | 0.06   | 0.04   | 0.05   | 0.09   | 0.06   | <0.01  |
| Hf (ppm)   | 0.50   | 2.40   | 0.70   | 0.70   | 0.40   | 0.40   | 0.40   | 0.60   | 0.40   | 0.80   | 0.20   | 0.30   |
| Ta (ppm)   | 0.10   | 0.40   | 0.10   | 0.20   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   | 0.10   |
| Y (ppm)    | 7.00   | 13.80  | 13.50  | 15.50  | 5.20   | 5.00   | 6.40   | 9.30   | 5.60   | 16.80  | 3.70   | 5.30   |
| La (ppm)   | 2.90   | 6.40   | 6.10   | 6.30   | 1.30   | 1.40   | 4.40   | 2.30   | 1.40   | 2.90   | 1.40   | 1.30   |
| Ce (ppm)   | 7.20   | 15.40  | 13.70  | 15.10  | 3.70   | 3.80   | 8.80   | 7.00   | 3.90   | 9.50   | 3.00   | 4.00   |
| Pr (ppm)   | 1.15   | 2.31   | 2.09   | 2.14   | 0.56   | 0.61   | 1.21   | 1.19   | 0.89   | 1.72   | 0.43   | 0.64   |
| Nd (ppm)   | 5.80   | 11.00  | 10.40  | 11.40  | 3.20   | 3.50   | 6.00   | 6.10   | 3.80   | 10.30  | 2.10   | 3.20   |
| Sm (ppm)   | 1.41   | 2.95   | 2.54   | 2.96   | 0.84   | 1.17   | 1.16   | 1.91   | 1.05   | 3.21   | 0.70   | 0.94   |
| Eu (ppm)   | 0.58   | 0.83   | 0.91   | 1.05   | 0.30   | 0.34   | 0.75   | 0.65   | 0.42   | 1.18   | 0.31   | 0.30   |
| Gd (ppm)   | 1.55   | 2.74   | 2.87   | 2.85   | 0.98   | 0.87   | 1.31   | 1.91   | 1.20   | 3.36   | 0.68   | 1.04   |
| Tb (ppm)   | 0.21   | 0.41   | 0.41   | 0.48   | 0.15   | 0.18   | 0.23   | 0.28   | 0.18   | 0.56   | 0.13   | 0.16   |
| Dy (ppm)   | 1.39   | 2.40   | 2.32   | 2.78   | 0.94   | 1.03   | 1.08   | 1.63   | 1.06   | 3.22   | 0.70   | 1.07   |
| Ho (ppm)   | 0.29   | 0.55   | 0.54   | 0.63   | 0.21   | 0.22   | 0.26   | 0.40   | 0.22   | 0.70   | 0.15   | 0.21   |
| Er (ppm)   | 0.86   | 1.47   | 1.40   | 1.65   | 0.52   | 0.49   | 0.64   | 1.04   | 0.61   | 1.67   | 0.38   | 0.59   |
| Tm (ppm)   | 0.11   | 0.21   | 0.22   | 0.24   | 0.08   | 0.09   | 0.10   | 0.16   | 0.10   | 0.24   | 0.05   | 0.09   |
| Yb (ppm)   | 0.78   | 1.43   | 1.40   | 1.47   | 0.55   | 0.57   | 0.78   | 0.87   | 0.57   | 1.58   | 0.36   | 0.50   |
| Lu (ppm)   | 0.12   | 0.23   | 0.21   | 0.25   | 0.10   | 0.09   | 0.10   | 0.14   | 0.10   | 0.22   | 0.06   | 0.09   |
| Pt (ppb)   | 0.5    | 0.6    | 6.1    | 6.6    | 1.7    | 0.6    | 0.9    | 0.2    | 0.4    | 0.1    | 13.2   | 3.5    |
| Pd (ppb)   | 1.8    | 2.1    | 13.9   | 13.2   | 4.9    | 1.6    | 3.0    | 0.4    | 0.8    | <0.2   | 16.5   | 5.6    |
| Au (ppb)   | 9      | 6      | 58     | 55     | 8      | 24     | 9      | 3      | 3      | 4      | 15     | 38     |

DU - Olivine Cumulate; PD - olivine-pyroxene cumulate; PX - pyroxene cumulate; DB - diabase

S - Southern; N - Northern

**Appendix B: Conditions and compositions results from thermodynamic modeling using Alphamelts for Northern Sequence of Americano do Brasil.**

*Environment settings used in alphaMELTS for northern sequence of Americano do Brasil rocks.*

```
!Default values of environment variables (version 1.6)
ALPHAMELTS_VERSION MELTS
!ALPHAMELTS_OLD_GARNET true
!ALPHAMELTS_OLD_SPINEL true
!ALPHAMELTS_OLD_BIOTITE true
!ALPHAMELTS_2_AMPH true
ALPHAMELTS_MODE isobaric
!ALPHAMELTS_PTPATH_FILE filename
ALPHAMELTS_DELTAP 0
ALPHAMELTS_DELTAT -10
ALPHAMELTS_MAXP +10000
ALPHAMELTS_MINP +0
ALPHAMELTS_MAXT +2000
ALPHAMELTS_MINT +950
!ALPHAMELTS_ALTERNATIVE_FO2 true
!ALPHAMELTS_LIQUID_FO2 true
ALPHAMELTS_IMPOSE_FO2 true
!ALPHAMELTS_FO2_PRESSURE_TERM true
!ALPHAMELTS_METASTABLE_ISOGRAD true
!ALPHAMELTS_CONTINUOUS true
!ALPHAMELTS_MINF 0.005
!ALPHAMELTS_MINPHI 0.002
!ALPHAMELTS_CONTINUOUS_RATIO float

!ALPHAMELTS_CONTINUOUS_VOLUME true
!ALPHAMELTS_FRACTIONATE_SOLIDS true
!ALPHAMELTS_MASSIN 0.1
!ALPHAMELTS_FRACTIONATE_WATER true
!ALPHAMELTS_MINW float
!ALPHAMELTS_FRACTIONATE_TARGET true
!ALPHAMELTS_MGO_TARGET 8.0
!ALPHAMELTS_MGNUMBER_TARGET float
!ALPHAMELTS_ASSIMILATE true
!ALPHAMELTS_FLUX_MELTING true
!ALPHAMELTS_DRY_ITER_PATIENCE 100
ALPHAMELTS_DO_TRACE true
ALPHAMELTS_DO_TRACE_H2O true
!ALPHAMELTS_HK_OL_TRACE_H2O true
!ALPHAMELTS_HK_PXGT_TRACE_H2O true
!ALPHAMELTS_2X_OPX_TRACE_H2O true
!ALPHAMELTS_TRACE_DEFAULT_DPTX true
!ALPHAMELTS_TRACE_NORMALIZATION integer
!ALPHAMELTS_TRACE_USELIQFEMG true
!ALPHAMELTS_MULTIPLE_LIQUIDS true
!ALPHAMELTS_FRACTIONATE_SECOND_LIQUID true
!ALPHAMELTS_FOCUS true
!ALPHAMELTS_FOCUS_FACTOR float
```



```
!ALPHAMELTS_V20_BIN_FILE true  
ALPHAMELTS_CELSIUS_OUTPUT true  
!ALPHAMELTS_SAVE_ALL true  
ALPHAMELTS_SKIP_FAILURE true  
!ALPHAMELTS_MODE isenthalpic
```

**Cont. Appendix B:** *Results of Modeling for Northern Sequence of Americano do Brasil Rocks: Composition of solids (Phases)*

| P(bar) | T (°C) | mass  | V     | Liquid | Olivine | Orthopyroxene | Clinopyroxene | Plagioclase | Spinel |
|--------|--------|-------|-------|--------|---------|---------------|---------------|-------------|--------|
| 2500   | 1350   | 98.86 | 35.61 | 35.61  | -       | -             | -             | -           | -      |
| 2500   | 1340   | 98.86 | 35.58 | 35.58  | -       | -             | -             | -           | -      |
| 2500   | 1330   | 98.86 | 35.56 | 35.56  | -       | -             | -             | -           | -      |
| 2500   | 1320   | 99.36 | 36.34 | 36.34  | -       | -             | -             | -           | -      |
| 2500   | 1310   | 99.36 | 36.29 | 36.14  | 0.16    | -             | -             | -           | -      |
| 2500   | 1300   | 99.36 | 36.24 | 35.71  | 0.52    | -             | -             | -           | -      |
| 2500   | 1290   | 99.36 | 36.18 | 35.29  | 0.88    | -             | -             | -           | 0.01   |
| 2500   | 1280   | 99.35 | 36.12 | 34.88  | 1.22    | -             | -             | -           | 0.02   |
| 2500   | 1270   | 99.35 | 36.06 | 34.48  | 1.56    | -             | -             | -           | 0.02   |
| 2500   | 1260   | 99.35 | 36.01 | 34.09  | 1.89    | -             | -             | -           | 0.03   |
| 2500   | 1250   | 99.35 | 35.95 | 33.71  | 2.20    | -             | -             | -           | 0.04   |
| 2500   | 1240   | 99.35 | 35.90 | 33.34  | 2.51    | -             | -             | -           | 0.04   |
| 2500   | 1230   | 99.35 | 35.85 | 32.98  | 2.81    | -             | -             | -           | 0.05   |
| 2500   | 1220   | 99.35 | 35.79 | 32.63  | 3.11    | -             | -             | -           | 0.06   |
| 2500   | 1210   | 99.35 | 35.74 | 32.28  | 3.40    | -             | -             | -           | 0.07   |
| 2500   | 1200   | 99.35 | 35.69 | 31.94  | 3.68    | -             | -             | -           | 0.07   |
| 2500   | 1190   | 99.34 | 35.48 | 30.56  | 3.74    | -             | 1.09          | -           | 0.09   |
| 2500   | 1180   | 99.35 | 35.21 | 28.76  | 3.69    | -             | 2.64          | -           | 0.12   |
| 2500   | 1170   | 99.35 | 34.94 | 27.02  | 3.60    | 0.06          | 4.10          | -           | 0.16   |
| 2500   | 1160   | 99.36 | 34.66 | 25.23  | 3.30    | 0.60          | 5.31          | -           | 0.21   |
| 2500   | 1150   | 99.37 | 34.37 | 23.42  | 2.95    | 1.27          | 6.42          | -           | 0.31   |
| 2500   | 1140   | 99.39 | 34.10 | 20.86  | 2.70    | 2.07          | 7.17          | 0.82        | 0.48   |
| 2500   | 1130   | 99.42 | 33.84 | 18.22  | 2.44    | 2.89          | 7.76          | 1.81        | 0.73   |
| 2500   | 1120   | 99.45 | 33.63 | 15.96  | 2.17    | 3.63          | 8.19          | 2.70        | 0.98   |
| 2500   | 1110   | 99.48 | 33.46 | 14.13  | 1.96    | 4.24          | 8.46          | 3.49        | 1.19   |
| 2500   | 1100   | 99.49 | 33.33 | 12.67  | 1.82    | 4.71          | 8.60          | 4.19        | 1.34   |

**Cont. Appendix B:** *Results of Modeling for Northern Sequence of Americano do Brasil Rocks: Composition of solids (Major Oxides)*

| Solid  | Composition: |       |                  |                  |                                |                                |                                |      |      |      |      |                   |                  |                               |                  |
|--------|--------------|-------|------------------|------------------|--------------------------------|--------------------------------|--------------------------------|------|------|------|------|-------------------|------------------|-------------------------------|------------------|
| P(bar) | T (°C)       | mass  | SiO <sub>2</sub> | TiO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | Fe <sub>2</sub> O <sub>3</sub> | Cr <sub>2</sub> O <sub>3</sub> | FeO  | MnO  | MgO  | CaO  | Na <sub>2</sub> O | K <sub>2</sub> O | P <sub>2</sub> O <sub>5</sub> | H <sub>2</sub> O |
| 2500   | 1310         | 0.51  | 40.4             | 0.00             | 0.0                            | 0.00                           | 0.00                           | 12.1 | 0.22 | 47.0 | 0.33 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1300         | 1.69  | 40.3             | 0.00             | 0.0                            | 0.00                           | 0.00                           | 12.4 | 0.22 | 46.7 | 0.34 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1290         | 2.88  | 39.6             | 0.04             | 0.3                            | 0.27                           | 0.53                           | 12.8 | 0.22 | 45.9 | 0.34 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1280         | 4.03  | 39.4             | 0.04             | 0.3                            | 0.32                           | 0.59                           | 13.2 | 0.23 | 45.5 | 0.34 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1270         | 5.15  | 39.3             | 0.05             | 0.4                            | 0.36                           | 0.62                           | 13.6 | 0.23 | 45.1 | 0.35 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1260         | 6.25  | 39.2             | 0.05             | 0.4                            | 0.39                           | 0.63                           | 14.0 | 0.24 | 44.7 | 0.36 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1250         | 7.33  | 39.1             | 0.06             | 0.4                            | 0.41                           | 0.64                           | 14.5 | 0.24 | 44.4 | 0.36 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1240         | 8.38  | 38.9             | 0.06             | 0.4                            | 0.44                           | 0.64                           | 14.9 | 0.25 | 44.0 | 0.37 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1230         | 9.42  | 38.8             | 0.07             | 0.4                            | 0.47                           | 0.64                           | 15.3 | 0.25 | 43.6 | 0.38 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1220         | 10.44 | 38.7             | 0.07             | 0.4                            | 0.50                           | 0.63                           | 15.8 | 0.26 | 43.2 | 0.39 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1210         | 11.44 | 38.6             | 0.08             | 0.5                            | 0.54                           | 0.63                           | 16.3 | 0.26 | 42.8 | 0.39 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1200         | 12.43 | 38.5             | 0.09             | 0.5                            | 0.57                           | 0.62                           | 16.7 | 0.27 | 42.4 | 0.40 | 0.00              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1190         | 16.27 | 41.0             | 0.20             | 1.4                            | 0.95                           | 0.53                           | 15.1 | 0.22 | 36.5 | 4.07 | 0.04              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1180         | 21.31 | 42.9             | 0.35             | 2.4                            | 1.36                           | 0.45                           | 13.7 | 0.18 | 31.5 | 7.12 | 0.08              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1170         | 26.20 | 44.0             | 0.49             | 3.1                            | 1.71                           | 0.39                           | 13.0 | 0.15 | 28.2 | 8.83 | 0.11              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1160         | 31.23 | 44.8             | 0.68             | 3.8                            | 2.10                           | 0.35                           | 12.5 | 0.13 | 25.7 | 9.82 | 0.14              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1150         | 36.40 | 45.1             | 0.92             | 4.5                            | 2.58                           | 0.32                           | 12.1 | 0.11 | 23.8 | 10.5 | 0.16              | 0.00             | 0.00                          | 0.00             |
| 2500   | 1140         | 43.67 | 45.2             | 1.19             | 6.1                            | 3.04                           | 0.27                           | 11.7 | 0.10 | 21.4 | 10.7 | 0.32              | 0.01             | 0.00                          | 0.00             |
| 2500   | 1130         | 51.23 | 45.0             | 1.47             | 7.5                            | 3.55                           | 0.23                           | 11.5 | 0.09 | 19.5 | 10.8 | 0.48              | 0.01             | 0.00                          | 0.00             |
| 2500   | 1120         | 57.78 | 44.8             | 1.69             | 8.4                            | 3.98                           | 0.21                           | 11.4 | 0.08 | 18.1 | 10.7 | 0.60              | 0.02             | 0.00                          | 0.00             |
| 2500   | 1110         | 63.02 | 44.7             | 1.83             | 9.0                            | 4.25                           | 0.19                           | 11.3 | 0.08 | 17.2 | 10.7 | 0.70              | 0.02             | 0.00                          | 0.00             |
| 2500   | 1100         | 67.17 | 44.8             | 1.91             | 9.4                            | 4.42                           | 0.18                           | 11.3 | 0.08 | 16.6 | 10.6 | 0.79              | 0.03             | 0.00                          | 0.00             |

**Cont. Appendix B:** *Results of Modeling for Northern Sequence of Americano do Brasil Rocks: Composition of liquids (Trace elements)*

| P(bar) | T<br>(°C) | mass  | Ba   | Rb   | Sr    | Zr   | Hf  | Nb  | Ta  | Y   | Ni     | Cu   | Cr     | Co   | Sc   | V     | Zn |
|--------|-----------|-------|------|------|-------|------|-----|-----|-----|-----|--------|------|--------|------|------|-------|----|
| 2500   | 1310      | 0.51  | 0.1  | 0.00 | 0.1   | 1.1  | 0.0 | 0.0 | 0.0 | 0.1 | 4867.2 | 0.0  | 254.4  | 66.0 | 3.7  | 14.8  | 0  |
| 2500   | 1300      | 1.69  | 0.1  | 0.00 | 0.1   | 1.1  | 0.0 | 0.0 | 0.0 | 0.1 | 4442.2 | 0.0  | 256.6  | 66.0 | 3.7  | 15.0  | 0  |
| 2500   | 1290      | 2.88  | 0.1  | 0.00 | 0.1   | 1.1  | 0.0 | 0.0 | 0.0 | 0.1 | 4030.3 | 0.0  | 3817.8 | 67.0 | 3.7  | 14.9  | 0  |
| 2500   | 1280      | 4.03  | 0.1  | 0.00 | 0.1   | 1.1  | 0.0 | 0.0 | 0.0 | 0.1 | 3736.1 | 0.0  | 4058.8 | 67.1 | 3.7  | 15.1  | 0  |
| 2500   | 1270      | 5.15  | 0.1  | 0.00 | 0.1   | 1.1  | 0.0 | 0.0 | 0.0 | 0.1 | 3489.4 | 0.0  | 4098.6 | 67.2 | 3.8  | 15.2  | 0  |
| 2500   | 1260      | 6.25  | 0.1  | 0.00 | 0.1   | 1.1  | 0.0 | 0.0 | 0.0 | 0.1 | 3278.4 | 0.0  | 4062.3 | 67.3 | 3.8  | 15.4  | 0  |
| 2500   | 1250      | 7.33  | 0.1  | 0.00 | 0.1   | 1.1  | 0.0 | 0.0 | 0.0 | 0.1 | 3095.4 | 0.0  | 3994.3 | 67.3 | 3.8  | 15.5  | 0  |
| 2500   | 1240      | 8.38  | 0.1  | 0.00 | 0.1   | 1.1  | 0.0 | 0.0 | 0.0 | 0.1 | 2934.9 | 0.0  | 3913.7 | 67.3 | 3.9  | 15.7  | 0  |
| 2500   | 1230      | 9.42  | 0.1  | 0.00 | 0.1   | 1.1  | 0.0 | 0.0 | 0.0 | 0.1 | 2792.7 | 0.0  | 3829.3 | 67.4 | 3.9  | 15.8  | 0  |
| 2500   | 1220      | 10.44 | 0.1  | 0.00 | 0.1   | 1.1  | 0.0 | 0.0 | 0.0 | 0.1 | 2665.7 | 0.0  | 3745.6 | 67.4 | 3.9  | 16.0  | 0  |
| 2500   | 1210      | 11.44 | 0.1  | 0.00 | 0.1   | 1.2  | 0.0 | 0.0 | 0.0 | 0.1 | 2551.4 | 0.0  | 3664.8 | 67.4 | 4.0  | 16.1  | 0  |
| 2500   | 1200      | 12.43 | 0.1  | 0.00 | 0.1   | 1.2  | 0.0 | 0.0 | 0.0 | 0.1 | 2447.8 | 0.0  | 3588.1 | 67.5 | 4.0  | 16.3  | 0  |
| 2500   | 1190      | 16.27 | 0.1  | 0.00 | 9.1   | 3.7  | 0.2 | 0.1 | 0.0 | 0.9 | 2118.5 | 5.4  | 3169.9 | 78.8 | 6.1  | 91.0  | 0  |
| 2500   | 1180      | 21.31 | 0.1  | 0.00 | 17.9  | 6.1  | 0.3 | 0.1 | 0.0 | 1.8 | 1799.3 | 10.5 | 2761.9 | 86.3 | 8.0  | 152.5 | 0  |
| 2500   | 1170      | 26.20 | 0.1  | 0.01 | 23.9  | 7.8  | 0.4 | 0.1 | 0.0 | 2.3 | 1569.4 | 13.8 | 2469.9 | 89.1 | 9.4  | 187.5 | 0  |
| 2500   | 1160      | 31.23 | 0.1  | 0.01 | 27.8  | 9.1  | 0.5 | 0.2 | 0.0 | 2.7 | 1386.4 | 15.7 | 2234.9 | 90.3 | 10.4 | 210.8 | 0  |
| 2500   | 1150      | 36.40 | 0.1  | 0.01 | 31.2  | 10.2 | 0.6 | 0.2 | 0.0 | 2.9 | 1237.7 | 17.3 | 2037.6 | 90.0 | 11.2 | 225.6 | 0  |
| 2500   | 1140      | 43.67 | 5.7  | 0.03 | 73.8  | 10.9 | 0.6 | 0.2 | 0.0 | 3.1 | 1068.2 | 17.7 | 1783.7 | 85.7 | 11.5 | 225.0 | 0  |
| 2500   | 1130      | 51.23 | 11.9 | 0.05 | 113.2 | 11.8 | 0.6 | 0.2 | 0.0 | 3.3 | 936.8  | 18.3 | 1568.4 | 81.7 | 11.9 | 223.5 | 0  |
| 2500   | 1120      | 57.78 | 17.7 | 0.07 | 142.3 | 12.9 | 0.7 | 0.2 | 0.0 | 3.5 | 848.1  | 19.2 | 1412.7 | 78.8 | 12.4 | 223.3 | 0  |
| 2500   | 1110      | 63.02 | 23.4 | 0.10 | 164.4 | 14.0 | 0.7 | 0.3 | 0.0 | 3.8 | 789.2  | 20.1 | 1305.8 | 76.6 | 12.9 | 223.4 | 0  |
| 2500   | 1100      | 67.17 | 28.9 | 0.12 | 181.6 | 15.1 | 0.7 | 0.3 | 0.0 | 4.0 | 748.4  | 20.9 | 1230.8 | 75.0 | 13.3 | 223.7 | 0  |

**Cont. Appendix B:** *Results of Modeling for Northern Sequence of Americano do Brasil Rocks: Composition of liquids (Cont. Trace elements)*

| P(bar) | T (°C) | mass  | La   | Ce   | Pr   | Nd   | Sm   | Eu   | Gd   | Tb   | Dy   | Ho   | Er   | Tm   | Yb   | Lu   | H2O  |
|--------|--------|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 2500   | 1310   | 0.51  | 0.01 | 0.01 | 0    | 0.02 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1300   | 1.69  | 0.01 | 0.01 | 0    | 0.02 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1290   | 2.88  | 0.01 | 0.02 | 0    | 0.02 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1280   | 4.03  | 0.01 | 0.02 | 0    | 0.02 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1270   | 5.15  | 0.01 | 0.02 | 0    | 0.02 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1260   | 6.25  | 0.01 | 0.02 | 0    | 0.02 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1250   | 7.33  | 0.01 | 0.02 | 0    | 0.02 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1240   | 8.38  | 0.01 | 0.02 | 0    | 0.02 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1230   | 9.42  | 0.01 | 0.02 | 0    | 0.02 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1220   | 10.44 | 0.01 | 0.02 | 0    | 0.02 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1210   | 11.44 | 0.01 | 0.02 | 0    | 0.02 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1200   | 12.43 | 0.01 | 0.02 | 0    | 0.03 | 0.01 | 0    | 0.01 | 0    | 0.01 | 0    | 0    | 0    | 0    | 0    | 1.4  |
| 2500   | 1190   | 16.27 | 0.19 | 0.73 | 0.15 | 0.99 | 0.31 | 0.12 | 0.33 | 0.05 | 0.32 | 0.05 | 0.13 | 0.02 | 0.10 | 0.02 | 2.6  |
| 2500   | 1180   | 21.31 | 0.37 | 1.41 | 0.29 | 1.91 | 0.59 | 0.23 | 0.63 | 0.10 | 0.61 | 0.10 | 0.26 | 0.03 | 0.20 | 0.03 | 3.8  |
| 2500   | 1170   | 26.20 | 0.49 | 1.88 | 0.39 | 2.54 | 0.78 | 0.31 | 0.83 | 0.13 | 0.80 | 0.14 | 0.34 | 0.04 | 0.26 | 0.04 | 4.8  |
| 2500   | 1160   | 31.23 | 0.57 | 2.19 | 0.45 | 2.93 | 0.90 | 0.35 | 0.96 | 0.15 | 0.92 | 0.16 | 0.39 | 0.05 | 0.30 | 0.05 | 5.6  |
| 2500   | 1150   | 36.40 | 0.64 | 2.46 | 0.50 | 3.25 | 0.99 | 0.39 | 1.06 | 0.16 | 1.02 | 0.17 | 0.43 | 0.05 | 0.34 | 0.05 | 6.4  |
| 2500   | 1140   | 43.67 | 0.98 | 3.04 | 0.57 | 3.57 | 1.06 | 0.48 | 1.11 | 0.17 | 1.06 | 0.18 | 0.45 | 0.06 | 0.36 | 0.05 | 7.5  |
| 2500   | 1130   | 51.23 | 1.35 | 3.70 | 0.66 | 3.94 | 1.15 | 0.56 | 1.18 | 0.18 | 1.12 | 0.19 | 0.48 | 0.06 | 0.38 | 0.06 | 8.7  |
| 2500   | 1120   | 57.78 | 1.72 | 4.37 | 0.75 | 4.34 | 1.24 | 0.64 | 1.26 | 0.19 | 1.19 | 0.21 | 0.51 | 0.06 | 0.40 | 0.06 | 10.2 |
| 2500   | 1110   | 63.02 | 2.07 | 5.03 | 0.83 | 4.74 | 1.34 | 0.71 | 1.34 | 0.21 | 1.26 | 0.22 | 0.54 | 0.07 | 0.43 | 0.07 | 11.8 |
| 2500   | 1100   | 67.17 | 2.41 | 5.66 | 0.92 | 5.12 | 1.43 | 0.77 | 1.42 | 0.22 | 1.33 | 0.23 | 0.57 | 0.07 | 0.46 | 0.07 | 13.3 |

**Cont. Appendix B:** *Results of Modeling for Northern Sequence of Americano do Brasil Rocks: Composition of liquids (Major Oxides)*

| P(bar) | T (°C) | mass  | SiO <sub>2</sub> | TiO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | Fe <sub>2</sub> O <sub>3</sub> | Cr <sub>2</sub> O <sub>3</sub> | FeO   | MnO  | MgO  | CaO   | Na <sub>2</sub> O | K <sub>2</sub> O | P <sub>2</sub> O <sub>5</sub> | H <sub>2</sub> O |
|--------|--------|-------|------------------|------------------|--------------------------------|--------------------------------|--------------------------------|-------|------|------|-------|-------------------|------------------|-------------------------------|------------------|
| 2500   | 1350   | 98.86 | 47.4             | 1.83             | 12.1                           | 2.23                           | 0.12                           | 11.44 | 0.17 | 12.5 | 9.44  | 2.10              | 0.42             | 0.19                          | 0.00             |
| 2500   | 1340   | 98.86 | 47.4             | 1.83             | 12.1                           | 2.24                           | 0.12                           | 11.44 | 0.17 | 12.5 | 9.44  | 2.10              | 0.42             | 0.19                          | 0.00             |
| 2500   | 1330   | 98.86 | 47.4             | 1.83             | 12.1                           | 2.24                           | 0.12                           | 11.44 | 0.17 | 12.5 | 9.44  | 2.10              | 0.42             | 0.19                          | 0.00             |
| 2500   | 1320   | 99.36 | 47.2             | 1.82             | 12.1                           | 2.23                           | 0.12                           | 11.38 | 0.17 | 12.4 | 9.39  | 2.09              | 0.42             | 0.19                          | 0.50             |
| 2500   | 1310   | 98.85 | 47.2             | 1.83             | 12.1                           | 2.24                           | 0.12                           | 11.38 | 0.17 | 12.2 | 9.44  | 2.10              | 0.42             | 0.19                          | 0.50             |
| 2500   | 1300   | 97.67 | 47.3             | 1.85             | 12.3                           | 2.25                           | 0.12                           | 11.37 | 0.17 | 11.8 | 9.55  | 2.13              | 0.43             | 0.19                          | 0.51             |
| 2500   | 1290   | 96.47 | 47.4             | 1.88             | 12.4                           | 2.27                           | 0.11                           | 11.36 | 0.17 | 11.4 | 9.66  | 2.16              | 0.44             | 0.20                          | 0.51             |
| 2500   | 1280   | 95.32 | 47.5             | 1.90             | 12.6                           | 2.28                           | 0.10                           | 11.33 | 0.17 | 11.0 | 9.77  | 2.18              | 0.44             | 0.20                          | 0.52             |
| 2500   | 1270   | 94.20 | 47.6             | 1.92             | 12.7                           | 2.29                           | 0.09                           | 11.30 | 0.17 | 10.6 | 9.89  | 2.21              | 0.45             | 0.20                          | 0.53             |
| 2500   | 1260   | 93.10 | 47.7             | 1.94             | 12.9                           | 2.30                           | 0.09                           | 11.25 | 0.17 | 10.2 | 10.00 | 2.23              | 0.45             | 0.20                          | 0.53             |
| 2500   | 1250   | 92.02 | 47.9             | 1.96             | 13.0                           | 2.31                           | 0.08                           | 11.20 | 0.17 | 9.9  | 10.11 | 2.26              | 0.46             | 0.21                          | 0.54             |
| 2500   | 1240   | 90.97 | 48.0             | 1.98             | 13.2                           | 2.31                           | 0.07                           | 11.13 | 0.16 | 9.5  | 10.22 | 2.29              | 0.46             | 0.21                          | 0.55             |
| 2500   | 1230   | 89.93 | 48.1             | 2.01             | 13.3                           | 2.32                           | 0.07                           | 11.05 | 0.16 | 9.1  | 10.33 | 2.31              | 0.47             | 0.21                          | 0.55             |
| 2500   | 1220   | 88.91 | 48.2             | 2.03             | 13.4                           | 2.32                           | 0.06                           | 10.96 | 0.16 | 8.8  | 10.45 | 2.34              | 0.47             | 0.21                          | 0.56             |
| 2500   | 1210   | 87.91 | 48.3             | 2.05             | 13.6                           | 2.32                           | 0.05                           | 10.86 | 0.16 | 8.4  | 10.56 | 2.37              | 0.48             | 0.22                          | 0.57             |
| 2500   | 1200   | 86.92 | 48.5             | 2.07             | 13.7                           | 2.32                           | 0.05                           | 10.75 | 0.16 | 8.1  | 10.68 | 2.39              | 0.48             | 0.22                          | 0.57             |
| 2500   | 1190   | 83.08 | 48.4             | 2.14             | 14.2                           | 2.32                           | 0.04                           | 10.79 | 0.16 | 7.7  | 10.43 | 2.50              | 0.51             | 0.23                          | 0.60             |
| 2500   | 1180   | 78.04 | 48.4             | 2.22             | 14.7                           | 2.32                           | 0.03                           | 10.87 | 0.17 | 7.2  | 10.01 | 2.64              | 0.54             | 0.24                          | 0.64             |
| 2500   | 1170   | 73.15 | 48.4             | 2.30             | 15.3                           | 2.31                           | 0.02                           | 10.89 | 0.18 | 6.7  | 9.59  | 2.80              | 0.57             | 0.26                          | 0.68             |
| 2500   | 1160   | 68.13 | 48.3             | 2.35             | 15.9                           | 2.30                           | 0.01                           | 10.87 | 0.19 | 6.3  | 9.19  | 2.99              | 0.62             | 0.28                          | 0.73             |
| 2500   | 1150   | 62.97 | 48.4             | 2.34             | 16.5                           | 2.27                           | 0.01                           | 10.72 | 0.21 | 5.8  | 8.77  | 3.21              | 0.67             | 0.30                          | 0.79             |
| 2500   | 1140   | 55.72 | 48.8             | 2.32             | 16.7                           | 2.25                           | 0.00                           | 10.52 | 0.23 | 5.4  | 8.35  | 3.48              | 0.75             | 0.34                          | 0.89             |
| 2500   | 1130   | 48.19 | 49.5             | 2.19             | 17.0                           | 2.19                           | 0.00                           | 10.01 | 0.26 | 4.9  | 7.92  | 3.81              | 0.86             | 0.39                          | 1.03             |
| 2500   | 1120   | 41.67 | 50.4             | 2.00             | 17.2                           | 2.08                           | 0.00                           | 9.27  | 0.29 | 4.4  | 7.51  | 4.16              | 0.99             | 0.46                          | 1.19             |
| 2500   | 1110   | 36.45 | 51.3             | 1.81             | 17.4                           | 1.97                           | 0.00                           | 8.51  | 0.32 | 4.0  | 7.14  | 4.50              | 1.12             | 0.52                          | 1.36             |

**Cont. Appendix B:** *Results of Modeling for Northern Sequence of Americano do Brasil Rocks: Composition of liquids (Trace elements)*

| P(bar) | T (°C) | mass | Ba     | Rb    | Sr    | Zr    | Hf   | Nb    | Ta   | Y     | Ni     | Cu     | Cr     | Co    | Sc    | V      | Zn     |
|--------|--------|------|--------|-------|-------|-------|------|-------|------|-------|--------|--------|--------|-------|-------|--------|--------|
| 2500   | 1350   | 98.9 | 190    | 7     | 275   | 105   | 3    | 8     | 1    | 17    | 540    | 59     | 845    | 66    | 23    | 246    | 90     |
| 2500   | 1340   | 98.9 | 190    | 7     | 275   | 105   | 3    | 8     | 1    | 17    | 540    | 59     | 845    | 66    | 23    | 246    | 90     |
| 2500   | 1330   | 98.9 | 190    | 7     | 275   | 105   | 3    | 8     | 1    | 17    | 540    | 59     | 845    | 66    | 23    | 246    | 90     |
| 2500   | 1320   | 99.4 | 190    | 7     | 275   | 105   | 3    | 8     | 1    | 17    | 540    | 59     | 845    | 66    | 23    | 246    | 90     |
| 2500   | 1310   | 98.9 | 190.98 | 7.04  | 276.4 | 105.5 | 3.02 | 8.44  | 1.21 | 17.09 | 517.79 | 59.30  | 848.03 | 66.00 | 23.10 | 247.19 | 90.46  |
| 2500   | 1300   | 97.7 | 193.28 | 7.12  | 279.8 | 106.8 | 3.05 | 8.54  | 1.22 | 17.29 | 472.58 | 60.02  | 855.17 | 66.00 | 23.33 | 249.99 | 91.56  |
| 2500   | 1290   | 96.5 | 195.68 | 7.21  | 283.2 | 108.1 | 3.09 | 8.65  | 1.24 | 17.51 | 435.66 | 60.76  | 756.13 | 65.97 | 23.58 | 252.91 | 92.69  |
| 2500   | 1280   | 95.3 | 198.04 | 7.30  | 286.6 | 109.4 | 3.13 | 8.75  | 1.25 | 17.72 | 404.79 | 61.50  | 709.04 | 65.95 | 23.81 | 255.77 | 93.81  |
| 2500   | 1270   | 94.2 | 200.39 | 7.38  | 290.0 | 110.7 | 3.16 | 8.86  | 1.27 | 17.93 | 378.60 | 62.23  | 666.95 | 65.93 | 24.05 | 258.63 | 94.93  |
| 2500   | 1260   | 93.1 | 202.76 | 7.47  | 293.5 | 112.0 | 3.20 | 8.96  | 1.28 | 18.14 | 356.09 | 62.96  | 628.93 | 65.91 | 24.29 | 261.49 | 96.04  |
| 2500   | 1250   | 92.0 | 205.13 | 7.56  | 296.9 | 113.3 | 3.24 | 9.07  | 1.30 | 18.35 | 336.51 | 63.70  | 594.22 | 65.90 | 24.53 | 264.35 | 97.17  |
| 2500   | 1240   | 91.0 | 207.50 | 7.64  | 300.3 | 114.6 | 3.28 | 9.17  | 1.31 | 18.56 | 319.32 | 64.44  | 562.23 | 65.88 | 24.76 | 267.22 | 98.29  |
| 2500   | 1230   | 89.9 | 209.89 | 7.73  | 303.8 | 115.9 | 3.31 | 9.27  | 1.32 | 18.77 | 304.09 | 65.18  | 532.48 | 65.86 | 25.00 | 270.10 | 99.43  |
| 2500   | 1220   | 88.9 | 212.30 | 7.82  | 307.3 | 117.2 | 3.35 | 9.38  | 1.34 | 18.98 | 290.49 | 65.93  | 504.54 | 65.84 | 25.24 | 273.00 | 100.56 |
| 2500   | 1210   | 87.9 | 214.72 | 7.91  | 310.8 | 118.5 | 3.39 | 9.49  | 1.36 | 19.20 | 278.26 | 66.68  | 478.06 | 65.81 | 25.48 | 275.91 | 101.71 |
| 2500   | 1200   | 86.9 | 217.16 | 8.00  | 314.3 | 119.8 | 3.43 | 9.59  | 1.37 | 19.42 | 267.20 | 67.44  | 452.76 | 65.79 | 25.72 | 278.85 | 102.87 |
| 2500   | 1190   | 83.1 | 227.18 | 8.37  | 327.1 | 124.8 | 3.55 | 10.03 | 1.43 | 20.14 | 230.96 | 69.49  | 389.81 | 63.50 | 26.31 | 276.35 | 107.62 |
| 2500   | 1180   | 78.0 | 241.86 | 8.91  | 345.2 | 132.0 | 3.73 | 10.66 | 1.52 | 21.16 | 196.12 | 72.25  | 321.54 | 60.47 | 27.08 | 271.54 | 114.58 |
| 2500   | 1170   | 73.2 | 258.01 | 9.50  | 364.9 | 139.8 | 3.92 | 11.36 | 1.62 | 22.26 | 171.36 | 75.19  | 263.09 | 57.73 | 27.89 | 266.97 | 122.23 |
| 2500   | 1160   | 68.1 | 277.05 | 10.21 | 388.3 | 149.0 | 4.14 | 12.18 | 1.74 | 23.57 | 151.99 | 78.83  | 207.83 | 54.85 | 28.79 | 262.14 | 131.26 |
| 2500   | 1150   | 63.0 | 299.76 | 11.04 | 415.9 | 159.8 | 4.41 | 13.15 | 1.88 | 25.12 | 136.73 | 83.12  | 155.61 | 52.10 | 29.82 | 257.78 | 142.02 |
| 2500   | 1140   | 55.7 | 334.47 | 12.46 | 432.6 | 178.7 | 4.89 | 14.83 | 2.12 | 27.90 | 126.02 | 91.36  | 109.38 | 50.58 | 32.00 | 262.44 | 160.53 |
| 2500   | 1130   | 48.2 | 379.34 | 14.39 | 447.0 | 204.1 | 5.53 | 17.10 | 2.45 | 31.58 | 118.19 | 102.26 | 75.98  | 49.33 | 34.79 | 269.93 | 185.68 |
| 2500   | 1120   | 41.7 | 428.88 | 16.61 | 459.1 | 232.7 | 6.24 | 19.71 | 2.82 | 35.69 | 112.77 | 114.23 | 57.83  | 48.31 | 37.70 | 277.54 | 214.79 |
| 2500   | 1110   | 36.5 | 478.07 | 18.94 | 466.2 | 262.3 | 6.97 | 22.46 | 3.22 | 39.88 | 109.24 | 126.30 | 48.45  | 47.67 | 40.50 | 285.03 | 245.59 |
| 2500   | 1100   | 32.3 | 524.89 | 21.30 | 469.1 | 291.9 | 7.69 | 25.24 | 3.62 | 44.02 | 106.91 | 138.09 | 43.17  | 47.32 | 43.10 | 292.25 | 277.03 |

**Cont. Appendix B:** *Results of Modeling for Northern Sequence of Americano do Brasil Rocks: Composition of liquids (Continuation Trace elements)*

| P(bar) | T (°C) | mass | La    | Ce    | Pr   | Nd    | Sm   | Eu   | Gd   | Tb   | Dy   | Ho   | Er   | Tm   | Yb   | Lu   | H2O   |
|--------|--------|------|-------|-------|------|-------|------|------|------|------|------|------|------|------|------|------|-------|
| 2500   | 1350   | 98.9 | 13    | 28    | 4    | 18    | 4.50 | 1.5  | 4.2  | 0.63 | 3.7  | 0.67 | 1.7  | 0.22 | 1.4  | 0.21 | 0     |
| 2500   | 1340   | 98.9 | 13    | 28    | 4    | 18    | 4.50 | 1.5  | 4.2  | 0.63 | 3.7  | 0.67 | 1.7  | 0.22 | 1.4  | 0.21 | 0     |
| 2500   | 1330   | 98.9 | 13    | 28    | 4    | 18    | 4.50 | 1.5  | 4.2  | 0.63 | 3.7  | 0.67 | 1.7  | 0.22 | 1.4  | 0.21 | 0     |
| 2500   | 1320   | 99.4 | 13    | 28    | 4    | 18    | 4.50 | 1.5  | 4.2  | 0.63 | 3.7  | 0.67 | 1.7  | 0.22 | 1.4  | 0.21 | 5000  |
| 2500   | 1310   | 98.9 | 13.07 | 28.14 | 3.82 | 18.09 | 4.52 | 1.51 | 4.22 | 0.63 | 3.72 | 0.67 | 1.71 | 0.22 | 1.41 | 0.21 | 5026  |
| 2500   | 1300   | 97.7 | 13.22 | 28.48 | 3.87 | 18.31 | 4.58 | 1.53 | 4.27 | 0.64 | 3.76 | 0.68 | 1.73 | 0.22 | 1.42 | 0.21 | 5086  |
| 2500   | 1290   | 96.5 | 13.39 | 28.84 | 3.91 | 18.54 | 4.63 | 1.54 | 4.33 | 0.65 | 3.81 | 0.69 | 1.75 | 0.23 | 1.44 | 0.22 | 5149  |
| 2500   | 1280   | 95.3 | 13.55 | 29.18 | 3.96 | 18.76 | 4.69 | 1.56 | 4.38 | 0.66 | 3.86 | 0.70 | 1.77 | 0.23 | 1.46 | 0.22 | 5211  |
| 2500   | 1270   | 94.2 | 13.71 | 29.53 | 4.01 | 18.98 | 4.75 | 1.58 | 4.43 | 0.66 | 3.90 | 0.71 | 1.79 | 0.23 | 1.48 | 0.22 | 5274  |
| 2500   | 1260   | 93.1 | 13.87 | 29.88 | 4.05 | 19.21 | 4.80 | 1.60 | 4.48 | 0.67 | 3.95 | 0.71 | 1.81 | 0.23 | 1.49 | 0.22 | 5336  |
| 2500   | 1250   | 92.0 | 14.03 | 30.23 | 4.10 | 19.43 | 4.86 | 1.62 | 4.53 | 0.68 | 3.99 | 0.72 | 1.84 | 0.24 | 1.51 | 0.23 | 5398  |
| 2500   | 1240   | 91.0 | 14.20 | 30.58 | 4.15 | 19.66 | 4.91 | 1.64 | 4.59 | 0.69 | 4.04 | 0.73 | 1.86 | 0.24 | 1.53 | 0.23 | 5461  |
| 2500   | 1230   | 89.9 | 14.36 | 30.93 | 4.20 | 19.88 | 4.97 | 1.66 | 4.64 | 0.70 | 4.09 | 0.74 | 1.88 | 0.24 | 1.55 | 0.23 | 5523  |
| 2500   | 1220   | 88.9 | 14.52 | 31.28 | 4.25 | 20.11 | 5.03 | 1.68 | 4.69 | 0.70 | 4.13 | 0.75 | 1.90 | 0.25 | 1.56 | 0.23 | 5587  |
| 2500   | 1210   | 87.9 | 14.69 | 31.64 | 4.29 | 20.34 | 5.08 | 1.69 | 4.75 | 0.71 | 4.18 | 0.76 | 1.92 | 0.25 | 1.58 | 0.24 | 5650  |
| 2500   | 1200   | 86.9 | 14.86 | 32.00 | 4.34 | 20.57 | 5.14 | 1.71 | 4.80 | 0.72 | 4.23 | 0.77 | 1.94 | 0.25 | 1.60 | 0.24 | 5715  |
| 2500   | 1190   | 83.1 | 15.51 | 33.34 | 4.51 | 21.33 | 5.32 | 1.77 | 4.96 | 0.74 | 4.36 | 0.79 | 2.01 | 0.26 | 1.65 | 0.25 | 5978  |
| 2500   | 1180   | 78.0 | 16.45 | 35.26 | 4.76 | 22.39 | 5.57 | 1.85 | 5.17 | 0.78 | 4.54 | 0.82 | 2.09 | 0.27 | 1.73 | 0.26 | 6364  |
| 2500   | 1170   | 73.2 | 17.48 | 37.35 | 5.02 | 23.54 | 5.83 | 1.93 | 5.41 | 0.81 | 4.74 | 0.86 | 2.19 | 0.28 | 1.81 | 0.27 | 6789  |
| 2500   | 1160   | 68.1 | 18.70 | 39.83 | 5.34 | 24.91 | 6.15 | 2.03 | 5.69 | 0.85 | 4.97 | 0.90 | 2.30 | 0.30 | 1.90 | 0.29 | 7290  |
| 2500   | 1150   | 63.0 | 20.14 | 42.77 | 5.71 | 26.52 | 6.53 | 2.14 | 6.02 | 0.90 | 5.25 | 0.96 | 2.43 | 0.32 | 2.01 | 0.30 | 7887  |
| 2500   | 1140   | 55.7 | 22.42 | 47.56 | 6.33 | 29.31 | 7.19 | 2.30 | 6.62 | 0.99 | 5.77 | 1.05 | 2.68 | 0.35 | 2.22 | 0.33 | 8913  |
| 2500   | 1130   | 48.2 | 25.38 | 53.83 | 7.14 | 32.94 | 8.06 | 2.49 | 7.41 | 1.11 | 6.44 | 1.18 | 3.00 | 0.39 | 2.49 | 0.37 | 10306 |
| 2500   | 1120   | 41.7 | 28.64 | 60.76 | 8.03 | 36.94 | 9.02 | 2.69 | 8.28 | 1.23 | 7.18 | 1.31 | 3.35 | 0.44 | 2.78 | 0.42 | 11919 |



|      |      |      |       |       |      |       |       |      |      |      |      |      |      |      |      |      |       |
|------|------|------|-------|-------|------|-------|-------|------|------|------|------|------|------|------|------|------|-------|
| 2500 | 1110 | 36.5 | 31.89 | 67.71 | 8.93 | 40.93 | 9.97  | 2.86 | 9.14 | 1.36 | 7.91 | 1.45 | 3.70 | 0.48 | 3.08 | 0.46 | 13624 |
| 2500 | 1100 | 32.3 | 35.00 | 74.42 | 9.79 | 44.78 | 10.89 | 3.02 | 9.98 | 1.49 | 8.62 | 1.58 | 4.05 | 0.53 | 3.36 | 0.50 | 15363 |

| Phase    |             |       |        |         |               |               |         |             |        |         |
|----------|-------------|-------|--------|---------|---------------|---------------|---------|-------------|--------|---------|
| Masses:  |             |       |        |         |               |               |         |             |        |         |
| Pressure | Temperature | mass  | Liquid | Olivine | Orthopyroxene | Clinopyroxene | Biotite | Plagioclase | Spinel | Apatite |
| 2500     | 1350        | 98.86 | 98.86  | 0.00    | 0.00          | 0.00          | 0.00    | 0.00        | 0.00   | 0.00    |
| 2500     | 1340        | 98.86 | 98.86  | 0.00    | 0.00          | 0.00          | 0.00    | 0.00        | 0.00   | 0.00    |
| 2500     | 1330        | 98.86 | 98.86  | 0.00    | 0.00          | 0.00          | 0.00    | 0.00        | 0.00   | 0.00    |
| 2500     | 1320        | 99.36 | 99.36  | 0.00    | 0.00          | 0.00          | 0.00    | 0.00        | 0.00   | 0.00    |
| 2500     | 1310        | 99.36 | 98.85  | 0.51    | 0.00          | 0.00          | 0.00    | 0.00        | 0.00   | 0.00    |
| 2500     | 1300        | 99.36 | 97.67  | 1.69    | 0.00          | 0.00          | 0.00    | 0.00        | 0.00   | 0.00    |
| 2500     | 1290        | 99.36 | 96.47  | 2.84    | 0.00          | 0.00          | 0.00    | 0.00        | 0.05   | 0.00    |
| 2500     | 1280        | 99.35 | 95.32  | 3.96    | 0.00          | 0.00          | 0.00    | 0.00        | 0.07   | 0.00    |
| 2500     | 1270        | 99.35 | 94.20  | 5.05    | 0.00          | 0.00          | 0.00    | 0.00        | 0.10   | 0.00    |
| 2500     | 1260        | 99.35 | 93.10  | 6.12    | 0.00          | 0.00          | 0.00    | 0.00        | 0.13   | 0.00    |
| 2500     | 1250        | 99.35 | 92.02  | 7.17    | 0.00          | 0.00          | 0.00    | 0.00        | 0.16   | 0.00    |
| 2500     | 1240        | 99.35 | 90.97  | 8.20    | 0.00          | 0.00          | 0.00    | 0.00        | 0.19   | 0.00    |
| 2500     | 1230        | 99.35 | 89.93  | 9.20    | 0.00          | 0.00          | 0.00    | 0.00        | 0.22   | 0.00    |
| 2500     | 1220        | 99.35 | 88.91  | 10.19   | 0.00          | 0.00          | 0.00    | 0.00        | 0.25   | 0.00    |
| 2500     | 1210        | 99.35 | 87.91  | 11.16   | 0.00          | 0.00          | 0.00    | 0.00        | 0.28   | 0.00    |
| 2500     | 1200        | 99.35 | 86.92  | 12.11   | 0.00          | 0.00          | 0.00    | 0.00        | 0.32   | 0.00    |
| 2500     | 1190        | 99.34 | 83.08  | 12.35   | 0.00          | 3.52          | 0.00    | 0.00        | 0.39   | 0.00    |
| 2500     | 1180        | 99.35 | 78.04  | 12.22   | 0.00          | 8.57          | 0.00    | 0.00        | 0.51   | 0.00    |
| 2500     | 1170        | 99.35 | 73.15  | 11.97   | 0.20          | 13.35         | 0.00    | 0.00        | 0.67   | 0.00    |
| 2500     | 1160        | 99.36 | 68.13  | 11.03   | 1.95          | 17.33         | 0.00    | 0.00        | 0.93   | 0.00    |
| 2500     | 1150        | 99.37 | 62.97  | 9.89    | 4.15          | 21.02         | 0.00    | 0.00        | 1.35   | 0.00    |
| 2500     | 1140        | 99.39 | 55.72  | 9.09    | 6.78          | 23.51         | 0.00    | 2.19        | 2.10   | 0.00    |
| 2500     | 1130        | 99.42 | 48.19  | 8.23    | 9.49          | 25.48         | 0.00    | 4.82        | 3.21   | 0.00    |
| 2500     | 1120        | 99.45 | 41.67  | 7.35    | 11.95         | 26.94         | 0.00    | 7.18        | 4.37   | 0.00    |
| 2500     | 1110        | 99.48 | 36.45  | 6.67    | 13.95         | 27.82         | 0.00    | 9.28        | 5.31   | 0.00    |

## Appendix C: Conditions and compositions results from thermodynamic modeling using alphaMELTS for Southern Sequence of Americano do Brasil.

*Environment settings used in alphaMELTS for Southern sequence of Americano do Brasil rocks.*

```
! *****
! Assimilation-batch crystallization (ABC) of Assimilant
! *****
! this variable chooses MELTS or pMELTS; for low-pressure use
MELTS
ALPHAMELTS_VERSION      MELTS
ALPHAMELTS_CELSIUS_OUTPUT true
!ALPHAMELTS_ALTERNATIVE_FO2 true
! ALPHAMELTS_IMPOSE_FO2 true
ALPHAMELTS_ASSIMILATE true
! isothermal, isobaric, isentropic, isenthalpic, isochoric, geothermal or
PTPath
ALPHAMELTS_MODE          isenthalpic
!ALPHAMELTS_PTPATH_FILE ptpath.txt
ALPHAMELTS_DELTAP        0
ALPHAMELTS_DELTAT        0
ALPHAMELTS_MAXP          30000
ALPHAMELTS_MINP          1
ALPHAMELTS_MAXT          2000
ALPHAMELTS_MINT          900
!ALPHAMELTS_FRACTIONATE_SOLIDS true
!ALPHAMELTS_MASSIN        0.001
!ALPHAMELTS_FRACTIONATE_WATER true
!ALPHAMELTS_MINW          0.9
ALPHAMELTS_DO_TRACE      true
ALPHAMELTS_DO_TRACE_H2O  true
!ALPHAMELTS_HK_OL_TRACE_H2O true
!ALPHAMELTS_HK_PXGT_TRACE_H2O mineral-mineral
!ALPHAMELTS_2X_OPX_TRACE_H2O true
ALPHAMELTS_TRACE_DEFAULT_DPTX true
!ALPHAMELTS_TRACE_NORMALIZATION 1
!ALPHAMELTS_TRACE_INPUT_FILE yourtraceinfile.txt
ALPHAMELTS_TRACE_USELIQFEMG true
!ALPHAMELTS_SAVE_ALL true
```

**Cont. Appendix C: *Composition of the assimilant***

Title: Americano do Brasil Country Rock (Sample CMJ115 from Silva et al, 2011)

Initial composition: SiO<sub>2</sub> 63.5

Initial composition: TiO<sub>2</sub> 0.48

Initial composition: Al<sub>2</sub>O<sub>3</sub> 15.90

Initial composition: Fe<sub>2</sub>O<sub>3</sub> 5.60

Initial composition: MnO 0.08

Initial composition: MgO 2.36

Initial composition: CaO 5.42

Initial composition: Na<sub>2</sub>O 4.13

Initial composition: K<sub>2</sub>O 0.78

Initial composition: P<sub>2</sub>O<sub>5</sub> 0.08

Initial composition: Cr<sub>2</sub>O<sub>3</sub> 0.01

Initial composition: H<sub>2</sub>O 2.0

Initial trace: V 101

Initial trace: Co 20

Initial trace: Ni 98

Initial trace: Rb 8.7

Initial trace: Sr 485

Initial trace: Y 9

Initial trace: Zr 116

Initial trace: Nb 1.7

Initial trace: Ba 391

Initial trace: La 12.2

Initial trace: Ce 23.8

Initial trace: Pr 2.94

Initial trace: Nd 12.6

Initial trace: Sm 2.39

Initial trace: Eu 0.9

Initial trace: Gd 2.5

Initial trace: Tb 0.3

Initial trace: Dy 1.69

Initial trace: Ho 0.33

Initial trace: Er 0.96

Initial trace: Tm 0.13

Initial trace: Yb 0.87

Initial trace: Ga 17.4

Initial trace: Lu 0.13

Initial trace: Hf 3.3

Initial trace: Ta 0.1

Initial trace: Th 0.71

Initial trace: U 0.16

Initial Temperature: 300

Initial Pressure: 2500

log fo<sub>2</sub> Path: FMQ

**Cont. Appendix C: Results of Modeling for Southern Sequence of Americano do Brasil Rocks: Composition of solids (Phases)**

| P (bar) | T (°C) | mass   | Liquid | Olivine | Orthopyroxene | Clinopyroxene | Plagioclase | Spinel |
|---------|--------|--------|--------|---------|---------------|---------------|-------------|--------|
| 2500    | 1315   | 100.37 | 100.37 | -       | -             | -             | -           | -      |
| 2500    | 1307   | 101.37 | 100.63 | 0.74    | -             | -             | -           | -      |
| 2500    | 1299   | 102.37 | 100.86 | 1.51    | -             | -             | -           | -      |
| 2500    | 1291   | 103.37 | 101.10 | 2.27    | -             | -             | -           | -      |
| 2500    | 1284   | 104.37 | 101.34 | 3.02    | -             | -             | -           | 0.01   |
| 2500    | 1276   | 105.37 | 101.59 | 3.75    | -             | -             | -           | 0.03   |
| 2500    | 1269   | 106.37 | 101.84 | 4.48    | -             | -             | -           | 0.05   |
| 2500    | 1261   | 107.37 | 102.10 | 5.20    | -             | -             | -           | 0.06   |
| 2500    | 1254   | 108.37 | 102.38 | 5.90    | -             | -             | -           | 0.08   |
| 2500    | 1247   | 109.37 | 102.66 | 6.60    | -             | -             | -           | 0.10   |
| 2500    | 1240   | 110.37 | 102.95 | 7.29    | -             | -             | -           | 0.12   |
| 2500    | 1233   | 111.37 | 103.26 | 7.97    | -             | -             | -           | 0.14   |
| 2500    | 1226   | 112.37 | 103.56 | 8.64    | -             | -             | -           | 0.16   |
| 2500    | 1219   | 113.37 | 103.37 | 8.23    | 1.58          | -             | -           | 0.18   |
| 2500    | 1213   | 114.37 | 103.02 | 7.48    | 3.66          | -             | -           | 0.21   |
| 2500    | 1207   | 115.37 | 102.67 | 6.71    | 5.75          | -             | -           | 0.23   |
| 2500    | 1201   | 116.37 | 102.31 | 5.93    | 7.88          | -             | -           | 0.25   |
| 2500    | 1196   | 117.37 | 101.94 | 5.13    | 10.02         | -             | -           | 0.28   |
| 2500    | 1190   | 118.37 | 101.56 | 4.32    | 12.19         | -             | -           | 0.30   |
| 2500    | 1185   | 119.37 | 100.98 | 3.50    | 14.08         | 0.47          | -           | 0.33   |
| 2500    | 1181   | 120.37 | 99.83  | 2.70    | 15.19         | 2.29          | -           | 0.36   |
| 2500    | 1177   | 121.37 | 98.70  | 1.90    | 16.32         | 4.06          | -           | 0.38   |
| 2500    | 1174   | 122.37 | 97.59  | 1.09    | 17.49         | 5.78          | -           | 0.41   |
| 2500    | 1170   | 123.37 | 96.51  | 0.27    | 18.69         | 7.46          | -           | 0.44   |
| 2500    | 1166   | 124.37 | 95.59  | 0.00    | 19.18         | 9.12          | -           | 0.47   |
| 2500    | 1163   | 125.37 | 94.78  | 0.00    | 19.33         | 10.75         | -           | 0.50   |

|      |      |        |       |      |       |       |       |      |
|------|------|--------|-------|------|-------|-------|-------|------|
| 2500 | 1159 | 126.37 | 94.00 | 0.00 | 19.50 | 12.33 | -     | 0.54 |
| 2500 | 1155 | 127.37 | 93.24 | 0.00 | 19.69 | 13.87 | -     | 0.57 |
| 2500 | 1151 | 128.37 | 92.50 | 0.00 | 19.90 | 15.36 | -     | 0.61 |
| 2500 | 1147 | 129.37 | 91.79 | 0.00 | 20.13 | 16.80 | -     | 0.64 |
| 2500 | 1144 | 130.37 | 90.75 | 0.00 | 20.61 | 17.74 | 0.60  | 0.68 |
| 2500 | 1141 | 131.37 | 89.33 | 0.00 | 21.33 | 18.15 | 1.85  | 0.71 |
| 2500 | 1138 | 132.37 | 87.94 | 0.00 | 22.06 | 18.54 | 3.09  | 0.74 |
| 2500 | 1135 | 133.37 | 86.57 | 0.00 | 22.79 | 18.91 | 4.32  | 0.79 |
| 2500 | 1133 | 134.37 | 85.23 | 0.00 | 23.51 | 19.25 | 5.54  | 0.84 |
| 2500 | 1130 | 135.37 | 83.91 | 0.00 | 24.23 | 19.57 | 6.76  | 0.89 |
| 2500 | 1127 | 136.37 | 82.60 | 0.00 | 24.95 | 19.88 | 7.98  | 0.96 |
| 2500 | 1124 | 137.37 | 81.32 | 0.00 | 25.66 | 20.16 | 9.19  | 1.03 |
| 2500 | 1121 | 138.37 | 80.06 | 0.00 | 26.36 | 20.43 | 10.39 | 1.12 |
| 2500 | 1118 | 139.37 | 78.82 | 0.00 | 27.06 | 20.68 | 11.60 | 1.21 |
| 2500 | 1115 | 140.37 | 77.59 | 0.00 | 27.74 | 20.92 | 12.80 | 1.32 |
| 2500 | 1112 | 141.37 | 76.38 | 0.00 | 28.42 | 21.14 | 14.00 | 1.43 |
| 2500 | 1109 | 142.37 | 75.20 | 0.00 | 29.08 | 21.34 | 15.20 | 1.55 |

**Cont. Appendix C: Results of Modeling for Southern Sequence of Americano do Brasil Rocks: Composition of solids (Major Oxides)**

| P (bar) | T (°C) | mass  | SiO <sub>2</sub> | TiO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | Fe <sub>2</sub> O <sub>3</sub> | Cr <sub>2</sub> O <sub>3</sub> | FeO  | MnO | MgO  | CaO | Na <sub>2</sub> O | K <sub>2</sub> O | P <sub>2</sub> O <sub>5</sub> | H <sub>2</sub> O |
|---------|--------|-------|------------------|------------------|--------------------------------|--------------------------------|--------------------------------|------|-----|------|-----|-------------------|------------------|-------------------------------|------------------|
| 2500    | 1307   | 0.74  | 40.3             | 0.0              | 0.0                            | -1.9                           | 0.0                            | 14.3 | 0.2 | 46.7 | 0.3 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1299   | 1.51  | 40.2             | 0.0              | 0.0                            | -1.0                           | 0.0                            | 13.7 | 0.2 | 46.4 | 0.3 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1291   | 2.27  | 40.2             | 0.0              | 0.0                            | -0.6                           | 0.0                            | 13.7 | 0.2 | 46.2 | 0.3 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1284   | 3.03  | 40.0             | 0.0              | 0.1                            | -0.4                           | 0.1                            | 13.8 | 0.2 | 45.8 | 0.3 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1276   | 3.78  | 39.8             | 0.0              | 0.1                            | -0.3                           | 0.3                            | 14.0 | 0.2 | 45.5 | 0.3 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1269   | 4.53  | 39.6             | 0.0              | 0.2                            | -0.2                           | 0.3                            | 14.3 | 0.2 | 45.1 | 0.3 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1261   | 5.26  | 39.5             | 0.0              | 0.2                            | -0.1                           | 0.4                            | 14.5 | 0.2 | 44.8 | 0.3 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1254   | 5.99  | 39.3             | 0.0              | 0.2                            | 0.0                            | 0.5                            | 14.8 | 0.2 | 44.5 | 0.3 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1247   | 6.70  | 39.2             | 0.0              | 0.3                            | 0.1                            | 0.5                            | 15.1 | 0.2 | 44.2 | 0.3 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1240   | 7.41  | 39.1             | 0.0              | 0.3                            | 0.1                            | 0.5                            | 15.4 | 0.2 | 43.9 | 0.3 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1233   | 8.11  | 39.0             | 0.0              | 0.3                            | 0.1                            | 0.5                            | 15.7 | 0.2 | 43.6 | 0.4 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1226   | 8.80  | 38.9             | 0.1              | 0.3                            | 0.2                            | 0.5                            | 16.0 | 0.3 | 43.3 | 0.4 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1219   | 10.00 | 41.3             | 0.1              | 0.7                            | 0.3                            | 0.5                            | 15.3 | 0.2 | 40.9 | 0.6 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1213   | 11.34 | 43.8             | 0.1              | 1.1                            | 0.5                            | 0.5                            | 14.5 | 0.2 | 38.5 | 0.8 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1207   | 12.69 | 45.7             | 0.1              | 1.4                            | 0.6                            | 0.5                            | 13.9 | 0.1 | 36.5 | 1.1 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1201   | 14.06 | 47.3             | 0.1              | 1.6                            | 0.7                            | 0.5                            | 13.5 | 0.1 | 34.8 | 1.3 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1196   | 15.43 | 48.6             | 0.1              | 1.9                            | 0.8                            | 0.5                            | 13.1 | 0.1 | 33.4 | 1.5 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1190   | 16.81 | 49.7             | 0.2              | 2.1                            | 0.9                            | 0.5                            | 12.8 | 0.1 | 32.2 | 1.7 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1185   | 18.39 | 50.6             | 0.2              | 2.3                            | 1.0                            | 0.4                            | 12.4 | 0.1 | 30.8 | 2.2 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1181   | 20.53 | 51.2             | 0.2              | 2.6                            | 1.1                            | 0.4                            | 11.9 | 0.0 | 29.0 | 3.5 | 0.0               | 0                | 0                             | 0                |
| 2500    | 1177   | 22.66 | 51.6             | 0.3              | 2.9                            | 1.2                            | 0.4                            | 11.5 | 0.0 | 27.5 | 4.6 | 0.1               | 0                | 0                             | 0                |
| 2500    | 1174   | 24.77 | 52.0             | 0.3              | 3.2                            | 1.3                            | 0.4                            | 11.1 | 0.0 | 26.2 | 5.4 | 0.1               | 0                | 0                             | 0                |
| 2500    | 1170   | 26.86 | 52.3             | 0.3              | 3.5                            | 1.4                            | 0.3                            | 10.8 | 0.0 | 25.2 | 6.1 | 0.1               | 0                | 0                             | 0                |
| 2500    | 1166   | 28.77 | 52.2             | 0.4              | 3.6                            | 1.4                            | 0.3                            | 10.8 | 0.0 | 24.5 | 6.7 | 0.1               | 0                | 0                             | 0                |
| 2500    | 1163   | 30.58 | 52.0             | 0.4              | 3.8                            | 1.5                            | 0.3                            | 10.8 | 0.0 | 24.0 | 7.2 | 0.1               | 0                | 0                             | 0                |
| 2500    | 1159   | 32.37 | 51.8             | 0.4              | 3.9                            | 1.5                            | 0.3                            | 10.9 | 0.0 | 23.5 | 7.6 | 0.1               | 0                | 0                             | 0                |

|      |      |       |      |     |      |     |     |      |     |      |     |     |   |   |   |
|------|------|-------|------|-----|------|-----|-----|------|-----|------|-----|-----|---|---|---|
| 2500 | 1155 | 34.13 | 51.6 | 0.5 | 4.0  | 1.6 | 0.3 | 10.9 | 0.0 | 23.0 | 8.0 | 0.1 | 0 | 0 | 0 |
| 2500 | 1151 | 35.86 | 51.4 | 0.5 | 4.1  | 1.6 | 0.3 | 11.0 | 0.0 | 22.6 | 8.3 | 0.1 | 0 | 0 | 0 |
| 2500 | 1147 | 37.57 | 51.2 | 0.5 | 4.2  | 1.7 | 0.3 | 11.1 | 0.0 | 22.2 | 8.6 | 0.1 | 0 | 0 | 0 |
| 2500 | 1144 | 39.62 | 51.1 | 0.5 | 4.7  | 1.7 | 0.3 | 11.0 | 0.0 | 21.7 | 8.8 | 0.2 | 0 | 0 | 0 |
| 2500 | 1141 | 42.04 | 51.0 | 0.6 | 5.5  | 1.7 | 0.3 | 10.9 | 0.0 | 20.9 | 9.0 | 0.3 | 0 | 0 | 0 |
| 2500 | 1138 | 44.43 | 51.0 | 0.6 | 6.1  | 1.6 | 0.2 | 10.7 | 0.0 | 20.3 | 9.1 | 0.4 | 0 | 0 | 0 |
| 2500 | 1135 | 46.79 | 50.9 | 0.6 | 6.7  | 1.6 | 0.2 | 10.6 | 0.0 | 19.7 | 9.2 | 0.5 | 0 | 0 | 0 |
| 2500 | 1133 | 49.14 | 50.9 | 0.6 | 7.2  | 1.6 | 0.2 | 10.6 | 0.0 | 19.1 | 9.2 | 0.5 | 0 | 0 | 0 |
| 2500 | 1130 | 51.46 | 50.8 | 0.6 | 7.7  | 1.6 | 0.2 | 10.5 | 0.0 | 18.6 | 9.3 | 0.6 | 0 | 0 | 0 |
| 2500 | 1127 | 53.76 | 50.8 | 0.6 | 8.1  | 1.6 | 0.2 | 10.5 | 0.0 | 18.2 | 9.3 | 0.7 | 0 | 0 | 0 |
| 2500 | 1124 | 56.04 | 50.7 | 0.6 | 8.5  | 1.6 | 0.2 | 10.4 | 0.0 | 17.8 | 9.4 | 0.7 | 0 | 0 | 0 |
| 2500 | 1121 | 58.31 | 50.7 | 0.7 | 8.9  | 1.6 | 0.2 | 10.4 | 0.0 | 17.4 | 9.4 | 0.8 | 0 | 0 | 0 |
| 2500 | 1118 | 60.55 | 50.6 | 0.7 | 9.2  | 1.6 | 0.2 | 10.4 | 0.0 | 17.0 | 9.4 | 0.9 | 0 | 0 | 0 |
| 2500 | 1115 | 62.77 | 50.6 | 0.7 | 9.5  | 1.6 | 0.2 | 10.4 | 0.0 | 16.6 | 9.4 | 0.9 | 0 | 0 | 0 |
| 2500 | 1112 | 64.98 | 50.5 | 0.7 | 9.7  | 1.6 | 0.2 | 10.4 | 0.0 | 16.3 | 9.4 | 1.0 | 0 | 0 | 0 |
| 2500 | 1109 | 67.17 | 50.5 | 0.8 | 10.0 | 1.6 | 0.2 | 10.4 | 0.0 | 16.0 | 9.4 | 1.0 | 0 | 0 | 0 |



**Cont. Appendix C: Results of Modeling for Southern Sequence of Americano do Brasil Rocks: Composition of solids (Traces)**

| P (bar) | T (°C) | mass  | Ba   | Rb   | Sr   | Zr   | Hf   | Nb   | Ta   | Y    | La   | Ce   | Pr   | Nd   |
|---------|--------|-------|------|------|------|------|------|------|------|------|------|------|------|------|
| 2500    | 1307   | 0.74  | 0.06 | 0.00 | 0.05 | 1.06 | 0.00 | 0.04 | 0.01 | 0.08 | 0.01 | 0.01 | 0.00 | 0.02 |
| 2500    | 1299   | 1.51  | 0.06 | 0.00 | 0.05 | 1.07 | 0.00 | 0.04 | 0.01 | 0.09 | 0.01 | 0.01 | 0.00 | 0.02 |
| 2500    | 1291   | 2.27  | 0.06 | 0.00 | 0.06 | 1.08 | 0.00 | 0.04 | 0.01 | 0.09 | 0.01 | 0.01 | 0.00 | 0.02 |
| 2500    | 1284   | 3.03  | 0.06 | 0.00 | 0.06 | 1.08 | 0.00 | 0.04 | 0.01 | 0.09 | 0.01 | 0.02 | 0.00 | 0.02 |
| 2500    | 1276   | 3.78  | 0.06 | 0.00 | 0.06 | 1.09 | 0.00 | 0.04 | 0.01 | 0.09 | 0.01 | 0.02 | 0.00 | 0.02 |
| 2500    | 1269   | 4.53  | 0.06 | 0.00 | 0.06 | 1.09 | 0.00 | 0.04 | 0.01 | 0.09 | 0.01 | 0.02 | 0.00 | 0.02 |
| 2500    | 1261   | 5.26  | 0.06 | 0.00 | 0.06 | 1.10 | 0.00 | 0.04 | 0.01 | 0.09 | 0.01 | 0.02 | 0.00 | 0.02 |
| 2500    | 1254   | 5.99  | 0.07 | 0.00 | 0.06 | 1.10 | 0.00 | 0.04 | 0.01 | 0.09 | 0.01 | 0.02 | 0.00 | 0.02 |
| 2500    | 1247   | 6.70  | 0.07 | 0.00 | 0.06 | 1.11 | 0.00 | 0.04 | 0.01 | 0.09 | 0.01 | 0.02 | 0.00 | 0.02 |
| 2500    | 1240   | 7.41  | 0.07 | 0.00 | 0.06 | 1.12 | 0.00 | 0.04 | 0.01 | 0.09 | 0.01 | 0.02 | 0.00 | 0.02 |
| 2500    | 1233   | 8.11  | 0.07 | 0.00 | 0.06 | 1.12 | 0.00 | 0.04 | 0.01 | 0.09 | 0.01 | 0.02 | 0.00 | 0.02 |
| 2500    | 1226   | 8.80  | 0.07 | 0.00 | 0.06 | 1.13 | 0.00 | 0.04 | 0.01 | 0.09 | 0.01 | 0.02 | 0.00 | 0.02 |
| 2500    | 1219   | 10.00 | 0.06 | 0.00 | 0.42 | 1.51 | 0.01 | 0.04 | 0.01 | 0.09 | 0.01 | 0.03 | 0.01 | 0.04 |
| 2500    | 1213   | 11.34 | 0.06 | 0.00 | 0.80 | 1.92 | 0.01 | 0.04 | 0.01 | 0.09 | 0.02 | 0.05 | 0.01 | 0.06 |
| 2500    | 1207   | 12.69 | 0.05 | 0.00 | 1.12 | 2.25 | 0.02 | 0.04 | 0.01 | 0.09 | 0.02 | 0.06 | 0.01 | 0.07 |
| 2500    | 1201   | 14.06 | 0.05 | 0.00 | 1.39 | 2.54 | 0.02 | 0.04 | 0.01 | 0.09 | 0.02 | 0.06 | 0.01 | 0.09 |
| 2500    | 1196   | 15.43 | 0.04 | 0.00 | 1.63 | 2.79 | 0.02 | 0.04 | 0.01 | 0.09 | 0.02 | 0.07 | 0.02 | 0.10 |
| 2500    | 1190   | 16.81 | 0.04 | 0.00 | 1.84 | 3.01 | 0.03 | 0.04 | 0.01 | 0.09 | 0.03 | 0.08 | 0.02 | 0.11 |
| 2500    | 1185   | 18.39 | 0.04 | 0.00 | 2.45 | 3.45 | 0.05 | 0.05 | 0.01 | 0.42 | 0.06 | 0.21 | 0.04 | 0.27 |
| 2500    | 1181   | 20.53 | 0.03 | 0.00 | 4.04 | 4.43 | 0.12 | 0.06 | 0.01 | 1.53 | 0.19 | 0.63 | 0.12 | 0.81 |
| 2500    | 1177   | 22.66 | 0.03 | 0.01 | 5.34 | 5.26 | 0.17 | 0.07 | 0.01 | 2.44 | 0.29 | 0.98 | 0.19 | 1.26 |
| 2500    | 1174   | 24.77 | 0.03 | 0.01 | 6.44 | 5.97 | 0.22 | 0.08 | 0.01 | 3.19 | 0.38 | 1.27 | 0.25 | 1.63 |
| 2500    | 1170   | 26.86 | 0.02 | 0.01 | 7.37 | 6.59 | 0.26 | 0.08 | 0.01 | 3.83 | 0.46 | 1.53 | 0.30 | 1.96 |
| 2500    | 1166   | 28.77 | 0.02 | 0.01 | 8.15 | 7.10 | 0.30 | 0.09 | 0.01 | 4.41 | 0.53 | 1.77 | 0.35 | 2.26 |

| P (bar) | T (°C) | mass  | Ba    | Rb   | Sr     | Zr   | Hf   | Nb   | Ta   | Y    | La   | Ce   | Pr   | Nd   |
|---------|--------|-------|-------|------|--------|------|------|------|------|------|------|------|------|------|
| 2500    | 1163   | 30.58 | 0.02  | 0.01 | 8.82   | 7.55 | 0.33 | 0.09 | 0.01 | 4.94 | 0.60 | 1.98 | 0.39 | 2.53 |
| 2500    | 1159   | 32.37 | 0.02  | 0.01 | 9.41   | 7.95 | 0.36 | 0.10 | 0.01 | 5.40 | 0.66 | 2.18 | 0.43 | 2.78 |
| 2500    | 1155   | 34.13 | 0.02  | 0.01 | 9.93   | 8.33 | 0.39 | 0.10 | 0.01 | 5.82 | 0.71 | 2.37 | 0.47 | 3.00 |
| 2500    | 1151   | 35.86 | 0.02  | 0.01 | 10.40  | 8.67 | 0.41 | 0.11 | 0.01 | 6.19 | 0.76 | 2.53 | 0.50 | 3.21 |
| 2500    | 1147   | 37.57 | 0.02  | 0.01 | 10.81  | 8.99 | 0.43 | 0.11 | 0.02 | 6.52 | 0.81 | 2.69 | 0.53 | 3.40 |
| 2500    | 1144   | 39.62 | 2.10  | 0.01 | 25.83  | 9.12 | 0.44 | 0.11 | 0.02 | 6.62 | 0.87 | 2.81 | 0.55 | 3.49 |
| 2500    | 1141   | 42.04 | 6.17  | 0.01 | 53.84  | 9.07 | 0.43 | 0.11 | 0.02 | 6.49 | 0.93 | 2.91 | 0.55 | 3.48 |
| 2500    | 1138   | 44.43 | 9.93  | 0.02 | 78.50  | 9.03 | 0.43 | 0.12 | 0.02 | 6.38 | 0.99 | 3.00 | 0.56 | 3.49 |
| 2500    | 1135   | 46.79 | 13.43 | 0.02 | 100.40 | 9.02 | 0.43 | 0.12 | 0.01 | 6.28 | 1.05 | 3.09 | 0.57 | 3.49 |
| 2500    | 1133   | 49.14 | 16.71 | 0.03 | 119.96 | 9.01 | 0.42 | 0.12 | 0.01 | 6.19 | 1.11 | 3.17 | 0.57 | 3.50 |
| 2500    | 1130   | 51.46 | 19.82 | 0.03 | 137.54 | 9.02 | 0.42 | 0.12 | 0.01 | 6.11 | 1.16 | 3.26 | 0.58 | 3.51 |
| 2500    | 1127   | 53.76 | 22.78 | 0.03 | 153.44 | 9.03 | 0.42 | 0.12 | 0.01 | 6.04 | 1.21 | 3.34 | 0.59 | 3.52 |
| 2500    | 1124   | 56.04 | 25.61 | 0.03 | 167.88 | 9.05 | 0.42 | 0.12 | 0.01 | 5.98 | 1.26 | 3.42 | 0.59 | 3.53 |
| 2500    | 1121   | 58.31 | 28.34 | 0.04 | 181.07 | 9.08 | 0.42 | 0.12 | 0.01 | 5.93 | 1.31 | 3.51 | 0.60 | 3.55 |
| 2500    | 1118   | 60.55 | 30.97 | 0.04 | 193.17 | 9.12 | 0.42 | 0.12 | 0.01 | 5.88 | 1.36 | 3.59 | 0.61 | 3.57 |
| 2500    | 1115   | 62.77 | 33.53 | 0.04 | 204.31 | 9.16 | 0.42 | 0.13 | 0.01 | 5.84 | 1.41 | 3.67 | 0.62 | 3.60 |
| 2500    | 1112   | 64.98 | 36.02 | 0.05 | 214.61 | 9.20 | 0.42 | 0.13 | 0.01 | 5.81 | 1.46 | 3.76 | 0.63 | 3.62 |
| 2500    | 1109   | 67.17 | 38.46 | 0.05 | 224.16 | 9.26 | 0.42 | 0.13 | 0.01 | 5.78 | 1.51 | 3.84 | 0.63 | 3.65 |

| P (bar) | T (°C) | Sm   | Eu   | Gd   | Tb   | Dy   | Ho   | Er   | Tm   | Yb   | Lu   | H <sub>2</sub> O |
|---------|--------|------|------|------|------|------|------|------|------|------|------|------------------|
| 2500    | 1307   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.38             |
| 2500    | 1299   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.40             |
| 2500    | 1291   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.41             |
| 2500    | 1284   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.42             |
| 2500    | 1276   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.42             |
| 2500    | 1269   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.43             |
| 2500    | 1261   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.44             |
| 2500    | 1254   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.45             |
| 2500    | 1247   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.46             |
| 2500    | 1240   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.46             |
| 2500    | 1233   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.47             |
| 2500    | 1226   | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.48             |
| 2500    | 1219   | 0.01 | 0.01 | 0.02 | 0.00 | 0.02 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 1.80             |
| 2500    | 1213   | 0.02 | 0.01 | 0.03 | 0.00 | 0.03 | 0.01 | 0.02 | 0.00 | 0.03 | 0.00 | 2.16             |
| 2500    | 1207   | 0.03 | 0.01 | 0.04 | 0.01 | 0.04 | 0.01 | 0.03 | 0.00 | 0.03 | 0.01 | 2.46             |
| 2500    | 1201   | 0.03 | 0.01 | 0.04 | 0.01 | 0.05 | 0.01 | 0.03 | 0.01 | 0.04 | 0.01 | 2.72             |
| 2500    | 1196   | 0.03 | 0.01 | 0.05 | 0.01 | 0.06 | 0.01 | 0.04 | 0.01 | 0.05 | 0.01 | 2.96             |
| 2500    | 1190   | 0.04 | 0.02 | 0.06 | 0.01 | 0.07 | 0.01 | 0.04 | 0.01 | 0.05 | 0.01 | 3.18             |
| 2500    | 1185   | 0.10 | 0.04 | 0.13 | 0.02 | 0.14 | 0.03 | 0.08 | 0.01 | 0.08 | 0.01 | 3.49             |
| 2500    | 1181   | 0.30 | 0.12 | 0.37 | 0.06 | 0.37 | 0.07 | 0.19 | 0.03 | 0.17 | 0.03 | 4.07             |
| 2500    | 1177   | 0.47 | 0.18 | 0.57 | 0.09 | 0.56 | 0.11 | 0.28 | 0.04 | 0.24 | 0.04 | 4.59             |
| 2500    | 1174   | 0.61 | 0.24 | 0.74 | 0.12 | 0.72 | 0.14 | 0.35 | 0.05 | 0.30 | 0.05 | 5.05             |
| 2500    | 1170   | 0.73 | 0.28 | 0.88 | 0.14 | 0.86 | 0.16 | 0.42 | 0.05 | 0.35 | 0.05 | 5.48             |
| 2500    | 1166   | 0.84 | 0.32 | 1.01 | 0.16 | 0.98 | 0.18 | 0.47 | 0.06 | 0.39 | 0.06 | 6.09             |
| 2500    | 1163   | 0.93 | 0.36 | 1.12 | 0.18 | 1.08 | 0.20 | 0.52 | 0.07 | 0.43 | 0.06 | 6.40             |
| 2500    | 1159   | 1.02 | 0.40 | 1.23 | 0.19 | 1.18 | 0.22 | 0.57 | 0.07 | 0.47 | 0.07 | 6.68             |
| 2500    | 1155   | 1.10 | 0.43 | 1.32 | 0.21 | 1.26 | 0.24 | 0.61 | 0.08 | 0.50 | 0.07 | 6.95             |

| P (bar) | T (°C) | Sm   | Eu   | Gd   | Tb   | Dy   | Ho   | Er   | Tm   | Yb   | Lu   | H <sub>2</sub> O |
|---------|--------|------|------|------|------|------|------|------|------|------|------|------------------|
| 2500    | 1151   | 1.17 | 0.45 | 1.40 | 0.22 | 1.34 | 0.25 | 0.65 | 0.08 | 0.53 | 0.08 | 7.21             |
| 2500    | 1147   | 1.24 | 0.48 | 1.48 | 0.23 | 1.41 | 0.26 | 0.68 | 0.09 | 0.55 | 0.08 | 7.45             |
| 2500    | 1144   | 1.26 | 0.49 | 1.50 | 0.23 | 1.43 | 0.27 | 0.69 | 0.09 | 0.56 | 0.08 | 7.67             |
| 2500    | 1141   | 1.25 | 0.48 | 1.48 | 0.23 | 1.40 | 0.26 | 0.67 | 0.09 | 0.55 | 0.08 | 7.87             |
| 2500    | 1138   | 1.23 | 0.47 | 1.46 | 0.23 | 1.38 | 0.26 | 0.66 | 0.09 | 0.54 | 0.08 | 8.08             |
| 2500    | 1135   | 1.22 | 0.47 | 1.44 | 0.22 | 1.35 | 0.25 | 0.65 | 0.08 | 0.53 | 0.08 | 8.29             |
| 2500    | 1133   | 1.21 | 0.47 | 1.43 | 0.22 | 1.34 | 0.25 | 0.64 | 0.08 | 0.52 | 0.08 | 8.51             |
| 2500    | 1130   | 1.21 | 0.46 | 1.41 | 0.22 | 1.32 | 0.25 | 0.63 | 0.08 | 0.52 | 0.08 | 8.74             |
| 2500    | 1127   | 1.20 | 0.46 | 1.40 | 0.22 | 1.30 | 0.24 | 0.63 | 0.08 | 0.51 | 0.07 | 8.97             |
| 2500    | 1124   | 1.19 | 0.46 | 1.39 | 0.21 | 1.29 | 0.24 | 0.62 | 0.08 | 0.50 | 0.07 | 9.21             |
| 2500    | 1121   | 1.19 | 0.45 | 1.38 | 0.21 | 1.28 | 0.24 | 0.61 | 0.08 | 0.50 | 0.07 | 9.45             |
| 2500    | 1118   | 1.19 | 0.45 | 1.37 | 0.21 | 1.27 | 0.24 | 0.61 | 0.08 | 0.50 | 0.07 | 9.70             |
| 2500    | 1115   | 1.19 | 0.45 | 1.37 | 0.21 | 1.26 | 0.23 | 0.60 | 0.08 | 0.49 | 0.07 | 9.95             |
| 2500    | 1112   | 1.19 | 0.45 | 1.37 | 0.21 | 1.25 | 0.23 | 0.60 | 0.08 | 0.49 | 0.07 | 10.21            |
| 2500    | 1109   | 1.19 | 0.45 | 1.36 | 0.21 | 1.25 | 0.23 | 0.60 | 0.08 | 0.49 | 0.07 | 10.47            |

**Cont. Appendix C: Results of Modeling for Southern Sequence of Americano do Brasil Rocks: Composition of Liquid (Major Oxides)**

| P(bar) | T (°C) | mass  | SiO <sub>2</sub> | TiO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | Fe <sub>2</sub> O <sub>3</sub> | Cr <sub>2</sub> O <sub>3</sub> | FeO   | MnO  | MgO   | CaO  | Na <sub>2</sub> O | K <sub>2</sub> O | P <sub>2</sub> O <sub>5</sub> | H <sub>2</sub> O |
|--------|--------|-------|------------------|------------------|--------------------------------|--------------------------------|--------------------------------|-------|------|-------|------|-------------------|------------------|-------------------------------|------------------|
| 2500   | 1314.7 | 100.4 | 47.4             | 1.81             | 12.1                           | 2.22                           | 0.120                          | 11.31 | 0.17 | 12.30 | 9.35 | 2.11              | 0.43             | 0.19                          | 0.50             |
| 2500   | 1306.7 | 100.6 | 47.6             | 1.81             | 12.2                           | 2.22                           | 0.119                          | 11.24 | 0.17 | 11.95 | 9.38 | 2.15              | 0.43             | 0.19                          | 0.51             |
| 2500   | 1298.9 | 100.9 | 47.8             | 1.81             | 12.4                           | 2.21                           | 0.119                          | 11.16 | 0.17 | 11.59 | 9.41 | 2.19              | 0.44             | 0.19                          | 0.52             |
| 2500   | 1291.2 | 101.1 | 48.0             | 1.81             | 12.5                           | 2.21                           | 0.119                          | 11.09 | 0.17 | 11.24 | 9.44 | 2.22              | 0.45             | 0.19                          | 0.53             |
| 2500   | 1283.6 | 101.3 | 48.3             | 1.81             | 12.6                           | 2.20                           | 0.116                          | 11.00 | 0.16 | 10.91 | 9.47 | 2.26              | 0.45             | 0.19                          | 0.54             |
| 2500   | 1276.1 | 101.6 | 48.5             | 1.81             | 12.8                           | 2.19                           | 0.109                          | 10.92 | 0.16 | 10.58 | 9.50 | 2.29              | 0.46             | 0.19                          | 0.55             |
| 2500   | 1268.7 | 101.8 | 48.7             | 1.81             | 12.9                           | 2.19                           | 0.103                          | 10.82 | 0.16 | 10.26 | 9.52 | 2.33              | 0.47             | 0.19                          | 0.55             |
| 2500   | 1261.3 | 102.1 | 48.9             | 1.81             | 13.0                           | 2.18                           | 0.097                          | 10.73 | 0.16 | 9.94  | 9.55 | 2.36              | 0.47             | 0.19                          | 0.56             |
| 2500   | 1254.0 | 102.4 | 49.2             | 1.81             | 13.1                           | 2.17                           | 0.091                          | 10.63 | 0.16 | 9.64  | 9.58 | 2.40              | 0.48             | 0.19                          | 0.57             |
| 2500   | 1246.8 | 102.7 | 49.4             | 1.81             | 13.2                           | 2.16                           | 0.086                          | 10.53 | 0.16 | 9.35  | 9.60 | 2.43              | 0.49             | 0.19                          | 0.58             |
| 2500   | 1239.7 | 103.0 | 49.6             | 1.81             | 13.4                           | 2.15                           | 0.081                          | 10.42 | 0.16 | 9.06  | 9.62 | 2.47              | 0.49             | 0.19                          | 0.59             |
| 2500   | 1232.7 | 103.3 | 49.8             | 1.81             | 13.5                           | 2.14                           | 0.075                          | 10.31 | 0.15 | 8.78  | 9.65 | 2.50              | 0.50             | 0.19                          | 0.60             |
| 2500   | 1225.7 | 103.6 | 50.0             | 1.80             | 13.6                           | 2.13                           | 0.070                          | 10.20 | 0.15 | 8.51  | 9.67 | 2.53              | 0.50             | 0.19                          | 0.60             |
| 2500   | 1219.4 | 103.4 | 50.1             | 1.81             | 13.7                           | 2.12                           | 0.066                          | 10.15 | 0.15 | 8.28  | 9.71 | 2.58              | 0.51             | 0.19                          | 0.61             |
| 2500   | 1213.4 | 103.0 | 50.1             | 1.82             | 13.9                           | 2.10                           | 0.061                          | 10.12 | 0.16 | 8.07  | 9.76 | 2.63              | 0.52             | 0.20                          | 0.63             |
| 2500   | 1207.4 | 102.7 | 50.0             | 1.82             | 14.0                           | 2.09                           | 0.057                          | 10.09 | 0.16 | 7.86  | 9.81 | 2.68              | 0.53             | 0.20                          | 0.64             |
| 2500   | 1201.5 | 102.3 | 50.0             | 1.83             | 14.2                           | 2.07                           | 0.053                          | 10.05 | 0.16 | 7.65  | 9.86 | 2.73              | 0.54             | 0.20                          | 0.65             |
| 2500   | 1195.6 | 101.9 | 50.0             | 1.84             | 14.3                           | 2.06                           | 0.049                          | 10.01 | 0.17 | 7.45  | 9.90 | 2.78              | 0.55             | 0.20                          | 0.66             |
| 2500   | 1189.8 | 101.6 | 50.0             | 1.85             | 14.5                           | 2.04                           | 0.046                          | 9.97  | 0.17 | 7.26  | 9.94 | 2.83              | 0.56             | 0.20                          | 0.67             |
| 2500   | 1184.6 | 101.0 | 50.0             | 1.86             | 14.7                           | 2.02                           | 0.042                          | 9.94  | 0.17 | 7.07  | 9.93 | 2.88              | 0.57             | 0.20                          | 0.69             |
| 2500   | 1181.0 | 99.8  | 50.0             | 1.87             | 14.9                           | 2.00                           | 0.040                          | 9.95  | 0.18 | 6.88  | 9.78 | 2.95              | 0.59             | 0.21                          | 0.71             |
| 2500   | 1177.4 | 98.7  | 50.0             | 1.88             | 15.1                           | 1.98                           | 0.037                          | 9.96  | 0.18 | 6.70  | 9.63 | 3.03              | 0.60             | 0.21                          | 0.72             |
| 2500   | 1173.8 | 97.6  | 50.0             | 1.90             | 15.3                           | 1.95                           | 0.034                          | 9.97  | 0.19 | 6.53  | 9.48 | 3.10              | 0.62             | 0.21                          | 0.74             |
| 2500   | 1170.1 | 96.5  | 50.0             | 1.91             | 15.5                           | 1.93                           | 0.032                          | 9.97  | 0.20 | 6.35  | 9.33 | 3.17              | 0.63             | 0.22                          | 0.76             |
| 2500   | 1166.4 | 95.6  | 50.2             | 1.91             | 15.7                           | 1.90                           | 0.030                          | 9.92  | 0.20 | 6.14  | 9.18 | 3.24              | 0.65             | 0.22                          | 0.78             |
| 2500   | 1162.6 | 94.8  | 50.3             | 1.92             | 15.9                           | 1.87                           | 0.028                          | 9.84  | 0.20 | 5.92  | 9.03 | 3.31              | 0.66             | 0.22                          | 0.80             |

|      |        |      |      |      |      |      |       |      |      |      |      |      |      |      |      |
|------|--------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|
| 2500 | 1158.8 | 94.0 | 50.5 | 1.92 | 16.1 | 1.84 | 0.025 | 9.75 | 0.20 | 5.71 | 8.88 | 3.38 | 0.67 | 0.23 | 0.81 |
| 2500 | 1155.0 | 93.2 | 50.7 | 1.92 | 16.2 | 1.81 | 0.023 | 9.66 | 0.21 | 5.50 | 8.72 | 3.45 | 0.69 | 0.23 | 0.83 |
| 2500 | 1151.2 | 92.5 | 50.9 | 1.92 | 16.4 | 1.77 | 0.022 | 9.56 | 0.21 | 5.30 | 8.57 | 3.51 | 0.70 | 0.23 | 0.85 |
| 2500 | 1147.4 | 91.8 | 51.1 | 1.91 | 16.6 | 1.74 | 0.020 | 9.45 | 0.21 | 5.10 | 8.43 | 3.58 | 0.72 | 0.23 | 0.87 |
| 2500 | 1144.1 | 90.7 | 51.3 | 1.92 | 16.7 | 1.72 | 0.019 | 9.39 | 0.22 | 4.93 | 8.30 | 3.64 | 0.73 | 0.24 | 0.89 |
| 2500 | 1141.2 | 89.3 | 51.5 | 1.94 | 16.6 | 1.71 | 0.018 | 9.37 | 0.22 | 4.80 | 8.19 | 3.69 | 0.75 | 0.24 | 0.91 |
| 2500 | 1138.4 | 87.9 | 51.7 | 1.96 | 16.6 | 1.71 | 0.017 | 9.34 | 0.22 | 4.66 | 8.08 | 3.75 | 0.77 | 0.25 | 0.94 |
| 2500 | 1135.5 | 86.6 | 51.9 | 1.97 | 16.6 | 1.70 | 0.016 | 9.31 | 0.23 | 4.53 | 7.98 | 3.80 | 0.79 | 0.25 | 0.97 |
| 2500 | 1132.6 | 85.2 | 52.1 | 1.98 | 16.5 | 1.69 | 0.015 | 9.27 | 0.23 | 4.40 | 7.88 | 3.85 | 0.81 | 0.26 | 0.99 |
| 2500 | 1129.7 | 83.9 | 52.3 | 2.00 | 16.5 | 1.67 | 0.014 | 9.22 | 0.24 | 4.27 | 7.78 | 3.90 | 0.83 | 0.26 | 1.02 |
| 2500 | 1126.8 | 82.6 | 52.5 | 2.00 | 16.4 | 1.66 | 0.013 | 9.17 | 0.24 | 4.15 | 7.68 | 3.95 | 0.85 | 0.27 | 1.05 |
| 2500 | 1123.9 | 81.3 | 52.8 | 2.01 | 16.4 | 1.64 | 0.012 | 9.10 | 0.25 | 4.03 | 7.58 | 4.00 | 0.87 | 0.27 | 1.08 |
| 2500 | 1120.9 | 80.1 | 53.0 | 2.01 | 16.4 | 1.62 | 0.011 | 9.03 | 0.25 | 3.91 | 7.49 | 4.05 | 0.89 | 0.28 | 1.11 |
| 2500 | 1118.0 | 78.8 | 53.2 | 2.01 | 16.3 | 1.59 | 0.010 | 8.95 | 0.26 | 3.79 | 7.39 | 4.09 | 0.91 | 0.28 | 1.14 |
| 2500 | 1115.1 | 77.6 | 53.5 | 2.01 | 16.3 | 1.56 | 0.009 | 8.86 | 0.26 | 3.68 | 7.30 | 4.14 | 0.94 | 0.29 | 1.17 |
| 2500 | 1112.2 | 76.4 | 53.7 | 2.01 | 16.3 | 1.54 | 0.008 | 8.76 | 0.27 | 3.57 | 7.21 | 4.18 | 0.96 | 0.29 | 1.20 |
| 2500 | 1109.2 | 75.2 | 54.0 | 2.00 | 16.2 | 1.50 | 0.008 | 8.65 | 0.27 | 3.46 | 7.12 | 4.23 | 0.98 | 0.30 | 1.23 |

**Cont. Appendix C:** *Results of Modeling for Southern Sequence of Americano do Brasil Rocks: Composition of Liquid (Traces)*

| P(bar) | T (°C) | mass   | Ba    | Rb   | Sr    | Zr     | Hf   | Nb   | Ta   | Y     |
|--------|--------|--------|-------|------|-------|--------|------|------|------|-------|
| 2500   | 1314.7 | 100.37 | 192.0 | 7.02 | 277.1 | 105.11 | 3.00 | 8.33 | 1.19 | 16.92 |
| 2500   | 1306.7 | 100.63 | 195.4 | 7.09 | 281.2 | 105.98 | 3.03 | 8.33 | 1.19 | 16.97 |
| 2500   | 1298.9 | 100.86 | 198.8 | 7.16 | 285.4 | 106.88 | 3.05 | 8.33 | 1.19 | 17.02 |
| 2500   | 1291.2 | 101.10 | 202.2 | 7.22 | 289.5 | 107.77 | 3.08 | 8.32 | 1.18 | 17.06 |
| 2500   | 1283.6 | 101.34 | 205.6 | 7.29 | 293.6 | 108.65 | 3.10 | 8.32 | 1.18 | 17.11 |
| 2500   | 1276.1 | 101.59 | 208.9 | 7.36 | 297.6 | 109.52 | 3.13 | 8.32 | 1.18 | 17.16 |
| 2500   | 1268.7 | 101.84 | 212.3 | 7.43 | 301.7 | 110.37 | 3.15 | 8.31 | 1.18 | 17.20 |
| 2500   | 1261.3 | 102.10 | 215.5 | 7.49 | 305.6 | 111.22 | 3.18 | 8.31 | 1.18 | 17.24 |
| 2500   | 1254.0 | 102.38 | 218.8 | 7.56 | 309.5 | 112.04 | 3.20 | 8.30 | 1.17 | 17.29 |
| 2500   | 1246.8 | 102.66 | 222.0 | 7.62 | 313.4 | 112.86 | 3.23 | 8.29 | 1.17 | 17.33 |
| 2500   | 1239.7 | 102.95 | 225.2 | 7.69 | 317.2 | 113.65 | 3.25 | 8.29 | 1.17 | 17.36 |
| 2500   | 1232.7 | 103.26 | 228.3 | 7.75 | 321.0 | 114.44 | 3.27 | 8.28 | 1.17 | 17.40 |
| 2500   | 1225.7 | 103.56 | 231.4 | 7.81 | 324.7 | 115.21 | 3.29 | 8.27 | 1.16 | 17.43 |
| 2500   | 1219.4 | 103.37 | 235.6 | 7.91 | 330.0 | 116.50 | 3.33 | 8.30 | 1.17 | 17.55 |
| 2500   | 1213.4 | 103.02 | 240.2 | 8.02 | 335.8 | 117.95 | 3.37 | 8.34 | 1.17 | 17.70 |
| 2500   | 1207.4 | 102.67 | 244.8 | 8.13 | 341.6 | 119.42 | 3.42 | 8.39 | 1.18 | 17.84 |
| 2500   | 1201.5 | 102.31 | 249.5 | 8.24 | 347.5 | 120.91 | 3.46 | 8.44 | 1.18 | 17.99 |
| 2500   | 1195.6 | 101.94 | 254.2 | 8.36 | 353.5 | 122.42 | 3.50 | 8.48 | 1.19 | 18.15 |
| 2500   | 1189.8 | 101.56 | 259.0 | 8.48 | 359.5 | 123.94 | 3.55 | 8.53 | 1.19 | 18.30 |
| 2500   | 1184.6 | 100.98 | 264.4 | 8.61 | 366.2 | 125.67 | 3.60 | 8.59 | 1.20 | 18.43 |
| 2500   | 1181.0 | 99.83  | 271.4 | 8.80 | 374.9 | 128.00 | 3.66 | 8.71 | 1.21 | 18.50 |
| 2500   | 1177.4 | 98.70  | 278.4 | 8.98 | 383.7 | 130.35 | 3.72 | 8.82 | 1.23 | 18.56 |
| 2500   | 1173.8 | 97.59  | 285.6 | 9.18 | 392.7 | 132.73 | 3.78 | 8.93 | 1.24 | 18.62 |
| 2500   | 1170.1 | 96.51  | 292.9 | 9.37 | 401.7 | 135.13 | 3.84 | 9.05 | 1.26 | 18.68 |
| 2500   | 1166.4 | 95.59  | 299.7 | 9.55 | 410.2 | 137.34 | 3.89 | 9.15 | 1.27 | 18.70 |
| 2500   | 1162.6 | 94.78  | 306.4 | 9.72 | 418.5 | 139.46 | 3.94 | 9.24 | 1.28 | 18.70 |

|      |        |       |       |       |       |        |      |       |      |       |
|------|--------|-------|-------|-------|-------|--------|------|-------|------|-------|
| 2500 | 1158.8 | 94.00 | 313.2 | 9.90  | 426.8 | 141.58 | 4.00 | 9.33  | 1.29 | 18.70 |
| 2500 | 1155.0 | 93.24 | 319.9 | 10.07 | 435.1 | 143.69 | 4.05 | 9.42  | 1.30 | 18.69 |
| 2500 | 1151.2 | 92.50 | 326.7 | 10.24 | 443.4 | 145.80 | 4.10 | 9.51  | 1.31 | 18.68 |
| 2500 | 1147.4 | 91.79 | 333.5 | 10.42 | 451.8 | 147.90 | 4.15 | 9.60  | 1.33 | 18.67 |
| 2500 | 1144.1 | 90.75 | 340.7 | 10.63 | 455.5 | 150.62 | 4.22 | 9.73  | 1.34 | 18.80 |
| 2500 | 1141.2 | 89.33 | 348.5 | 10.90 | 454.3 | 154.09 | 4.32 | 9.90  | 1.36 | 19.08 |
| 2500 | 1138.4 | 87.94 | 356.4 | 11.17 | 453.1 | 157.61 | 4.41 | 10.07 | 1.39 | 19.36 |
| 2500 | 1135.5 | 86.57 | 364.4 | 11.44 | 451.9 | 161.20 | 4.51 | 10.25 | 1.41 | 19.65 |
| 2500 | 1132.6 | 85.23 | 372.5 | 11.72 | 450.6 | 164.86 | 4.61 | 10.42 | 1.43 | 19.95 |
| 2500 | 1129.7 | 83.91 | 380.6 | 12.01 | 449.4 | 168.59 | 4.71 | 10.60 | 1.46 | 20.25 |
| 2500 | 1126.8 | 82.60 | 388.9 | 12.30 | 448.2 | 172.39 | 4.81 | 10.79 | 1.48 | 20.55 |
| 2500 | 1123.9 | 81.32 | 397.2 | 12.59 | 446.9 | 176.26 | 4.92 | 10.97 | 1.50 | 20.86 |
| 2500 | 1120.9 | 80.06 | 405.6 | 12.90 | 445.7 | 180.21 | 5.03 | 11.16 | 1.53 | 21.17 |
| 2500 | 1118.0 | 78.82 | 414.2 | 13.21 | 444.4 | 184.24 | 5.14 | 11.36 | 1.55 | 21.48 |
| 2500 | 1115.1 | 77.59 | 422.8 | 13.53 | 443.2 | 188.35 | 5.25 | 11.55 | 1.58 | 21.80 |
| 2500 | 1112.2 | 76.38 | 431.5 | 13.85 | 441.8 | 192.54 | 5.36 | 11.75 | 1.60 | 22.12 |
| 2500 | 1109.2 | 75.20 | 440.3 | 14.18 | 440.5 | 196.81 | 5.48 | 11.96 | 1.63 | 22.44 |



**Cont. Appendix C: Results of Modeling for Southern Sequence of Americano do Brasil Rocks: Composition of Liquid (Cont. Traces)**

| P(bar) | T (°C) | mass   | La    | Ce    | Pr   | Nd    | Sm   | Eu   | Gd   | Tb   | Dy   | Ho   | Er   | Tm   | Yb   | Lu   | H2O    |
|--------|--------|--------|-------|-------|------|-------|------|------|------|------|------|------|------|------|------|------|--------|
| 2500   | 1314.7 | 100.37 | 12.99 | 27.96 | 3.79 | 17.95 | 4.48 | 1.49 | 4.18 | 0.63 | 3.68 | 0.67 | 1.69 | 0.22 | 1.39 | 0.21 | 5019.5 |
| 2500   | 1306.7 | 100.63 | 13.08 | 28.12 | 3.81 | 18.03 | 4.49 | 1.50 | 4.20 | 0.63 | 3.69 | 0.67 | 1.70 | 0.22 | 1.40 | 0.21 | 5106.6 |
| 2500   | 1298.9 | 100.86 | 13.17 | 28.29 | 3.83 | 18.11 | 4.50 | 1.50 | 4.21 | 0.63 | 3.70 | 0.67 | 1.70 | 0.22 | 1.41 | 0.21 | 5194.7 |
| 2500   | 1291.2 | 101.10 | 13.26 | 28.46 | 3.85 | 18.19 | 4.52 | 1.51 | 4.23 | 0.63 | 3.70 | 0.67 | 1.71 | 0.22 | 1.41 | 0.21 | 5281.9 |
| 2500   | 1283.6 | 101.34 | 13.35 | 28.63 | 3.87 | 18.27 | 4.53 | 1.52 | 4.24 | 0.63 | 3.71 | 0.67 | 1.71 | 0.22 | 1.42 | 0.21 | 5368.5 |
| 2500   | 1276.1 | 101.59 | 13.44 | 28.79 | 3.89 | 18.35 | 4.54 | 1.52 | 4.26 | 0.63 | 3.72 | 0.67 | 1.72 | 0.22 | 1.42 | 0.21 | 5454.6 |
| 2500   | 1268.7 | 101.84 | 13.52 | 28.96 | 3.91 | 18.43 | 4.55 | 1.53 | 4.27 | 0.64 | 3.73 | 0.68 | 1.72 | 0.22 | 1.43 | 0.21 | 5539.8 |
| 2500   | 1261.3 | 102.10 | 13.61 | 29.11 | 3.93 | 18.50 | 4.57 | 1.53 | 4.28 | 0.64 | 3.73 | 0.68 | 1.73 | 0.22 | 1.43 | 0.21 | 5624.0 |
| 2500   | 1254.0 | 102.38 | 13.69 | 29.27 | 3.95 | 18.58 | 4.58 | 1.53 | 4.30 | 0.64 | 3.74 | 0.68 | 1.73 | 0.22 | 1.44 | 0.22 | 5707.3 |
| 2500   | 1246.8 | 102.66 | 13.77 | 29.42 | 3.96 | 18.65 | 4.59 | 1.54 | 4.31 | 0.64 | 3.75 | 0.68 | 1.74 | 0.23 | 1.44 | 0.22 | 5789.5 |
| 2500   | 1239.7 | 102.95 | 13.85 | 29.57 | 3.98 | 18.72 | 4.60 | 1.54 | 4.32 | 0.64 | 3.75 | 0.68 | 1.74 | 0.23 | 1.44 | 0.22 | 5870.9 |
| 2500   | 1232.7 | 103.26 | 13.93 | 29.71 | 4.00 | 18.78 | 4.61 | 1.55 | 4.33 | 0.64 | 3.76 | 0.68 | 1.75 | 0.23 | 1.45 | 0.22 | 5951.2 |
| 2500   | 1225.7 | 103.56 | 14.00 | 29.85 | 4.01 | 18.85 | 4.62 | 1.55 | 4.34 | 0.64 | 3.76 | 0.68 | 1.75 | 0.23 | 1.45 | 0.22 | 6030.6 |
| 2500   | 1219.4 | 103.37 | 14.15 | 30.14 | 4.05 | 19.01 | 4.65 | 1.56 | 4.37 | 0.65 | 3.78 | 0.69 | 1.76 | 0.23 | 1.46 | 0.22 | 6139.3 |
| 2500   | 1213.4 | 103.02 | 14.31 | 30.47 | 4.09 | 19.19 | 4.69 | 1.58 | 4.41 | 0.65 | 3.81 | 0.69 | 1.78 | 0.23 | 1.47 | 0.22 | 6257.7 |
| 2500   | 1207.4 | 102.67 | 14.48 | 30.80 | 4.13 | 19.37 | 4.72 | 1.59 | 4.45 | 0.66 | 3.84 | 0.70 | 1.79 | 0.23 | 1.49 | 0.22 | 6376.9 |
| 2500   | 1201.5 | 102.31 | 14.65 | 31.14 | 4.18 | 19.56 | 4.76 | 1.60 | 4.49 | 0.66 | 3.87 | 0.70 | 1.81 | 0.23 | 1.50 | 0.22 | 6498.1 |
| 2500   | 1195.6 | 101.94 | 14.82 | 31.49 | 4.22 | 19.76 | 4.80 | 1.62 | 4.53 | 0.67 | 3.90 | 0.71 | 1.82 | 0.24 | 1.51 | 0.23 | 6620.4 |
| 2500   | 1189.8 | 101.56 | 15.00 | 31.83 | 4.27 | 19.95 | 4.84 | 1.63 | 4.57 | 0.67 | 3.93 | 0.71 | 1.84 | 0.24 | 1.52 | 0.23 | 6743.9 |
| 2500   | 1184.6 | 100.98 | 15.20 | 32.23 | 4.31 | 20.16 | 4.88 | 1.65 | 4.60 | 0.68 | 3.95 | 0.72 | 1.85 | 0.24 | 1.53 | 0.23 | 6882.3 |
| 2500   | 1181.0 | 99.83  | 15.47 | 32.75 | 4.38 | 20.40 | 4.92 | 1.66 | 4.63 | 0.68 | 3.96 | 0.72 | 1.86 | 0.24 | 1.54 | 0.23 | 7062.0 |
| 2500   | 1177.4 | 98.70  | 15.74 | 33.27 | 4.44 | 20.64 | 4.96 | 1.67 | 4.65 | 0.68 | 3.97 | 0.72 | 1.86 | 0.24 | 1.55 | 0.23 | 7244.5 |
| 2500   | 1173.8 | 97.59  | 16.01 | 33.79 | 4.50 | 20.88 | 4.99 | 1.68 | 4.68 | 0.68 | 3.98 | 0.73 | 1.87 | 0.24 | 1.55 | 0.23 | 7429.7 |
| 2500   | 1170.1 | 96.51  | 16.29 | 34.32 | 4.56 | 21.12 | 5.03 | 1.69 | 4.70 | 0.68 | 3.99 | 0.73 | 1.87 | 0.24 | 1.56 | 0.23 | 7617.7 |
| 2500   | 1166.4 | 95.59  | 16.54 | 34.80 | 4.61 | 21.33 | 5.05 | 1.70 | 4.72 | 0.69 | 3.99 | 0.73 | 1.88 | 0.24 | 1.56 | 0.23 | 7795.3 |
| 2500   | 1162.6 | 94.78  | 16.78 | 35.24 | 4.66 | 21.51 | 5.07 | 1.70 | 4.73 | 0.69 | 3.99 | 0.73 | 1.88 | 0.24 | 1.57 | 0.24 | 7968.0 |

|      |        |       |       |       |      |       |      |      |      |      |      |      |      |      |      |      |        |
|------|--------|-------|-------|-------|------|-------|------|------|------|------|------|------|------|------|------|------|--------|
| 2500 | 1158.8 | 94.00 | 17.02 | 35.68 | 4.71 | 21.69 | 5.09 | 1.71 | 4.74 | 0.69 | 3.99 | 0.73 | 1.88 | 0.24 | 1.57 | 0.24 | 8141.5 |
| 2500 | 1155.0 | 93.24 | 17.26 | 36.12 | 4.76 | 21.87 | 5.11 | 1.71 | 4.74 | 0.69 | 3.99 | 0.73 | 1.88 | 0.24 | 1.57 | 0.24 | 8315.6 |
| 2500 | 1151.2 | 92.50 | 17.49 | 36.56 | 4.81 | 22.04 | 5.13 | 1.72 | 4.75 | 0.69 | 3.98 | 0.73 | 1.88 | 0.24 | 1.57 | 0.24 | 8490.2 |
| 2500 | 1147.4 | 91.79 | 17.73 | 36.99 | 4.86 | 22.21 | 5.15 | 1.72 | 4.76 | 0.69 | 3.98 | 0.73 | 1.88 | 0.24 | 1.57 | 0.24 | 8665.2 |
| 2500 | 1144.1 | 90.75 | 18.02 | 37.56 | 4.93 | 22.49 | 5.19 | 1.74 | 4.80 | 0.69 | 4.01 | 0.73 | 1.89 | 0.25 | 1.59 | 0.24 | 8875.8 |
| 2500 | 1141.2 | 89.33 | 18.39 | 38.30 | 5.02 | 22.90 | 5.28 | 1.76 | 4.87 | 0.70 | 4.06 | 0.74 | 1.92 | 0.25 | 1.61 | 0.24 | 9128.9 |
| 2500 | 1138.4 | 87.94 | 18.77 | 39.05 | 5.11 | 23.31 | 5.36 | 1.79 | 4.95 | 0.71 | 4.12 | 0.75 | 1.95 | 0.25 | 1.64 | 0.25 | 9387.5 |
| 2500 | 1135.5 | 86.57 | 19.14 | 39.82 | 5.21 | 23.72 | 5.44 | 1.82 | 5.02 | 0.72 | 4.18 | 0.76 | 1.98 | 0.26 | 1.66 | 0.25 | 9651.6 |
| 2500 | 1132.6 | 85.23 | 19.53 | 40.59 | 5.31 | 24.14 | 5.53 | 1.85 | 5.10 | 0.73 | 4.24 | 0.77 | 2.01 | 0.26 | 1.69 | 0.25 | 9921.5 |
| 2500 | 1129.7 | 83.91 | 19.92 | 41.37 | 5.41 | 24.57 | 5.62 | 1.88 | 5.18 | 0.74 | 4.30 | 0.78 | 2.04 | 0.27 | 1.72 | 0.26 | #####  |
| 2500 | 1126.8 | 82.60 | 20.31 | 42.17 | 5.51 | 25.01 | 5.70 | 1.91 | 5.26 | 0.75 | 4.36 | 0.80 | 2.07 | 0.27 | 1.74 | 0.26 | #####  |
| 2500 | 1123.9 | 81.32 | 20.71 | 42.97 | 5.61 | 25.45 | 5.79 | 1.94 | 5.34 | 0.76 | 4.42 | 0.81 | 2.10 | 0.27 | 1.77 | 0.27 | #####  |
| 2500 | 1120.9 | 80.06 | 21.12 | 43.79 | 5.71 | 25.89 | 5.88 | 1.97 | 5.42 | 0.77 | 4.48 | 0.82 | 2.13 | 0.28 | 1.80 | 0.27 | #####  |
| 2500 | 1118.0 | 78.82 | 21.53 | 44.62 | 5.81 | 26.34 | 5.97 | 2.00 | 5.51 | 0.78 | 4.55 | 0.83 | 2.16 | 0.28 | 1.83 | 0.27 | #####  |
| 2500 | 1115.1 | 77.59 | 21.95 | 45.46 | 5.92 | 26.80 | 6.07 | 2.03 | 5.59 | 0.80 | 4.61 | 0.84 | 2.20 | 0.29 | 1.85 | 0.28 | #####  |
| 2500 | 1112.2 | 76.38 | 22.37 | 46.31 | 6.03 | 27.26 | 6.16 | 2.06 | 5.68 | 0.81 | 4.68 | 0.86 | 2.23 | 0.29 | 1.88 | 0.28 | #####  |
| 2500 | 1109.2 | 75.20 | 22.80 | 47.18 | 6.14 | 27.73 | 6.25 | 2.09 | 5.76 | 0.82 | 4.74 | 0.87 | 2.26 | 0.30 | 1.91 | 0.29 | #####  |



## Appendix D: Whole-rock geochemistry data of Mangabal Complex

| Sample                         |     | MNN01  | MNN04  | MNN06 | MNN07 | MNN10 | MNN12  | MNN14  | MNN16 | MNN18 | MNN20  |
|--------------------------------|-----|--------|--------|-------|-------|-------|--------|--------|-------|-------|--------|
| Sequence                       |     | N      | N      | N     | N     | N     | N      | N      | N     | N     | N      |
| Lithology                      |     | DU     | DU     | HZ    | HZ    | AMP   | NT     | NT     | NT    | HZ    | HZ     |
| SiO <sub>2</sub>               | %   | 41.1   | 41.6   | 41.2  | 41.4  | 49.6  | 51.1   | 52.4   | 51.0  | 37.6  | 45.3   |
| TiO <sub>2</sub>               | %   | 0.35   | 0.34   | 0.81  | 0.60  | 0.49  | 0.78   | 0.56   | 0.55  | 0.23  | 0.69   |
| Al <sub>2</sub> O <sub>3</sub> | %   | 5.93   | 6.93   | 6.01  | 7.58  | 11.40 | 10.45  | 8.95   | 17.45 | 6.36  | 10.50  |
| Fe <sub>2</sub> O <sub>3</sub> | %   | 14.25  | 14.35  | 14.70 | 13.90 | 11.75 | 10.95  | 12.90  | 8.18  | 13.40 | 14.50  |
| MnO                            | %   | 0.20   | 0.20   | 0.20  | 0.19  | 0.19  | 0.21   | 0.24   | 0.14  | 0.18  | 0.20   |
| MgO                            | %   | 30.8   | 30.4   | 27.6  | 26.2  | 10.7  | 11.8   | 17.7   | 10.4  | 27.8  | 21.3   |
| CaO                            | %   | 4.05   | 3.75   | 4.36  | 4.48  | 11.6  | 12.8   | 5.4    | 8.4   | 2.68  | 5.18   |
| Na <sub>2</sub> O              | %   | 0.85   | 0.94   | 1.07  | 1.25  | 1.52  | 1.64   | 1.30   | 2.50  | 0.27  | 1.05   |
| K <sub>2</sub> O               | %   | 0.16   | 0.22   | 0.42  | 0.28  | 0.20  | 0.26   | 0.32   | 0.26  | 0.07  | 0.37   |
| P <sub>2</sub> O <sub>5</sub>  | %   | 0.05   | 0.07   | 0.11  | 0.08  | 0.04  | 0.06   | 0.10   | 0.07  | 0.03  | 0.07   |
| Cr <sub>2</sub> O <sub>3</sub> | %   | 0.47   | 0.46   | 0.42  | 0.37  | 0.05  | 0.06   | 0.11   | 0.11  | 0.23  | 0.13   |
| SrO                            | %   | 0.01   | 0.01   | 0.01  | 0.01  | 0.02  | 0.02   | 0.01   | 0.03  | <0.01 | <0.01  |
| BaO                            | %   | 0.01   | 0.01   | 0.01  | 0.01  | 0.01  | 0.01   | 0.01   | 0.01  | <0.01 | 0.01   |
| LOI                            | %   | 2.03   | 1.40   | 2.13  | 1.66  | 1.57  | 0.53   | 0.39   | 0.46  | 10.15 | 2.43   |
| Sum                            | %   | 100.26 | 100.68 | 99.05 | 98.01 | 99.09 | 100.62 | 100.39 | 99.51 | 99.00 | 101.73 |
| Cr                             | ppm | 3530   | 3470   | 3250  | 2800  | 340   | 440    | 850    | 820   | 1720  | 940    |
| Ba                             | ppm | 48.4   | 67.1   | 95.3  | 73.8  | 73.4  | 90.3   | 82.5   | 83.3  | 5.8   | 95.5   |
| Sr                             | ppm | 78     | 103    | 80    | 116   | 224   | 189    | 148    | 306   | 46    | 66     |
| V                              | ppm | 82     | 73     | 143   | 103   | 185   | 236    | 151    | 106   | 49    | 80     |
| Zr                             | ppm | 25     | 32     | 74    | 50    | 21    | 50     | 55     | 38    | 18    | 34     |
| U                              | ppm | 0.13   | 0.20   | 0.37  | 0.27  | 0.06  | 0.21   | 0.30   | 0.17  | 0.06  | 0.45   |
| Th                             | ppm | 0.76   | 0.91   | 1.83  | 1.08  | 0.24  | 0.65   | 0.93   | 0.54  | 0.24  | 1.14   |
| Rb                             | ppm | 5.10   | 7.70   | 15.40 | 9.30  | 3.90  | 6.00   | 9.10   | 5.20  | 0.80  | 10.90  |
| Nb                             | ppm | 1.80   | 1.20   | 3.10  | 2.30  | 0.60  | 1.40   | 1.60   | 1.10  | 0.40  | 2.50   |
| Cs                             | ppm | 0.31   | 0.43   | 0.94  | 0.54  | 0.08  | 0.28   | 0.42   | 0.22  | 0.20  | 0.79   |
| Hf                             | ppm | 0.70   | 0.90   | 2.00  | 1.30  | 0.80  | 1.60   | 1.60   | 1.20  | 0.60  | 1.00   |
| Ta                             | ppm | <0.1   | <0.1   | 0.30  | 0.20  | <0.1  | 0.20   | 0.20   | 0.20  | <0.01 | 0.20   |
| Y                              | ppm | 7.30   | 7.10   | 15.20 | 10.80 | 12.50 | 19.10  | 13.40  | 10.20 | 4.80  | 5.70   |
| La                             | ppm | 3.10   | 4.70   | 6.40  | 4.00  | 2.60  | 4.60   | 4.60   | 3.30  | 1.40  | 3.50   |
| Ce                             | ppm | 6.40   | 9.80   | 14.30 | 8.40  | 6.20  | 11.90  | 11.10  | 7.90  | 3.60  | 8.10   |
| Pr                             | ppm | 0.85   | 1.17   | 1.92  | 1.13  | 0.88  | 1.83   | 1.58   | 1.14  | 0.49  | 1.04   |
| Nd                             | ppm | 4.10   | 4.80   | 9.00  | 5.40  | 4.70  | 9.20   | 7.70   | 5.50  | 2.50  | 4.40   |
| Sm                             | ppm | 1.07   | 1.26   | 2.49  | 1.58  | 1.45  | 2.87   | 2.20   | 1.45  | 0.71  | 1.06   |
| Eu                             | ppm | 0.40   | 0.39   | 0.64  | 0.47  | 0.63  | 1.03   | 0.69   | 0.67  | 0.36  | 0.46   |
| Gd                             | ppm | 1.31   | 1.22   | 2.54  | 1.85  | 2.05  | 3.43   | 2.26   | 1.78  | 0.78  | 1.09   |
| Tb                             | ppm | 0.21   | 0.22   | 0.43  | 0.28  | 0.35  | 0.61   | 0.39   | 0.31  | 0.15  | 0.18   |
| Dy                             | ppm | 1.35   | 1.30   | 2.85  | 1.86  | 2.55  | 3.74   | 2.30   | 1.95  | 0.88  | 1.01   |
| Ho                             | ppm | 0.26   | 0.23   | 0.57  | 0.41  | 0.50  | 0.75   | 0.47   | 0.37  | 0.19  | 0.20   |
| Er                             | ppm | 0.85   | 0.74   | 1.59  | 1.16  | 1.42  | 2.20   | 1.57   | 1.19  | 0.53  | 0.64   |
| Tm                             | ppm | 0.13   | 0.10   | 0.23  | 0.16  | 0.20  | 0.26   | 0.22   | 0.16  | 0.10  | 0.08   |
| Yb                             | ppm | 0.80   | 0.77   | 1.57  | 1.10  | 1.28  | 2.15   | 1.53   | 1.05  | 0.61  | 0.61   |
| Lu                             | ppm | 0.11   | 0.11   | 0.21  | 0.15  | 0.22  | 0.31   | 0.25   | 0.19  | 0.08  | 0.10   |

DU - Olivine Cumulate; HZ - Poikilitic Harzburgite; NT - Pyroxene-plagioclase cumulate; AMP- Amphibolite; MU - meta olivine cumulate

| Sample                         | MNN03  | MNN05 | MNN09  | MNN15  | MNN17 | MNN19  | MNN21  | MNS07 | MNS09  | MNS11  |
|--------------------------------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|
| Sequence                       | N      | N     | N      | N      | N     | N      | N      | S     | S      | S      |
| Lithology                      | DU     | DU    | AMP    | AMP    | AMP   | AMP    | NO     | NT    | NT     | NT     |
| SiO <sub>2</sub>               | 40.9   | 40.3  | 53.4   | 51.8   | 46.5  | 50.6   | 52.1   | 51.4  | 52.5   | 51.6   |
| TiO <sub>2</sub>               | 0.44   | 0.37  | 1.19   | 0.58   | 0.60  | 0.31   | 0.69   | 0.47  | 0.41   | 0.24   |
| Al <sub>2</sub> O <sub>3</sub> | 5.87   | 6.45  | 18.20  | 15.20  | 17.25 | 17.45  | 14.55  | 14.45 | 14.30  | 19.55  |
| Fe <sub>2</sub> O <sub>3</sub> | 13.95  | 13.85 | 8.71   | 9.25   | 9.43  | 9.76   | 10.90  | 9.41  | 10.10  | 6.90   |
| MnO                            | 0.19   | 0.18  | 0.14   | 0.16   | 0.12  | 0.17   | 0.20   | 0.18  | 0.19   | 0.13   |
| MgO                            | 31.6   | 31.0  | 6.2    | 12.5   | 11.7  | 9.8    | 10.9   | 12.7  | 13.8   | 9.6    |
| CaO                            | 3.77   | 3.69  | 8.03   | 7.30   | 8.36  | 8.53   | 7.44   | 8.42  | 7.25   | 9.38   |
| Na <sub>2</sub> O              | 0.93   | 0.83  | 3.84   | 2.33   | 2.48  | 2.85   | 2.44   | 1.79  | 1.80   | 2.32   |
| K <sub>2</sub> O               | 0.18   | 0.31  | 1.14   | 0.40   | 0.33  | 0.75   | 0.16   | 0.23  | 0.27   | 0.28   |
| P <sub>2</sub> O <sub>5</sub>  | 0.03   | 0.04  | 0.12   | 0.08   | 0.09  | 0.06   | 0.09   | <0.01 | 0.02   | <0.01  |
| Cr <sub>2</sub> O <sub>3</sub> | 0.48   | 0.46  | 0.05   | 0.13   | 0.12  | 0.06   | 0.08   | 0.09  | 0.10   | 0.07   |
| SrO                            | <0.01  | 0.01  | 0.04   | 0.03   | 0.03  | 0.03   | 0.03   | 0.04  | 0.04   | 0.06   |
| BaO                            | <0.01  | 0.01  | 0.03   | 0.01   | 0.01  | 0.02   | 0.01   | 0.01  | 0.02   | 0.02   |
| LOI                            | 2.20   | 2.37  | 0.86   | 1.06   | 1.05  | 0.90   | 0.69   | 0.61  | 0.30   | 0.31   |
| Sum                            | 100.54 | 99.87 | 101.98 | 100.83 | 98.02 | 101.32 | 100.28 | 99.76 | 101.05 | 100.47 |
| Cr                             | 3690   | 3440  | 380    | 1010   | 860   | 470    | 530    | 720   | 790    | 550    |
| Ba                             | 42.8   | 50.6  | 261.0  | 111.5  | 95.8  | 137.0  | 46.8   | 120.5 | 131.5  | 169.5  |
| Sr                             | 79     | 81    | 374    | 268    | 294   | 326    | 255    | 381   | 373    | 518    |
| V                              | 100    | 93    | 174    | 135    | 84    | 69     | 167    | 114   | 107    | 66     |
| Zr                             | 24     | 28    | 111    | 38     | 44    | 26     | 53     | 13    | 12     | 6      |
| U                              | 0.15   | 0.29  | 0.88   | 0.16   | 0.19  | 0.54   | 0.21   | bdl   | 0.05   | <0.05  |
| Th                             | 0.54   | 0.83  | 2.82   | 0.44   | 0.54  | 0.49   | 0.53   | 0.08  | 0.24   | 0.10   |
| Rb                             | 4.80   | 10.00 | 38.80  | 10.60  | 6.80  | 26.70  | 2.00   | 1.90  | 2.80   | 1.70   |
| Nb                             | 0.90   | 1.10  | 5.00   | 1.00   | 1.50  | 2.40   | 2.00   | 0.40  | 0.80   | 0.30   |
| Cs                             | 0.48   | 0.76  | 1.96   | 0.59   | 0.44  | 1.53   | 0.32   | 0.08  | 0.09   | 0.09   |
| Hf                             | 0.60   | 0.70  | 2.70   | 1.00   | 1.00  | 0.60   | 1.40   | 0.40  | 0.40   | 0.20   |
| Ta                             | 0.10   | 0.20  | 0.40   | 0.10   | 0.10  | 0.30   | 0.20   | <0.1  | <0.1   | <0.1   |
| Y                              | 7.00   | 6.40  | 18.40  | 10.50  | 9.50  | 17.80  | 17.80  | 5.40  | 5.30   | 3.00   |
| La                             | 2.20   | 2.60  | 9.90   | 3.10   | 3.80  | 3.00   | 4.60   | 2.70  | 3.50   | 4.10   |
| Ce                             | 4.60   | 5.70  | 22.00  | 6.90   | 8.50  | 8.10   | 12.60  | 5.60  | 6.80   | 7.20   |
| Pr                             | 0.68   | 0.68  | 2.85   | 0.99   | 1.21  | 1.24   | 1.94   | 0.67  | 0.87   | 0.75   |
| Nd                             | 3.40   | 3.20  | 12.80  | 5.00   | 5.90  | 6.20   | 9.60   | 3.20  | 3.60   | 2.80   |
| Sm                             | 0.97   | 0.95  | 3.29   | 1.58   | 1.79  | 2.12   | 2.88   | 0.67  | 0.79   | 0.57   |
| Eu                             | 0.36   | 0.33  | 1.05   | 0.63   | 0.57  | 0.89   | 1.02   | 0.49  | 0.51   | 0.56   |
| Gd                             | 1.22   | 1.07  | 3.24   | 1.70   | 1.71  | 2.49   | 3.17   | 0.82  | 0.84   | 0.49   |
| Tb                             | 0.23   | 0.18  | 0.53   | 0.29   | 0.32  | 0.47   | 0.48   | 0.15  | 0.14   | 0.09   |
| Dy                             | 1.21   | 1.09  | 3.20   | 1.66   | 1.67  | 3.06   | 3.21   | 0.86  | 0.89   | 0.45   |
| Ho                             | 0.25   | 0.26  | 0.73   | 0.40   | 0.42  | 0.68   | 0.69   | 0.19  | 0.19   | 0.12   |
| Er                             | 0.76   | 0.59  | 1.97   | 1.11   | 0.97  | 1.79   | 1.89   | 0.68  | 0.56   | 0.36   |
| Tm                             | 0.11   | 0.10  | 0.30   | 0.19   | 0.15  | 0.26   | 0.30   | 0.10  | 0.10   | 0.06   |
| Yb                             | 0.79   | 0.62  | 1.90   | 1.11   | 0.77  | 1.68   | 1.82   | 0.71  | 0.72   | 0.37   |
| Lu                             | 0.10   | 0.11  | 0.29   | 0.20   | 0.18  | 0.27   | 0.30   | 0.10  | 0.10   | 0.08   |

DU - Olivine Cumulate; HZ - Poikilitic Harzburgite; NT - Pyroxene-plagioclase cumulate; AMP- Amphibolite; MU - meta olivine cumulate

| Sample | MNS14 | MNS16 | MNS19 | MNS20 | MNS22 | MNS24 | MNS26 | MNS02 | MNS05 | MNS06 |
|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|

| Sequence                       | S     | S     | S      | S      | S     | S     | S      | S     | S     | S      |
|--------------------------------|-------|-------|--------|--------|-------|-------|--------|-------|-------|--------|
| Lithology                      | FD    | NT    | HZ     | HZ     | AMP   | AMP   | NO     | AMP   | AMP   | AMP    |
| SiO <sub>2</sub>               | 43.2  | 49.9  | 51.5   | 42.0   | 48.6  | 42.5  | 52.2   | 47.5  | 50.0  | 52.3   |
| TiO <sub>2</sub>               | 0.25  | 0.29  | 0.35   | 0.38   | 0.36  | 0.24  | 0.53   | 0.51  | 0.35  | 0.35   |
| Al <sub>2</sub> O <sub>3</sub> | 11.30 | 11.65 | 3.29   | 8.37   | 11.95 | 7.98  | 14.35  | 10.85 | 13.15 | 13.90  |
| Fe <sub>2</sub> O <sub>3</sub> | 10.25 | 10.55 | 13.20  | 14.60  | 12.55 | 14.90 | 10.25  | 15.05 | 10.55 | 10.40  |
| MnO                            | 0.15  | 0.16  | 0.22   | 0.21   | 0.18  | 0.19  | 0.20   | 0.23  | 0.23  | 0.21   |
| MgO                            | 22.8  | 18.2  | 27.5   | 26.2   | 14.0  | 23.6  | 13.5   | 12.8  | 13.7  | 14.4   |
| CaO                            | 6.02  | 5.64  | 3.16   | 5.32   | 7.36  | 4.07  | 8.07   | 7.76  | 6.84  | 6.89   |
| Na <sub>2</sub> O              | 1.36  | 1.37  | 0.36   | 1.04   | 1.91  | 0.40  | 1.82   | 1.28  | 1.91  | 1.72   |
| K <sub>2</sub> O               | 0.16  | 0.09  | 0.20   | 0.21   | 0.37  | 0.08  | 0.23   | 0.30  | 0.26  | 0.19   |
| P <sub>2</sub> O <sub>5</sub>  | 0.02  | 0.02  | 0.04   | 0.16   | 0.02  | 0.03  | <0.01  | 0.04  | <0.01 | <0.01  |
| Cr <sub>2</sub> O <sub>3</sub> | 0.10  | 0.31  | 0.21   | 0.80   | 0.08  | 0.11  | 0.09   | 0.12  | 0.11  | 0.12   |
| SrO                            | 0.02  | 0.02  | <0.01  | 0.02   | 0.04  | <0.01 | 0.04   | 0.03  | 0.03  | 0.04   |
| BaO                            | 0.01  | <0.01 | 0.01   | 0.01   | 0.02  | <0.01 | 0.01   | 0.02  | 0.01  | 0.01   |
| LOI                            | 3.27  | 1.76  | 0.80   | 1.47   | 2.39  | 3.98  | 0.70   | 2.08  | 1.19  | 0.54   |
| Sum                            | 98.91 | 99.96 | 100.84 | 100.79 | 99.78 | 98.08 | 101.95 | 98.57 | 98.28 | 101.02 |
| Cr                             | 750   | 2290  | 1570   | 6050   | 620   | 820   | 690    | 860   | 780   | 780    |
| Ba                             | 56.6  | 40.2  | 50.1   | 63.5   | 130.5 | 8.9   | 107.0  | 145.5 | 86.6  | 86.0   |
| Sr                             | 156   | 215   | 37     | 115    | 362   | 33    | 367    | 329   | 310   | 331    |
| V                              | 57    | 59    | 86     | 99     | 105   | 64    | 119    | 101   | 97    | 89     |
| Zr                             | 12    | 13    | 28     | 22     | 17    | 15    | 12     | 39    | 6     | 5      |
| U                              | 0.05  | <0.05 | 0.12   | 0.11   | 0.13  | 0.14  | <0.05  | 0.41  | <0.05 | <0.05  |
| Th                             | 0.16  | 0.11  | 0.35   | 0.51   | 0.42  | 0.33  | 0.09   | 0.65  | 0.09  | 0.07   |
| Rb                             | 1.90  | 1.60  | 5.10   | 4.10   | 8.80  | 0.50  | 1.90   | 7.10  | 5.70  | 0.90   |
| Nb                             | 0.40  | 0.30  | 1.40   | 1.20   | 0.70  | 0.40  | 0.50   | 1.20  | 0.20  | 0.40   |
| Cs                             | 0.21  | 0.07  | 0.25   | 0.22   | 1.05  | 0.08  | 0.18   | 0.35  | 0.39  | 0.05   |
| Hf                             | 0.40  | 0.50  | 0.80   | 0.70   | 0.60  | 0.50  | 0.40   | 0.90  | 0.20  | 0.20   |
| Ta                             | <0.1  | <0.1  | 0.20   | <0.1   | <0.1  | <0.1  | <0.1   | 0.20  | 0.10  | 0.10   |
| Y                              | 4.70  | 4.90  | 11.90  | 6.00   | 7.80  | 5.60  | 6.30   | 9.50  | 4.10  | 3.60   |
| La                             | 1.30  | 1.40  | 2.80   | 2.50   | 3.50  | 1.80  | 2.60   | 3.70  | 1.60  | 2.10   |
| Ce                             | 3.10  | 3.00  | 8.50   | 5.80   | 7.40  | 4.70  | 5.20   | 9.30  | 3.30  | 3.40   |
| Pr                             | 0.41  | 0.40  | 1.28   | 0.79   | 0.97  | 0.58  | 0.68   | 1.21  | 0.37  | 0.42   |
| Nd                             | 2.00  | 1.70  | 6.80   | 3.80   | 4.40  | 3.00  | 3.20   | 6.60  | 1.80  | 1.80   |
| Sm                             | 0.67  | 0.43  | 2.05   | 1.19   | 1.06  | 0.79  | 1.03   | 1.89  | 0.57  | 0.36   |
| Eu                             | 0.37  | 0.27  | 0.39   | 0.39   | 0.51  | 0.27  | 0.50   | 0.54  | 0.37  | 0.36   |
| Gd                             | 0.81  | 0.64  | 2.15   | 1.15   | 1.24  | 1.03  | 0.96   | 1.85  | 0.58  | 0.47   |
| Tb                             | 0.14  | 0.14  | 0.34   | 0.19   | 0.22  | 0.16  | 0.18   | 0.28  | 0.11  | 0.09   |
| Dy                             | 0.93  | 0.81  | 2.19   | 1.09   | 1.53  | 1.03  | 1.05   | 1.67  | 0.59  | 0.64   |
| Ho                             | 0.19  | 0.20  | 0.42   | 0.24   | 0.28  | 0.21  | 0.23   | 0.33  | 0.15  | 0.15   |
| Er                             | 0.50  | 0.50  | 1.30   | 0.61   | 0.82  | 0.57  | 0.81   | 1.03  | 0.42  | 0.50   |
| Tm                             | 0.07  | 0.11  | 0.19   | 0.09   | 0.13  | 0.08  | 0.10   | 0.17  | 0.09  | 0.09   |
| Yb                             | 0.55  | 0.53  | 1.21   | 0.63   | 0.90  | 0.62  | 0.74   | 0.94  | 0.60  | 0.50   |
| Lu                             | 0.08  | 0.09  | 0.20   | 0.10   | 0.15  | 0.09  | 0.12   | 0.17  | 0.10  | 0.10   |

DU - Olivine Cumulate; HZ - Poikilitic Harzburgite; NT - Pyroxene-plagioclase cumulate; AMP - Amphibolite; MU - meta olivine cumulate

Sample MNS10 MNS11 MNS13 MNS17 MNS18 MNS21 MNS23 MNS25 MNS27

| Sequence                       | S     | S      | S      | S      | S     | S     | S     | S     | S     |
|--------------------------------|-------|--------|--------|--------|-------|-------|-------|-------|-------|
| Lithology                      | AMP   | NO     | AMP    | AMP    | MU    | MU    | MU    | AMP   | AMP   |
| SiO <sub>2</sub>               | 50.0  | 52.1   | 48.7   | 49.7   | 46.9  | 42.4  | 47.8  | 51.1  | 51.0  |
| TiO <sub>2</sub>               | 0.47  | 0.39   | 1.47   | 0.13   | 0.24  | 0.26  | 0.36  | 0.51  | 0.35  |
| Al <sub>2</sub> O <sub>3</sub> | 14.55 | 12.55  | 10.35  | 23.50  | 7.35  | 8.84  | 7.93  | 14.60 | 17.70 |
| Fe <sub>2</sub> O <sub>3</sub> | 9.64  | 10.60  | 15.65  | 4.64   | 13.40 | 14.85 | 13.25 | 9.64  | 6.99  |
| MnO                            | 0.18  | 0.20   | 0.25   | 0.06   | 0.19  | 0.19  | 0.21  | 0.18  | 0.13  |
| MgO                            | 12.2  | 16.0   | 14.2   | 7.4    | 23.8  | 24.3  | 21.3  | 13.0  | 8.7   |
| CaO                            | 7.63  | 6.43   | 6.77   | 10.50  | 4.02  | 4.37  | 4.49  | 7.37  | 10.00 |
| Na <sub>2</sub> O              | 1.76  | 1.44   | 1.40   | 3.06   | 0.90  | 0.55  | 0.80  | 1.86  | 2.75  |
| K <sub>2</sub> O               | 1.26  | 0.18   | 0.26   | 0.16   | 0.15  | 0.07  | 1.10  | 0.21  | 0.75  |
| P <sub>2</sub> O <sub>5</sub>  | <0.01 | <0.01  | 0.04   | 0.01   | 0.03  | 0.03  | 0.03  | 0.01  | 0.03  |
| Cr <sub>2</sub> O <sub>3</sub> | 0.09  | 0.14   | 0.11   | 0.03   | 0.19  | 0.26  | 0.17  | 0.10  | 0.04  |
| SrO                            | 0.04  | 0.03   | 0.02   | 0.07   | 0.01  | <0.01 | <0.01 | 0.04  | 0.05  |
| BaO                            | 0.03  | 0.01   | 0.01   | 0.01   | <0.01 | <0.01 | 0.01  | 0.01  | 0.02  |
| LOI                            | 1.19  | 0.09   | 0.86   | 1.07   | 1.11  | 3.59  | 2.01  | 1.22  | 0.93  |
| Sum                            | 98.99 | 100.11 | 100.09 | 100.38 | 98.29 | 99.71 | 99.46 | 99.80 | 99.44 |
| Cr                             | 630   | 1050   | 810    | 190    | 1420  | 2010  | 1210  | 750   | 320   |
| Ba                             | 240.0 | 89.1   | 126.5  | 103.5  | 34.5  | 9.6   | 101.5 | 119.5 | 183.5 |
| Sr                             | 317   | 308    | 255    | 590    | 123   | 54    | 37    | 362   | 494   |
| V                              | 103   | 111    | 322    | 22     | 78    | 77    | 98    | 97    | 94    |
| Zr                             | 13    | 10     | 42     | 6      | 15    | 9     | 18    | 11    | 13    |
| U                              | 0.21  | <0.05  | 0.16   | <0.05  | 0.11  | 0.06  | 0.20  | <0.05 | 0.09  |
| Th                             | 0.17  | 0.13   | 0.67   | 0.06   | 0.47  | 0.29  | 0.31  | 0.09  | 0.18  |
| Rb                             | 37.80 | 1.90   | 4.10   | 2.00   | 3.70  | 0.40  | 38.90 | 1.40  | 23.90 |
| Nb                             | 0.70  | 0.30   | 3.20   | 0.20   | 0.50  | 0.40  | 0.50  | 0.50  | 0.40  |
| Cs                             | 4.12  | 0.10   | 0.18   | 0.10   | 0.24  | 0.06  | 6.53  | 0.07  | 2.36  |
| Hf                             | 0.40  | 0.30   | 1.20   | 0.20   | 0.40  | 0.30  | 0.60  | 0.40  | 0.50  |
| Ta                             | 0.10  | 0.10   | 0.20   | 0.10   | 0.10  | 0.20  | 0.10  | 0.10  | 0.10  |
| Y                              | 5.80  | 4.70   | 12.00  | 2.10   | 4.40  | 3.80  | 6.90  | 6.50  | 7.50  |
| La                             | 3.60  | 2.30   | 4.50   | 2.40   | 1.60  | 1.80  | 2.20  | 2.80  | 3.70  |
| Ce                             | 7.00  | 4.30   | 10.60  | 4.30   | 3.30  | 3.80  | 5.20  | 5.80  | 8.00  |
| Pr                             | 0.91  | 0.52   | 1.46   | 0.50   | 0.40  | 0.47  | 0.70  | 0.70  | 0.95  |
| Nd                             | 3.90  | 2.50   | 7.50   | 2.40   | 2.10  | 2.20  | 3.50  | 3.30  | 5.10  |
| Sm                             | 1.05  | 0.63   | 1.87   | 0.33   | 0.53  | 0.57  | 0.94  | 0.78  | 1.29  |
| Eu                             | 0.49  | 0.40   | 0.61   | 0.42   | 0.17  | 0.29  | 0.42  | 0.53  | 0.69  |
| Gd                             | 0.93  | 0.69   | 1.87   | 0.32   | 0.60  | 0.67  | 1.07  | 0.96  | 1.30  |
| Tb                             | 0.15  | 0.12   | 0.37   | 0.07   | 0.11  | 0.13  | 0.19  | 0.15  | 0.22  |
| Dy                             | 0.94  | 0.74   | 2.15   | 0.40   | 0.71  | 0.75  | 1.13  | 1.07  | 1.48  |
| Ho                             | 0.20  | 0.17   | 0.48   | 0.07   | 0.16  | 0.18  | 0.25  | 0.25  | 0.32  |
| Er                             | 0.66  | 0.56   | 1.34   | 0.24   | 0.41  | 0.37  | 0.74  | 0.70  | 0.85  |
| Tm                             | 0.10  | 0.09   | 0.22   | 0.02   | 0.07  | 0.07  | 0.12  | 0.12  | 0.12  |
| Yb                             | 0.75  | 0.64   | 1.27   | 0.24   | 0.56  | 0.43  | 0.77  | 0.75  | 0.73  |
| Lu                             | 0.11  | 0.10   | 0.21   | 0.04   | 0.09  | 0.06  | 0.12  | 0.13  | 0.14  |

DU - Olivine Cumulate; HZ - Poikilitic Harzburgite; NT - Pyroxene-plagioclase cumulate; AMP- Amphibolite; MU - meta olivine cumulate

## Appendix E: Mineral Chemistry from Mangabal Complex

### Olivine

| Sequence                       | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Sample                         | MNN01 | MNN01 | MNN02 | MNN02 | MNN03 | MNN03 | MNN03 | MNN03 | MNN03 | MNN03 | MNN03 | MNN03 | MNN03 | MNN05 | MNN05 |
| No.                            | 1     | 2     | 2     | 3     | 15    | 14    | 13    | 12    | 11    | 10    | 9     | 8     | 7     | 2     | 1     |
| SiO <sub>2</sub>               | 38.5  | 38.9  | 38.3  | 38.3  | 39.7  | 39.8  | 39.7  | 40.2  | 40.1  | 40.0  | 40.1  | 39.9  | 40.4  | 38.9  | 39.6  |
| TiO <sub>2</sub>               | 0.2   | 0.2   | 0.0   | 0.1   | 0.1   | 0.0   | 0.1   | 0.3   | 0.1   | 0.0   | 0.0   | 0.3   | 0.0   | 0.1   | 0.1   |
| Al <sub>2</sub> O <sub>3</sub> | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Cr <sub>2</sub> O <sub>3</sub> | 0.1   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   |
| FeO                            | 16.0  | 16.2  | 15.9  | 15.9  | 17.0  | 16.8  | 17.1  | 16.9  | 16.7  | 16.7  | 16.5  | 17.1  | 17.0  | 17.4  | 16.9  |
| MnO                            | 0.3   | 0.3   | 0.1   | 0.3   | 0.2   | 0.1   | 0.2   | 0.3   | 0.2   | 0.1   | 0.3   | 0.3   | 0.3   | 0.1   | 0.2   |
| MgO                            | 43.3  | 43.3  | 43.7  | 43.5  | 42.3  | 42.8  | 42.3  | 42.1  | 42.6  | 43.0  | 43.2  | 42.6  | 42.5  | 41.7  | 42.2  |
| CaO                            | 0.2   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Na <sub>2</sub> O              | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| K <sub>2</sub> O               | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| F                              | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Cl                             | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| NiO                            | 0.3   | 0.2   | 0.3   | 0.2   | 0.3   | 0.2   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.2   | 0.2   | 0.3   | 0.2   |
| V <sub>2</sub> O <sub>3</sub>  | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   |
| P <sub>2</sub> O <sub>5</sub>  |       |       |       |       | 0.0   | 0.1   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Total                          | 98.9  | 99.2  | 98.4  | 98.5  | 99.8  | 99.8  | 99.9  | 100.1 | 100.1 | 100.2 | 100.5 | 100.5 | 100.6 | 98.5  | 99.3  |



**Cont. Appendix E: Mineral Chemistry from Mangabal Complex**

| Olivine                        |       |       |       |       |       |       |       |       |       |       |       |             |       |       |       |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------------|-------|-------|-------|
| Sequence                       | N     | N     | N     | N     | N     | N     | S     | S     | S     | S     | S     | S           | S     | S     | S     |
| Sample                         | MNN06 | MNN06 | MNN06 | MNN06 | MNN20 | MNN20 | MNS14 | MNS14 | MNS14 | MNS14 | MNS14 | MNS18       | MNS18 | MNS19 | MNS19 |
| No.                            | 3     | 1     | 2     | 4     | 1     | 2     | 2     | 3     | 5     | 6     | 7     | 1           | 2     | 1     | 3     |
| SiO <sub>2</sub>               | 39.2  | 39.4  | 39.4  | 39.4  | 38.9  | 38.9  | 39.3  | 39.2  | 40.3  | 40.0  | 39.8  | 39.4        | 39.3  | 38.5  | 37.9  |
| TiO <sub>2</sub>               | 0.0   | 0.0   | 0.2   | 0.3   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1         | 0.0   | 0.0   | 0.1   |
| Al <sub>2</sub> O <sub>3</sub> | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0         | 0.0   | 0.0   | 0.1   |
| Cr <sub>2</sub> O <sub>3</sub> | 0.1   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0         | 0.0   | 0.1   | 0.2   |
| FeO                            | 20.2  | 20.1  | 20.2  | 20.2  | 19.3  | 19.5  | 16.6  | 16.4  | 16.3  | 16.3  | 16.5  | <b>16.1</b> | 16.2  | 18.3  | 14.4  |
| MnO                            | 0.1   | 0.3   | 0.3   | 0.2   | 0.4   | 0.3   | 0.2   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3         | 0.2   | 0.3   | 0.2   |
| MgO                            | 40.5  | 40.1  | 40.3  | 40.7  | 39.8  | 40.4  | 43.3  | 42.5  | 43.6  | 44.2  | 43.6  | 43.5        | 42.8  | 42.1  | 46.4  |
| CaO                            | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0         | 0.0   | 0.0   | 0.1   |
| Na <sub>2</sub> O              | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0         | 0.0   | 0.0   | 0.1   |
| K <sub>2</sub> O               | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0         | 0.0   | 0.0   | 0.0   |
| F                              | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0         | 0.0   | 0.0   | 0.0   |
| Cl                             | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0         | 0.0   | 0.0   | 0.0   |
| NiO                            | 0.2   | 0.2   | 0.2   | 0.3   | 0.2   | 0.1   | 0.3   | 0.3   | 0.3   | 0.2   | 0.3   | 0.4         | 0.4   | 0.3   | 0.5   |
| V <sub>2</sub> O <sub>3</sub>  | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0         | 0.0   | 0.0   | 0.0   |
| P <sub>2</sub> O <sub>5</sub>  | 0.0   | 0.0   | 0.0   | 0.0   |       |       |       |       |       |       |       |             |       |       |       |
| Total                          | 100.3 | 100.3 | 100.6 | 101.3 | 98.5  | 99.2  | 99.7  | 98.9  | 100.8 | 101.1 | 100.7 | 99.8        | 99.0  | 99.7  | 100.0 |

**Cont. Appendix E: Mineral Chemistry from Mangabal Complex**

| Orthopyroxene                  |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
|--------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Sequence                       | S           | S           | S           | S           | S           | S           | S           | S           | S           | S           | S           | S           | S           | S           | S           |
| Sample                         | MNS07       | MNS11       | MNS11       | MNS11       | MNS11       | MNS11       | MNS11       | MNS11       | MNS11       | MNS11       | MNS11       | MNS11       | MNS11       | MNS13       | MNS13       |
| No.                            | 1           | 20          | 18          | 16          | 3           | 19          | 7           | 10          | 4           | 11          | 5           | 6           | 9           | 3           | 2           |
| SiO <sub>2</sub>               | 53.0        | 52.4        | 53.3        | 53.6        | 53.9        | 53.3        | 54.0        | 53.8        | 53.8        | 54.2        | 54.7        | 54.6        | 54.1        | 52.1        | 53.2        |
| TiO <sub>2</sub>               | 0.0         | 0.0         | 0.1         | 0.1         | 0.2         | 0.2         | 0.0         | 0.0         | 0.8         | 0.2         | 0.0         | 0.0         | 0.0         | 0.3         | 0.0         |
| Al <sub>2</sub> O <sub>3</sub> | 2.4         | 1.8         | 2.3         | 2.4         | 2.2         | 1.9         | 1.8         | 2.0         | 2.0         | 1.6         | 1.9         | 2.4         | 2.4         | 3.4         | 2.3         |
| Cr <sub>2</sub> O <sub>3</sub> | 0.2         | 0.3         | 0.1         | 0.2         | 0.1         | 0.1         | 0.2         | 0.2         | 0.1         | 0.2         | 0.2         | 0.1         | 0.1         | 0.1         | 0.0         |
| <b>FeO</b>                     | <b>17.1</b> | <b>19.9</b> | <b>17.2</b> | <b>17.8</b> | <b>16.7</b> | <b>18.3</b> | <b>19.0</b> | <b>19.2</b> | <b>16.9</b> | <b>19.7</b> | <b>15.2</b> | <b>18.1</b> | <b>19.8</b> | <b>17.8</b> | <b>18.5</b> |
| MnO                            | 0.4         | 0.6         | 0.3         | 0.5         | 0.5         | 0.5         | 0.4         | 0.5         | 0.5         | 0.5         | 0.3         | 0.4         | 0.6         | 0.6         | 0.7         |
| MgO                            | 25.7        | 23.2        | 25.3        | 24.0        | 25.5        | 25.5        | 24.4        | 24.0        | 24.8        | 24.0        | 25.6        | 24.9        | 24.0        | 21.6        | 23.8        |
| CaO                            | 0.4         | 0.2         | 0.9         | 1.1         | 0.5         | 0.2         | 0.2         | 0.4         | 1.5         | 0.2         | 2.7         | 0.3         | 0.3         | 2.7         | 0.6         |
| Na <sub>2</sub> O              | 0.0         | 0.0         | 0.0         | 0.1         | 0.0         | 0.0         | 0.0         | 0.1         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.2         | 0.0         |
| K <sub>2</sub> O               | 0.0         | 0.0         | 0.0         | 0.0         | 0.1         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         |
| F                              | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         |
| Cl                             | 0.0         | 0.0         | 0.0         | 0.0         | 0.1         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         |
| NiO                            | 0.1         | 0.1         | 0.1         | 0.0         | 0.1         | 0.0         | 0.0         | 0.1         | 0.0         | 0.0         | 0.1         | 0.1         | 0.0         | 0.1         | 0.1         |
| V <sub>2</sub> O <sub>3</sub>  | 0.0         | 0.0         | 0.0         | 0.1         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.1         | 0.0         | 0.0         | 0.0         |
| P <sub>2</sub> O <sub>5</sub>  |             | 0.0         |             | 0.0         |             |             | 0.0         | 0.0         |             | 0.0         |             | 0.0         | 0.0         |             |             |
| Total                          | 99.3        | 98.7        | 99.6        | 99.8        | 100.0       | 100.0       | 100.2       | 100.4       | 100.5       | 100.7       | 100.8       | 101.0       | 101.4       | 99.0        | 99.3        |

**Cont. Appendix E: Mineral Chemistry from Mangabal Complex**

| Sequence                       | Orthopyroxene |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|--------------------------------|---------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                | S             | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     |
| Sample                         | MNS13         | MNS14 | MNS14 | MNS14 | MNS14 | MNS14 | MNS14 | MNS14 | MNS14 | MNS14 | MNS16 | MNS16 | MNS16 | MNS16 | MNS16 | MNS16 |
| No.                            | 1             | 12    | 18    | 16    | 10    | 11    | 17    | 14    | 9     | 15    | 1     | 3     | 4     | 8     | 5     | 7     |
| SiO <sub>2</sub>               | 54.2          | 55.6  | 53.6  | 56.9  | 56.3  | 55.7  | 56.8  | 57.4  | 49.7  | 57.4  | 54.8  | 53.7  | 54.6  | 56.4  | 54.6  | 55.0  |
| TiO <sub>2</sub>               | 0.0           | 0.1   | 0.2   | 0.0   | 0.0   | 0.1   | 0.1   | 0.0   | 0.0   | 0.0   | 0.3   | 0.3   | 0.1   | 0.0   | 0.1   | 0.0   |
| Al <sub>2</sub> O <sub>3</sub> | 1.9           | 0.7   | 3.3   | 0.4   | 0.6   | 2.5   | 0.9   | 0.5   | 10.7  | 0.7   | 4.9   | 4.0   | 3.6   | 1.3   | 3.5   | 3.2   |
| Cr <sub>2</sub> O <sub>3</sub> | 0.0           | 0.0   | 0.5   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.6   | 0.4   | 0.4   | 0.1   | 0.4   | 0.4   |
| FeO                            | 17.5          | 10.6  | 10.1  | 10.4  | 11.0  | 11.2  | 10.8  | 10.5  | 11.5  | 10.7  | 6.3   | 11.0  | 11.1  | 11.7  | 11.8  | 13.0  |
| MnO                            | 0.6           | 0.3   | 0.3   | 0.2   | 0.1   | 0.3   | 0.3   | 0.3   | 0.2   | 0.4   | 0.1   | 0.3   | 0.3   | 0.1   | 0.2   | 0.2   |
| MgO                            | 24.2          | 31.1  | 29.1  | 30.9  | 31.7  | 29.6  | 31.6  | 31.9  | 28.6  | 31.7  | 22.7  | 26.7  | 27.6  | 30.4  | 28.3  | 28.1  |
| CaO                            | 0.8           | 0.1   | 1.2   | 0.2   | 0.1   | 0.5   | 0.1   | 0.1   | 0.2   | 0.1   | 8.8   | 2.8   | 2.3   | 0.1   | 1.3   | 0.9   |
| Na <sub>2</sub> O              | 0.0           | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.6   | 0.3   | 0.3   | 0.0   | 0.2   | 0.1   |
| K <sub>2</sub> O               | 0.0           | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| F                              | 0.0           | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Cl                             | 0.0           | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| NiO                            | 0.1           | 0.0   | 0.1   | 0.0   | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.0   | 0.1   | 0.1   | 0.1   | 0.1   | 0.0   | 0.0   |
| V <sub>2</sub> O <sub>3</sub>  | 0.0           | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.1   |
| P <sub>2</sub> O <sub>5</sub>  |               |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Total                          | 99.4          | 98.5  | 98.6  | 99.1  | 100.0 | 100.2 | 100.7 | 100.8 | 100.9 | 101.0 | 99.1  | 99.8  | 100.3 | 100.3 | 100.4 | 100.9 |

**Cont. Appendix E: Mineral Chemistry from Mangabal Complex**

| Sequence | Orthopyroxene |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|----------|---------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|          | S             | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     |
| Sample   | MNS18         | MNS18 | MNS18 | MNS18 | MNS18 | MNS18 | MNS18 | MNS18 | MNS19 | MNS19 | MNS19 | MNS19 | MNS19 | MNS19 | MNS19 | MNS19 |
| No.      | 5             | 6     | 4     | 9     | 3     | 8     | 7     | 1     | 5     | 8     | 2     | 13    | 1     | 7     | 10    | 11    |
| SiO2     | 53.3          | 53.3  | 54.0  | 55.0  | 53.9  | 54.8  | 55.0  | 56.0  | 55.1  | 55.1  | 53.8  | 54.5  | 54.5  | 55.4  | 56.3  | 56.2  |
| TiO2     | 0.0           | 0.1   | 0.0   | 0.0   | 0.6   | 0.2   | 0.1   | 0.1   | 0.0   | 0.2   | 0.1   | 0.4   | 0.0   | 0.1   | 0.1   | 0.1   |
| Al2O3    | 3.0           | 2.9   | 2.7   | 2.5   | 3.1   | 2.4   | 2.9   | 2.0   | 1.3   | 1.8   | 2.8   | 2.1   | 2.3   | 0.8   | 0.8   | 1.1   |
| Cr2O3    | 0.4           | 0.4   | 0.4   | 0.2   | 0.3   | 0.1   | 0.0   | 0.0   | 0.0   | 0.4   | 0.8   | 0.3   | 0.0   | 0.0   | 0.3   | 0.2   |
| FeO      | 13.2          | 12.8  | 10.8  | 10.6  | 10.5  | 10.6  | 11.0  | 11.1  | 12.9  | 11.2  | 10.5  | 12.3  | 13.0  | 11.9  | 9.6   | 10.3  |
| MnO      | 0.3           | 0.2   | 0.2   | 0.3   | 0.2   | 0.3   | 0.1   | 0.3   | 0.3   | 0.1   | 0.3   | 0.4   | 0.4   | 0.4   | 0.2   | 0.2   |
| MgO      | 26.3          | 27.0  | 29.7  | 30.2  | 29.2  | 31.0  | 30.8  | 30.8  | 29.0  | 28.3  | 30.7  | 28.7  | 28.7  | 30.5  | 30.8  | 31.0  |
| CaO      | 1.5           | 1.8   | 1.3   | 0.5   | 1.2   | 0.1   | 0.1   | 0.1   | 0.2   | 2.0   | 0.2   | 0.7   | 0.3   | 0.1   | 1.4   | 1.1   |
| Na2O     | 0.3           | 0.3   | 0.1   | 0.1   | 0.3   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| K2O      | 0.0           | 0.1   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| F        | 0.0           | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Cl       | 0.0           | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| NiO      | 0.2           | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.1   | 0.1   | 0.1   | 0.1   | 0.2   | 0.1   |
| V2O3     | 0.1           | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.1   | 0.1   | 0.0   | 0.1   |
| P2O5     |               |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Total    | 98.6          | 98.7  | 99.2  | 99.3  | 99.4  | 99.6  | 100.0 | 100.5 | 98.9  | 99.3  | 99.3  | 99.3  | 99.4  | 99.6  | 99.6  | 100.4 |

## Appendix E: Mineral Chemistry from Mangabal Complex

|       |       |       |       |       |       |       | Orthopyroxene |       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|---------------|-------|-------|-------|-------|-------|-------|-------|-------|
| S     | S     | S     | S     | S     | S     | S     | S             | S     | S     | S     | S     | S     | S     | S     | S     |
| MNS19 | MNS19 | MNS21 | MNS21 | MNS21 | MNS21 | MNS21 | MNS24         | MNS24 | MNS24 | MNS24 | MNS24 | MNS24 | MNS26 | MNS26 | MNS26 |
| 12    | 9     | 4     | 3     | 2     | 1     | 5     | 2             | 1     | 5     | 3     | 6     | 4     | 2     | 3     | 1     |
| 54.2  | 55.3  | 54.7  | 55.2  | 55.8  | 56.0  | 54.4  | 55.0          | 55.7  | 55.8  | 55.8  | 55.8  | 56.5  | 53.7  | 53.7  | 54.1  |
| 0.2   | 0.2   | 0.1   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.8   |
| 2.6   | 2.1   | 2.0   | 1.1   | 0.5   | 0.7   | 2.8   | 0.9           | 0.8   | 0.9   | 0.8   | 1.1   | 0.8   | 2.2   | 2.2   | 1.8   |
| 0.3   | 0.4   | 0.3   | 0.1   | 0.0   | 0.1   | 0.2   | 0.1           | 0.1   | 0.0   | 0.1   | 0.1   | 0.1   | 0.3   | 0.1   | 0.0   |
| 12.1  | 11.4  | 12.1  | 12.8  | 12.9  | 12.9  | 12.4  | 13.7          | 12.7  | 12.6  | 12.9  | 13.1  | 13.3  | 16.9  | 17.3  | 17.9  |
| 0.4   | 0.3   | 0.3   | 0.5   | 0.3   | 0.5   | 0.3   | 0.5           | 0.4   | 0.3   | 0.5   | 0.3   | 0.4   | 0.4   | 0.4   | 0.6   |
| 29.7  | 29.4  | 29.4  | 29.5  | 30.2  | 29.9  | 29.9  | 29.3          | 29.7  | 30.0  | 29.5  | 29.8  | 29.5  | 25.5  | 25.8  | 25.6  |
| 1.0   | 1.6   | 0.3   | 0.1   | 0.2   | 0.1   | 0.5   | 0.1           | 0.2   | 0.2   | 0.1   | 0.2   | 0.2   | 0.2   | 0.2   | 0.3   |
| 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.1   | 0.1   | 0.0           | 0.0   | 0.1   | 0.1   | 0.1   | 0.0   | 0.0   | 0.1   | 0.0   |
| 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.1   | 0.0   | 0.0           | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 100.6 | 101.0 | 99.2  | 99.3  | 100.1 | 100.4 | 100.5 | 99.5          | 99.7  | 99.8  | 99.9  | 100.5 | 101.0 | 99.3  | 99.9  | 101.1 |

**Cont. Appendix E: Mineral Chemistry from Mangabal Complex**

| Sequence                       | Orthopyroxene |       |       |       |       |        |        |       |       |       |       |       |       |       |       |
|--------------------------------|---------------|-------|-------|-------|-------|--------|--------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                | N             | N     | N     | N     | N     | N      | N      | N     | N     | N     | N     | N     | N     | N     | N     |
| Sample                         | MNN02         | MNN03 | MNN03 | MNN05 | MNN05 | MNN06  | MNN07  | MNN12 | MNN12 | MNN12 | MNN12 | MNN12 | MNN12 | MNN12 | MNN12 |
| Number                         | 2             | 1     | 4     | 1     | 2     | 1      | 1      | 4     | 5     | 6     | 7     | 12    | 13    | 14    | 15    |
| SiO <sub>2</sub>               | 53.21         | 55.99 | 54.26 | 55.60 | 53.97 | 56.37  | 55.58  | 51.94 | 52.47 | 49.69 | 52.35 | 52.07 | 52.44 | 51.52 | 51.59 |
| TiO <sub>2</sub>               | 0.81          | 0.00  | 0.05  | 0.00  | 0.00  | 0.12   | 0.15   | 0.09  | 0.08  | 1.94  | 0.19  | 0.21  | 0.00  | 0.14  | 0.41  |
| Al <sub>2</sub> O <sub>3</sub> | 2.81          | 0.61  | 3.89  | 1.53  | 1.64  | 1.31   | 1.09   | 1.79  | 2.65  | 1.86  | 2.06  | 2.15  | 2.15  | 2.07  | 2.07  |
| Cr <sub>2</sub> O <sub>3</sub> | 0.44          | 0.00  | 0.02  | 0.17  | 0.08  | 0.09   | 0.08   | 0.09  | 0.06  | 0.04  | 0.08  | 0.09  | 0.04  | 0.15  | 0.10  |
| FeO                            | 9.64          | 9.75  | 11.40 | 10.83 | 10.80 | 12.25  | 13.58  | 21.93 | 17.44 | 23.37 | 18.98 | 16.93 | 18.48 | 21.20 | 20.37 |
| MnO                            | 0.21          | 0.32  | 0.27  | 0.25  | 0.29  | 0.26   | 0.26   | 0.50  | 0.36  | 0.45  | 0.34  | 0.37  | 0.36  | 0.46  | 0.44  |
| MgO                            | 29.68         | 32.18 | 29.36 | 30.52 | 31.36 | 29.68  | 29.58  | 21.76 | 24.31 | 20.87 | 22.61 | 23.82 | 23.28 | 21.11 | 21.63 |
| CaO                            | 1.61          | 0.07  | 0.23  | 0.10  | 0.13  | 0.96   | 0.06   | 1.20  | 1.55  | 0.74  | 2.30  | 2.82  | 1.70  | 1.70  | 1.66  |
| Na <sub>2</sub> O              | 0.04          | 0.02  | 0.05  | 0.01  | 0.04  | 0.08   | 0.04   | 0.00  | 0.12  | 0.03  | 0.05  | 0.07  | 0.08  | 0.03  | 0.05  |
| K <sub>2</sub> O               | 0.02          | 0.00  | 0.01  | 0.01  | 0.06  | 0.01   | 0.00   | 0.02  | 0.00  | 0.00  | 0.01  | 0.00  | 0.02  | 0.03  | 0.01  |
| F                              |               |       |       |       |       |        |        |       |       |       |       |       |       |       |       |
| Cl                             |               |       |       |       |       |        |        |       |       |       |       |       |       |       |       |
| NiO                            |               |       |       |       |       |        |        |       |       |       |       |       |       |       |       |
| V <sub>2</sub> O <sub>3</sub>  |               |       |       |       |       |        |        |       |       |       |       |       |       |       |       |
| P <sub>2</sub> O <sub>5</sub>  |               |       |       |       |       |        |        |       |       |       |       |       |       |       |       |
| Total                          | 98.47         | 98.94 | 99.53 | 99.02 | 98.36 | 101.12 | 100.41 | 99.32 | 99.04 | 98.98 | 98.97 | 98.53 | 98.56 | 98.41 | 98.31 |

## Cont. Appendix E: Mineral Chemistry from Mangabal Complex

| Sequence | Orthopyroxene |        |        |        |        |       |       |       |       |       |       |        |        |        |        |        |
|----------|---------------|--------|--------|--------|--------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|--------|
|          | N             | N      | N      | N      | N      | N     | N     | N     | N     | N     | N     | N      | N      | N      | N      | N      |
| Sample   | MNN14         | MNN14  | MNN14  | MNN14  | MNN14  | MNN14 | MNN14 | MNN14 | MNN14 | MNN14 | MNN14 | MNN16  | MNN16  | MNN16  | MNN16  | MNN16  |
| Number   | 2             | 4      | 5      | 6      | 8      | 11    | 13    | 15    | 16    | 17    | 18    | 12     | 13     | 14     | 15     | 18     |
| SiO2     | 54.20         | 53.79  | 53.65  | 53.37  | 54.12  | 54.04 | 53.56 | 53.58 | 54.70 | 53.72 | 53.89 | 53.10  | 53.39  | 53.31  | 53.02  | 54.14  |
| TiO2     | 0.00          | 0.06   | 0.20   | 0.00   | 0.00   | 0.12  | 0.15  | 0.79  | 0.09  | 0.34  | 0.27  | 0.01   | 0.04   | 0.01   | 0.39   | 0.03   |
| Al2O3    | 2.15          | 1.89   | 2.03   | 2.18   | 1.99   | 2.21  | 2.09  | 2.25  | 1.62  | 2.08  | 2.04  | 3.07   | 2.93   | 2.85   | 2.67   | 2.44   |
| Cr2O3    | 0.35          | 0.06   | 0.04   | 0.24   | 0.20   | 0.11  | 0.12  | 0.22  | 0.23  | 0.169 | 0.031 | 0.237  | 0.18   | 0.283  | 0.041  | 0.031  |
| FeO      | 18.83         | 19.03  | 18.95  | 18.59  | 18.47  | 16.47 | 17.85 | 15.80 | 14.72 | 16.51 | 16.78 | 18.37  | 18.61  | 16.99  | 18.91  | 19.04  |
| MnO      | 0.39          | 0.37   | 0.37   | 0.56   | 0.22   | 0.37  | 0.60  | 0.32  | 0.33  | 0.31  | 0.32  | 0.41   | 0.33   | 0.35   | 0.30   | 0.21   |
| MgO      | 23.87         | 23.64  | 24.65  | 24.12  | 24.85  | 25.16 | 23.98 | 25.21 | 26.73 | 25.60 | 25.02 | 24.97  | 25.27  | 24.99  | 24.27  | 24.97  |
| CaO      | 0.66          | 1.64   | 0.54   | 1.24   | 0.34   | 1.15  | 1.12  | 1.12  | 0.94  | 0.55  | 0.83  | 0.10   | 0.16   | 1.37   | 1.08   | 0.09   |
| Na2O     | 0.04          | 0.03   | 0.05   | 0.02   | 0.00   | 0.01  | 0.05  | 0.10  | 0.00  | 0.01  | 0.05  | 0.04   | 0.00   | 0.01   | 0.02   | 0.01   |
| K2O      | 0.01          | 0.00   | 0.00   | 0.00   | 0.00   | 0.02  | 0.02  | 0.01  | 0.02  | 0.00  | 0.01  | 0.00   | 0.00   | 0.00   | 0.00   | 0.02   |
| F        |               |        |        |        |        |       |       |       |       |       |       |        |        |        |        |        |
| Cl       |               |        |        |        |        |       |       |       |       |       |       |        |        |        |        |        |
| NiO      |               |        |        |        |        |       |       |       |       |       |       |        |        |        |        |        |
| V2O3     |               |        |        |        |        |       |       |       |       |       |       |        |        |        |        |        |
| P2O5     |               |        |        |        |        |       |       |       |       |       |       |        |        |        |        |        |
| Total    | 100.49        | 100.52 | 100.50 | 100.31 | 100.19 | 99.67 | 99.54 | 99.39 | 99.38 | 99.29 | 99.25 | 100.30 | 100.91 | 100.16 | 100.70 | 100.98 |

**Cont. Appendix E: Mineral Chemistry from Mangabal Complex**

| Plagioclase                    |        |        |        |        |        |        |        |        |        |        |        |        |        |
|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Sequence                       | S      | S      | S      | S      | S      | S      | S      | S      | S      | S      | S      | S      | S      |
| Sample                         | MNS07  | MNS07  | MNS07  | MNS07  | MNS07  | MNS09  | MNS11  | MNS11  | MNS11  | MNS11  | MNS11  | MNS11  | MNS11  |
| No.                            | 1      | 2      | 3      | 4      | 5      | 1      | 1      | 3      | 5      | 6      | 7      | 8      | 9      |
| SiO <sub>2</sub>               | 53.864 | 59.852 | 50.127 | 48.39  | 52.368 | 52.962 | 47.569 | 51.206 | 47.058 | 52.88  | 52.609 | 52.497 | 52.462 |
| TiO <sub>2</sub>               | 0.009  | 0.01   | 0.218  | 0.05   | 0.123  | 0.108  | 0      | 0.267  | 0      | 0.035  | 0.054  | 0.094  | 0.078  |
| Al <sub>2</sub> O <sub>3</sub> | 28.863 | 24.636 | 30.735 | 32.483 | 29.604 | 28.716 | 32.806 | 30.045 | 33.835 | 30.257 | 30.033 | 29.702 | 29.307 |
| Cr <sub>2</sub> O <sub>3</sub> | 0.033  | 0      | 0      | 0.022  | 0.083  | 0      | 0.094  | 0.215  | 0      | 0.129  | 0.048  | 0.201  | 0      |
| FeO                            | 0.033  | 0.096  | 0.119  | 0.048  | 0.13   | 0.099  | 0.067  | 0.056  | 0.089  | 0      | 0.078  | 0.038  | 0.118  |
| MnO                            | 0.01   | 0.034  | 0      | 0      | 0.019  | 0.07   | 0.067  | 0.058  | 0.06   | 0.026  | 0      | 0.05   | 0.115  |
| MgO                            | 0      | 0.02   | 0.079  | 0      | 0      | 0.005  | 0.016  | 0.007  | 0      | 0.019  | 0.016  | 0.007  | 0      |
| CaO                            | 11.649 | 6.917  | 14.24  | 16.216 | 12.785 | 12.008 | 16.128 | 12.962 | 16.564 | 12.331 | 12.229 | 12.31  | 12.092 |
| Na <sub>2</sub> O              | 5.399  | 8.109  | 3.568  | 2.379  | 4.312  | 4.611  | 1.831  | 3.756  | 1.627  | 4.095  | 4.026  | 3.912  | 4.117  |
| K <sub>2</sub> O               | 0.088  | 0.07   | 0.032  | 0.044  | 0.065  | 0.096  | 0.026  | 0.114  | 0.037  | 0.085  | 0.102  | 0.071  | 0.136  |
| F                              | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| Cl                             | 0.015  | 0      | 0.008  | 0      | 0.001  | 0.012  | 0.004  | 0.003  | 0      | 0.012  | 0.003  | 0      | 0.033  |
| NiO                            | 0      | 0.011  | 0      | 0      | 0.054  | 0.011  | 0.079  | 0      | 0      | 0.037  | 0      | 0.009  | 0.015  |
| V <sub>2</sub> O <sub>3</sub>  | 0      | 0      | 0.027  | 0      | 0      | 0.002  | 0.01   | 0      | 0.018  | 0.015  | 0.027  | 0      | 0.065  |
| P <sub>2</sub> O <sub>5</sub>  |        |        |        |        |        |        | 0.062  | 0.059  | 0      | 0.049  | 0.049  | 0.023  | 0.026  |
| Total                          | 99.96  | 99.755 | 99.151 | 99.632 | 99.544 | 98.697 | 98.758 | 98.747 | 99.288 | 99.967 | 99.273 | 98.914 | 98.557 |



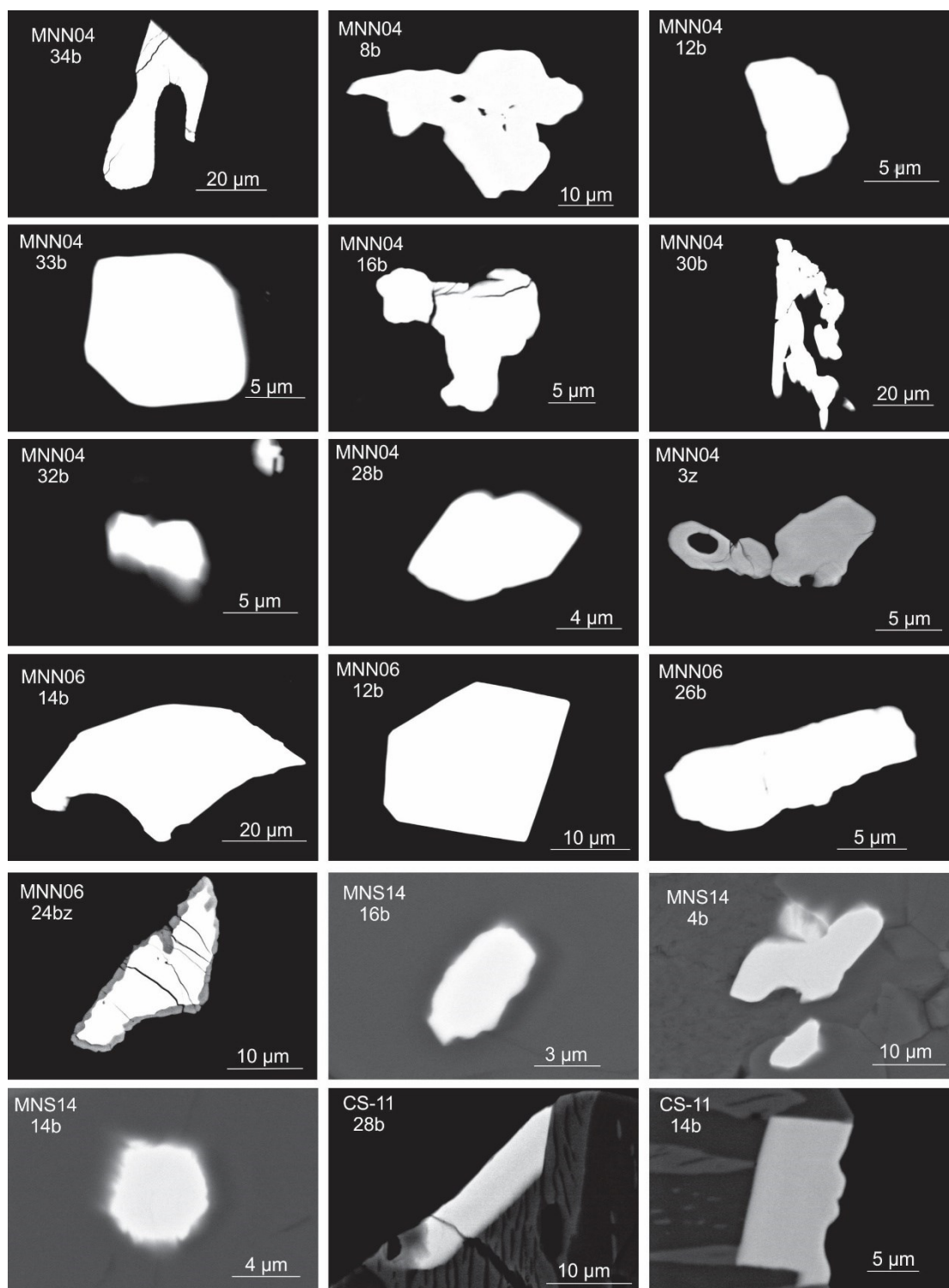
## Cont. Appendix E: Mineral Chemistry from Mangabal Complex

| Plagioclase                    |         |        |        |        |        |         |        |        |        |        |        |        |        |        |
|--------------------------------|---------|--------|--------|--------|--------|---------|--------|--------|--------|--------|--------|--------|--------|--------|
| Sequence                       | S       | S      | S      | S      | S      | S       | S      | S      | S      | S      | S      | S      | S      | S      |
| Sample                         | MNS11   | MNS11  | MNS11  | MNS11  | MNS11  | MNS12   | MNS12  | MNS12  | MNS12  | MNS12  | MNS13  | MNS13  | MNS13  | MNS13  |
| No.                            | 10      | 11     | 12     | 13     | 14     | 1       | 2      | 3      | 4      | 5      | 1      | 2      | 3      | 4      |
| SiO <sub>2</sub>               | 53.553  | 52.725 | 52.107 | 51.944 | 53.123 | 58.792  | 58.974 | 60.011 | 59.146 | 60.299 | 51.309 | 54.861 | 47.221 | 51.684 |
| TiO <sub>2</sub>               | 0.129   | 0.024  | 0.019  | 0.073  | 0.019  | 0.038   | 0.074  | 0.04   | 0.064  | 0.064  | 0      | 0      | 0      | 0.064  |
| Al <sub>2</sub> O <sub>3</sub> | 29.881  | 29.665 | 29.419 | 29.37  | 28.965 | 26.077  | 25.186 | 23.879 | 24.526 | 24.105 | 29.427 | 26.886 | 32.211 | 29.017 |
| Cr <sub>2</sub> O <sub>3</sub> | 0       | 0.012  | 0.073  | 0.119  | 0      | 0.07    | 0      | 0.003  | 0.119  | 0      | 0.008  | 0      | 0      | 0.06   |
| FeO                            | 0.123   | 0.164  | 0.154  | 0.407  | 0.053  | 0.051   | 0.012  | 0      | 0.021  | 0.043  | 0      | 0.088  | 0.015  | 0.182  |
| MnO                            | 0       | 0      | 0.059  | 0.042  | 0.019  | 0       | 0.005  | 0      | 0.061  | 0.107  | 0.009  | 0.032  | 0      | 0      |
| MgO                            | 0.017   | 0.005  | 0.012  | 0.022  | 0      | 0.034   | 0      | 0.03   | 0      | 0      | 0      | 0      | 0.003  | 0.184  |
| CaO                            | 12.08   | 12.156 | 12.269 | 12.47  | 12.63  | 8.608   | 7.47   | 6.482  | 7.237  | 6.649  | 13.372 | 11.014 | 16.813 | 12.329 |
| Na <sub>2</sub> O              | 4.504   | 3.949  | 4.204  | 3.788  | 4.362  | 7.026   | 7.57   | 7.958  | 7.705  | 7.962  | 4.238  | 5.736  | 1.867  | 4.384  |
| K <sub>2</sub> O               | 0.089   | 0.268  | 0.078  | 0.108  | 0.123  | 0.014   | 0.072  | 0.115  | 0.059  | 0.085  | 0.041  | 0.056  | 0.038  | 0.109  |
| F                              | 0       | 0      | 0      | 0      | 0      | 0       | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| Cl                             | 0       | 0.017  | 0.022  | 0      | 0      | 0.005   | 0.036  | 0      | 0      | 0.013  | 0      | 0.02   | 0      | 0.031  |
| NiO                            | 0       | 0.003  | 0      | 0.043  | 0      | 0.004   | 0      | 0      | 0      | 0.043  | 0      | 0.022  | 0      | 0.007  |
| V <sub>2</sub> O <sub>3</sub>  | 0.019   | 0.015  | 0      | 0.033  | 0      | 0.015   | 0.018  | 0      | 0      | 0.005  | 0.057  | 0.038  | 0.019  | 0.025  |
| P <sub>2</sub> O <sub>5</sub>  | 0       | 0      | 0.065  | 0.016  |        |         |        |        |        |        |        |        |        |        |
| Total                          | 100.395 | 98.999 | 98.476 | 98.435 | 99.294 | 100.733 | 99.409 | 98.518 | 98.938 | 99.372 | 98.461 | 98.748 | 98.187 | 98.069 |

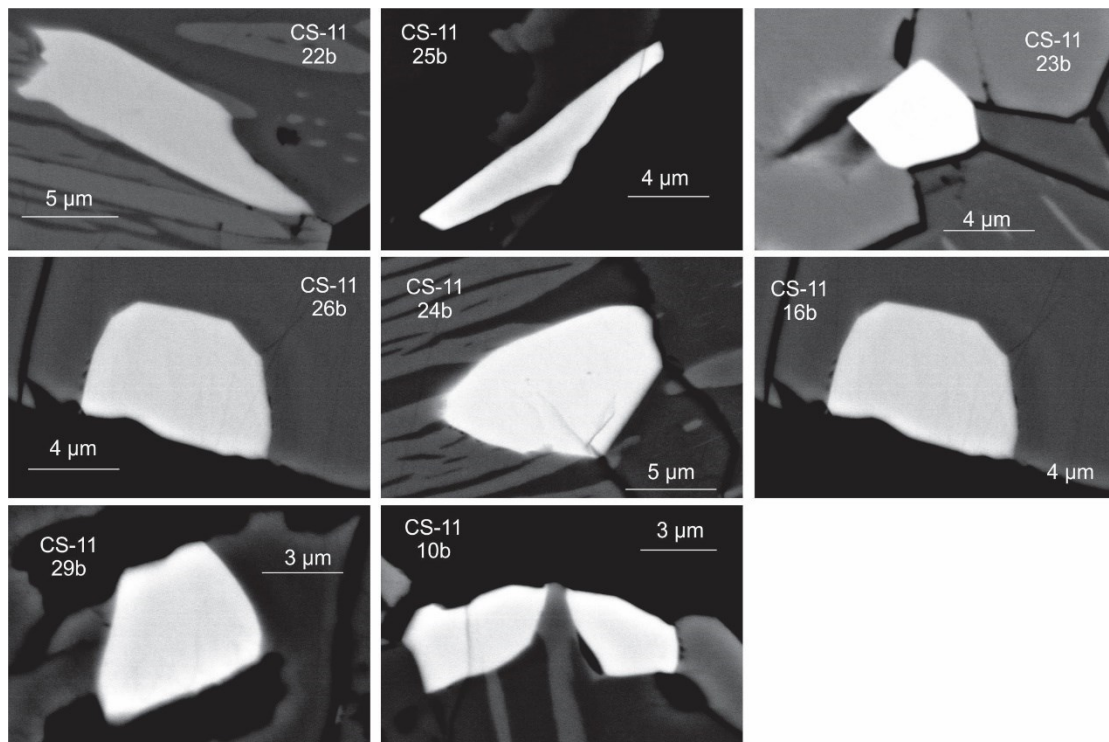
## Cont. Appendix E: Mineral Chemistry from Mangabal Complex

| Plagioclase |        |        |        |         |        |         |        |         |        |        |        |        |        |         |         |         |        |
|-------------|--------|--------|--------|---------|--------|---------|--------|---------|--------|--------|--------|--------|--------|---------|---------|---------|--------|
| Sequence    | S      | S      | S      | S       | S      | S       | N      | N       | N      | N      | N      | N      | N      | N       | N       | N       | N      |
| Sample      | MNS13  | MNS13  | MNS14  | MNS16   | MNS16  | MNS16   | MNN01  | MNN12   | MNN12  | MNN12  | MNN14  | MNN14  | MNN14  | MNN16   | MNN16   | MNN16   | MNN16  |
| No.         | 5      | 6      | 1      | 1       | 2      | 3       | 1      | 1       | 2      | 3      | 1      | 2      | 3      | 1       | 2       | 3       | 4      |
| SiO2        | 55.048 | 54.921 | 53.04  | 52.83   | 52.667 | 55.019  | 51.724 | 54.446  | 56.572 | 53.087 | 53.386 | 53.401 | 53.18  | 46.964  | 53.397  | 53.581  | 53.629 |
| TiO2        | 0.059  | 0      | 0.222  | 0.147   | 0      | 0.043   | 0.166  | 0       | 0      | 0.113  | 0.177  | 0.26   | 0.069  | 0.064   | 0       | 0.064   | 0.064  |
| Al2O3       | 27.102 | 26.779 | 28.578 | 29.897  | 28.937 | 28.286  | 29.014 | 28.8    | 27.292 | 28.604 | 28.641 | 27.966 | 28.302 | 34.454  | 29.655  | 29.605  | 28.839 |
| Cr2O3       | 0      | 0.085  | 0.06   | 0.059   | 0      | 0.011   | 0      | 0       | 0      | 0      | 0.037  | 0.06   | 0.026  | 0       | 0       | 0.06    | 0      |
| FeO         | 0.022  | 0.025  | 0.004  | 0.087   | 0.109  | 0.05    | 0.429  | 0.236   | 0.05   | 0.21   | 0.104  | 0.078  | 0.037  | 0.264   | 0.404   | 0.033   | 0.05   |
| MnO         | 0      | 0      | 0.041  | 0.002   | 0      | 0.074   | 0.096  | 0.14    | 0      | 0      | 0.011  | 0.005  | 0      | 0       | 0.03    | 0.006   | 0      |
| MgO         | 0      | 0      | 0.021  | 0       | 0.019  | 0.011   | 0.249  | 0.117   | 0      | 0.025  | 0      | 0.054  | 0.009  | 0       | 0       | 0.027   | 0.012  |
| CaO         | 10.888 | 10.648 | 12.274 | 13.207  | 12.571 | 11.813  | 11.513 | 11.182  | 9.299  | 11.784 | 12.08  | 12.06  | 11.914 | 17.48   | 12.553  | 12.31   | 11.869 |
| Na2O        | 5.453  | 5.585  | 4.805  | 4.48    | 4.306  | 4.989   | 4.962  | 5.45    | 6.2    | 5.017  | 4.848  | 4.834  | 4.705  | 1.329   | 4.723   | 4.588   | 4.957  |
| K2O         | 0.117  | 0.18   | 0.007  | 0.076   | 0.048  | 0.055   | 0.105  | 0.32    | 0.152  | 0.184  | 0.101  | 0.103  | 0.077  | 0       | 0.065   | 0.097   | 0.085  |
| F           | 0      | 0      | 0      | 0       | 0      | 0       | 0      | 0       | 0      | 0      | 0      | 0      | 0      | 0       | 0       | 0       | 0      |
| Cl          | 0.008  | 0.061  | 0      | 0       | 0.005  | 0.012   | 0.015  | 0       | 0      | 0.018  | 0      | 0.02   | 0.006  | 0.015   | 0       | 0.018   | 0      |
| NiO         | 0.025  | 0      | 0      | 0.011   | 0.05   | 0.065   | 0.007  | 0       | 0.029  | 0      | 0      | 0      | 0      | 0.012   | 0       | 0       | 0      |
| V2O3        | 0.042  | 0.033  | 0.019  | 0       | 0      | 0.019   | 0.047  | 0.002   | 0      | 0.01   | 0      | 0      | 0      | 0.039   | 0       | 0       | 0.048  |
| P2O5        |        |        |        |         |        |         |        |         |        |        |        |        |        |         |         |         |        |
| Total       | 98.762 | 98.303 | 99.071 | 100.796 | 98.711 | 100.444 | 98.324 | 100.693 | 99.594 | 99.048 | 99.385 | 98.836 | 98.324 | 100.618 | 100.827 | 100.385 | 99.553 |

**Appendix F: BSE images of analyzed baddeleyite and zircons of Mangabal Complex and Córrego Intrusion.**



**Appendix F: BSE images of analyzed baddeleyite and zircons of Mangabal Complex and Córrego Intrusion.**





## Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.

Mn: Mangabal; AMB: Americano do Brasil; S: Southern; N: Northern

| Complex                        | Amphibole |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |      |
|--------------------------------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
|                                | AMB       | AMB   | AMB   | AMB   | AMB   | AMB   | AMB   | AMB   | AMB   | AMB   | AMB   | AMB   | AMB   | AMB   | AMB   | AMB   | AMB  |
|                                | N         | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N    |
|                                | AMB31     | AMB31 | AMB31 | AMB31 | AMB31 | AMB31 | AMB31 | AMB31 | AMB31 | AMB31 | AMB31 | AMB31 | AMB31 | AMB31 | AMB31 | AMB31 | N    |
| DrillCore                      | 7         | 7     | 7     | 7     | 7     | 7     | 7     | 7     | 7     | 7     | 7     | 7     | 7     | 7     | 7     | 7     | 7    |
| Sample                         | 4         | 4     | 4     | 13    | 13    | 13    | 13    | 13    | 13    | 13    | 13    | 13    | 13    | 14    | 14    | 19    | 19   |
| No.                            | 24        | 26    | 22    | 37    | 38    | 41    | 39    | 35    | 58    | 46    | 22    | 27    | 69    | 66    | 24    | 25    | 26   |
| SiO <sub>2</sub>               | 42.3      | 43.6  | 42.5  | 56.0  | 56.3  | 56.9  | 55.2  | 49.2  | 46.8  | 58.1  | 42.6  | 47.7  | 42.5  | 41.1  | 43.0  | 42.8  | 43.2 |
| TiO <sub>2</sub>               | 0.9       | 1.1   | 1.8   | 0.3   | 0.1   | 0.3   | 0.1   | 0.6   | 0.3   | 0.0   | 1.3   | 0.8   | 1.2   | 1.3   | 1.8   | 1.3   | 1.7  |
| Al <sub>2</sub> O <sub>3</sub> | 13.4      | 13.2  | 11.9  | 2.1   | 2.3   | 1.3   | 2.6   | 4.0   | 11.3  | 1.6   | 12.9  | 9.1   | 13.1  | 14.5  | 13.9  | 14.0  | 14.0 |
| FeO                            | 7.2       | 6.4   | 6.8   | 4.0   | 3.3   | 3.7   | 3.7   | 4.5   | 7.1   | 3.1   | 8.6   | 5.3   | 8.8   | 16.6  | 8.4   | 8.6   | 8.5  |
| MnO                            | 0.1       | 0.1   | 0.0   | 0.1   | 0.1   | 0.0   | 0.1   | 0.0   | 0.1   | 0.1   | 0.1   | 0.0   | 0.0   | 0.1   | 0.1   | 0.1   | 0.2  |
| MgO                            | 16.7      | 17.4  | 17.5  | 21.5  | 21.7  | 21.5  | 21.6  | 17.3  | 17.1  | 22.2  | 15.9  | 18.1  | 15.9  | 9.0   | 15.3  | 15.0  | 15.1 |
| CaO                            | 11.0      | 11.4  | 12.0  | 13.0  | 12.6  | 12.5  | 12.5  | 19.8  | 12.5  | 13.2  | 11.7  | 12.5  | 11.8  | 10.6  | 11.3  | 11.9  | 11.5 |
| Na <sub>2</sub> O              | 3.1       | 3.2   | 2.9   | 0.4   | 0.6   | 0.3   | 0.7   | 0.8   | 2.1   | 0.3   | 2.7   | 2.2   | 2.4   | 3.1   | 2.9   | 2.9   | 2.7  |
| K <sub>2</sub> O               | 0.5       | 0.5   | 0.4   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.4   | 0.1   | 0.4   | 0.4   | 0.2   | 0.2   | 0.3  |
| F                              | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0  |
| Cl                             | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.2   | 0.0   | 0.0   | 0.0  |
| Cr <sub>2</sub> O <sub>3</sub> | 1.3       | 1.1   | 0.8   | 0.2   | 0.0   | 0.0   | 0.0   | 0.4   | 0.8   | 0.0   | 0.5   | 0.5   | 0.4   | 0.0   | 0.1   | 0.0   | 0.0  |
| NiO                            | 0.1       | 0.1   | 0.1   | 0.0   | 0.1   | 0.1   | 0.0   | 0.0   | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0  |
| V <sub>2</sub> O <sub>3</sub>  | 0.1       | 0.1   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.1   | 0.1   | 0.0   | 0.1   | 0.1   | 0.1   | 0.1  |
| BaO                            | 0.0       | 0.0   | 0.1   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.2   | 0.1   | 0.0   | 0.0   | 0.0  |
| Total                          | 96.5      | 98.2  | 96.7  | 97.7  | 97.1  | 96.6  | 96.6  | 96.7  | 98.2  | 98.7  | 96.9  | 96.6  | 96.8  | 97.1  | 97.1  | 97.0  | 97.3 |

## Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.

| Complex<br>Sequenc<br>e<br>DrillCor<br>e<br>Sample | Amphibole       |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|----------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                                    | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             |
|                                                    | N<br>AMB31<br>7 | N<br>AMB31<br>7 | N<br>AMB31<br>7 | N<br>AMB31<br>7 | N<br>AMB31<br>7 | N<br>AMB31<br>7 | N<br>AMB31<br>7 | N<br>AMB31<br>7 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 |
| No.                                                | 27              | 30              | 31              | 113             | 116             | 117             | 62              | 63              | 8               | 29              | 30              | 32              | 33              | 37              | 38              | 41              | 42              |
| SiO <sub>2</sub>                                   | 43.3            | 42.7            | 43.1            | 43.2            | 42.7            | 43.6            | 43.9            | 43.6            | 44.7            | 47.5            | 53.4            | 52.2            | 41.0            | 45.9            | 45.1            | 45.6            | 43.3            |
| TiO <sub>2</sub>                                   | 1.5             | 1.7             | 1.5             | 1.2             | 1.5             | 1.2             | 0.7             | 1.2             | 0.9             | 1.0             | 0.4             | 0.4             | 0.1             | 1.3             | 2.2             | 1.8             | 1.3             |
| Al <sub>2</sub> O <sub>3</sub>                     | 13.8            | 13.6            | 13.6            | 12.7            | 12.9            | 13.8            | 11.7            | 12.1            | 13.7            | 10.4            | 5.1             | 6.6             | 23.8            | 10.6            | 10.6            | 11.1            | 13.4            |
| FeO                                                | 9.2             | 8.7             | 8.6             | 8.0             | 6.9             | 7.5             | 6.7             | 6.6             | 11.6            | 12.1            | 10.1            | 9.8             | 10.0            | 13.3            | 13.4            | 12.6            | 13.0            |
| MnO                                                | 0.1             | 0.2             | 0.1             | 0.1             | 0.0             | 0.1             | 0.0             | 0.1             | 0.1             | 0.2             | 0.1             | 0.3             | 0.3             | 0.2             | 0.2             | 0.2             | 0.3             |
| MgO                                                | 15.4            | 15.4            | 15.4            | 16.8            | 16.6            | 17.0            | 17.5            | 17.4            | 12.9            | 13.5            | 16.8            | 16.1            | 0.0             | 12.8            | 12.2            | 12.8            | 11.8            |
| CaO                                                | 11.7            | 11.7            | 11.7            | 11.4            | 11.3            | 11.3            | 11.5            | 11.6            | 12.0            | 11.2            | 12.4            | 12.3            | 21.6            | 12.0            | 11.9            | 11.6            | 11.6            |
| Na <sub>2</sub> O                                  | 2.9             | 2.8             | 2.9             | 2.7             | 2.9             | 2.8             | 3.2             | 3.6             | 1.6             | 1.5             | 0.6             | 0.8             | 0.9             | 1.5             | 1.5             | 1.7             | 1.6             |
| K <sub>2</sub> O                                   | 0.2             | 0.2             | 0.3             | 0.3             | 0.3             | 0.3             | 0.3             | 0.3             | 0.4             | 0.4             | 0.1             | 0.1             | 0.0             | 0.5             | 0.5             | 0.5             | 0.5             |
| F                                                  | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             |
| Cl                                                 | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             |
| Cr <sub>2</sub> O <sub>3</sub>                     | 0.1             | 0.0             | 0.0             | 1.2             | 1.2             | 0.4             | 0.4             | 0.5             | 0.0             | 0.0             | 0.0             | 0.0             | 0.1             | 0.0             | 0.0             | 0.0             | 0.0             |
| NiO                                                | 0.1             | 0.0             | 0.0             | 0.0             | 0.1             | 0.2             | 0.0             | 0.0             | 0.0             | 0.1             | 0.1             | 0.0             | 0.0             | 0.0             | 0.1             | 0.1             | 0.0             |
| V <sub>2</sub> O <sub>3</sub>                      | 0.1             | 0.1             | 0.1             | 0.0             | 0.0             | 0.0             | 0.0             | 0.1             | 0.1             | 0.1             | 0.1             | 0.1             | 0.0             | 0.1             | 0.1             | 0.1             | 0.1             |
| BaO                                                | 0.0             | 0.0             | 0.1             | 0.2             | 0.0             | 0.0             | 0.1             | 0.0             |                 | 0.0             | 0.0             | 0.0             | 0.0             | 0.1             | 0.1             | 0.1             | 0.0             |
| Total                                              | 98.4            | 97.2            | 97.4            | 97.8            | 96.3            | 98.2            | 96.1            | 97.1            | 98.0            | 97.8            | 99.1            | 98.7            | 97.8            | 98.3            | 97.7            | 98.2            | 97.1            |

## Appendix G Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.

| Complex<br>Sequenc<br>e<br>DrillCor<br>e | Amphibole       |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
|------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                          | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             | AMB             |
|                                          | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 | S<br>AMB36<br>6 |
| Sample                                   | 1               | 1               | 1               | 1               | 2               | 2               | 2               | 3               | 3               | 3               | 3               | 3               | 3               | 3               | 3               | 3               | 3               |
| No.                                      | 44              | 45              | 46              | 48              | 93              | 98              | 95              | 2               | 6               | 7               | 13              | 14              | 16              | 17              | 18              | 22              | 23              |
| SiO <sub>2</sub>                         | 44.4            | 44.8            | 45.9            | 45.3            | 54.8            | 46.7            | 55.4            | 54.8            | 55.2            | 54.1            | 54.3            | 44.3            | 43.0            | 43.2            | 43.7            | 45.6            | 44.4            |
| TiO <sub>2</sub>                         | 1.3             | 0.5             | 0.7             | 1.7             | 0.2             | 1.6             | 0.0             | 0.3             | 0.0             | 0.4             | 0.2             | 1.3             | 2.3             | 5.9             | 1.7             | 1.6             | 1.7             |
| Al <sub>2</sub> O <sub>3</sub>           | 11.0            | 12.1            | 10.7            | 11.5            | 2.7             | 11.6            | 1.6             | 2.2             | 2.2             | 2.7             | 2.7             | 13.8            | 12.9            | 11.3            | 12.8            | 11.7            | 12.2            |
| FeO                                      | 13.4            | 12.8            | 12.1            | 12.1            | 13.2            | 8.1             | 11.4            | 10.4            | 11.1            | 11.7            | 11.6            | 9.9             | 11.0            | 9.7             | 11.0            | 9.6             | 10.4            |
| MnO                                      | 0.1             | 0.1             | 0.2             | 0.2             | 0.1             | 0.0             | 0.2             | 0.4             | 0.5             | 0.3             | 0.5             | 0.1             | 0.1             | 0.2             | 0.2             | 0.1             | 0.1             |
| MgO                                      | 12.4            | 12.4            | 14.2            | 13.3            | 15.8            | 16.0            | 16.8            | 16.9            | 16.8            | 16.3            | 16.4            | 14.1            | 14.0            | 14.4            | 14.4            | 15.2            | 14.6            |
| CaO                                      | 11.9            | 11.7            | 11.7            | 11.6            | 12.0            | 11.7            | 12.1            | 11.8            | 12.4            | 11.9            | 11.8            | 10.9            | 10.9            | 9.7             | 10.9            | 10.9            | 11.0            |
| Na <sub>2</sub> O                        | 1.7             | 1.7             | 1.5             | 1.8             | 0.3             | 1.6             | 0.3             | 0.3             | 0.2             | 0.4             | 0.3             | 2.1             | 2.2             | 1.8             | 2.3             | 1.8             | 2.0             |
| K <sub>2</sub> O                         | 0.5             | 0.4             | 0.3             | 0.4             | 0.0             | 0.6             | 0.0             | 0.0             | 0.0             | 0.0             | 0.1             | 0.3             | 0.3             | 0.3             | 0.3             | 0.4             | 0.3             |
| F                                        | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             |
| Cl                                       | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             |
| Cr <sub>2</sub> O <sub>3</sub>           | 0.0             | 0.1             | 0.0             | 0.0             | 0.0             | 0.2             | 0.1             | 0.1             | 0.0             | 0.0             | 0.0             | 0.1             | 0.1             | 0.2             | 0.1             | 0.1             | 0.0             |
| NiO                                      | 0.0             | 0.0             | 0.0             | 0.0             | 0.1             | 0.1             | 0.0             | 0.1             | 0.0             | 0.1             | 0.0             | 0.1             | 0.1             | 0.0             | 0.0             | 0.0             | 0.0             |
| V <sub>2</sub> O <sub>3</sub>            | 0.2             | 0.1             | 0.1             | 0.1             | 0.1             | 0.1             | 0.0             | 0.0             | 0.0             | 0.1             | 0.0             | 0.1             | 0.2             | 0.2             | 0.1             | 0.1             | 0.2             |
| BaO                                      | 0.1             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.0             | 0.1             | 0.1             | 0.1             | 0.1             | 0.1             |
| Total                                    | 97.0            | 96.8            | 97.4            | 98.2            | 99.1            | 98.3            | 98.0            | 97.5            | 98.5            | 98.1            | 97.7            | 97.1            | 97.1            | 97.1            | 97.6            | 97.1            | 97.1            |



## Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.

| Complex<br>Sequenc<br>e<br>DrillCor<br>e<br>Sample | Amphibole  |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |
|----------------------------------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
|                                                    | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        |
|                                                    | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          |
|                                                    | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 |
|                                                    | 3          | 3          | 3          | 3          | 4          | 4          | 4          | 4          | 4          | 4          | 4          | 4          | 4          | 4          | 4          | 5          | 5          |
| No.                                                | 24         | 27         | 28         | 10         | 5          | 9          | 10         | 11         | 7          | 8          | 18         | 19         | 15         | 16         | 13         | 56         | 57         |
| SiO <sub>2</sub>                                   | 46.2       | 46.0       | 44.3       | 53.3       | 52.7       | 54.9       | 55.2       | 54.3       | 44.4       | 44.1       | 44.5       | 56.7       | 44.5       | 44.8       | 55.2       | 52.5       | 56.5       |
| TiO <sub>2</sub>                                   | 1.1        | 1.5        | 1.0        | 0.1        | 0.2        | 0.1        | 0.1        | 0.1        | 1.8        | 1.6        | 1.4        | 0.0        | 1.9        | 1.2        | 0.1        | 0.3        | 0.1        |
| Al <sub>2</sub> O <sub>3</sub>                     | 12.0       | 11.8       | 13.2       | 3.6        | 4.6        | 2.4        | 1.7        | 3.1        | 12.3       | 12.3       | 11.8       | 0.9        | 11.7       | 12.0       | 2.1        | 5.3        | 1.0        |
| FeO                                                | 9.2        | 10.3       | 10.4       | 12.7       | 16.6       | 17.2       | 14.7       | 16.5       | 11.0       | 11.6       | 10.1       | 7.9        | 10.8       | 9.4        | 10.7       | 11.0       | 11.5       |
| MnO                                                | 0.2        | 0.2        | 0.1        | 0.3        | 0.6        | 0.6        | 0.6        | 0.7        | 0.1        | 0.3        | 0.1        | 0.5        | 0.3        | 0.1        | 0.3        | 0.2        | 0.3        |
| MgO                                                | 15.2       | 15.1       | 14.4       | 16.3       | 19.1       | 21.8       | 20.5       | 21.2       | 13.7       | 14.1       | 15.0       | 19.4       | 15.4       | 15.9       | 17.3       | 16.2       | 17.0       |
| CaO                                                | 11.6       | 10.7       | 11.1       | 11.2       | 3.6        | 0.9        | 5.2        | 1.5        | 10.5       | 10.5       | 11.4       | 12.3       | 10.5       | 11.4       | 11.5       | 12.0       | 11.3       |
| Na <sub>2</sub> O                                  | 1.9        | 2.1        | 2.4        | 0.4        | 0.9        | 0.5        | 0.4        | 0.5        | 2.5        | 2.4        | 2.2        | 0.2        | 2.3        | 2.2        | 0.7        | 0.9        | 0.6        |
| K <sub>2</sub> O                                   | 0.4        | 0.3        | 0.3        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.5        | 0.5        | 0.4        | 0.0        | 0.5        | 0.4        | 0.0        | 0.1        | 0.0        |
| F                                                  | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cl                                                 | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cr <sub>2</sub> O <sub>3</sub>                     | 0.1        | 0.0        | 0.1        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.0        |
| NiO                                                | 0.0        | 0.0        | 0.1        | 0.1        | 0.0        | 0.1        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        |
| V <sub>2</sub> O <sub>3</sub>                      | 0.1        | 0.1        | 0.1        | 0.0        |            |            |            |            | 0.0        | 0.1        | 0.1        | 0.0        | 0.1        | 0.1        | 0.0        | 0.0        | 0.0        |
| BaO                                                | 0.0        | 0.1        | 0.0        | 0.0        |            |            |            |            | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Total                                              | 98.0       | 98.1       | 97.6       | 98.0       | 98.4       | 98.6       | 98.6       | 98.1       | 96.7       | 97.5       | 97.1       | 98.0       | 98.1       | 97.6       | 98.0       | 98.5       | 98.4       |

## Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.

| Complex<br>Sequence<br>DrillCore<br>Sample | Amphibole  |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |
|--------------------------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
|                                            | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        |
|                                            | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          |
|                                            | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 |
|                                            | 5          | 5          | 5          | 5          | 5          | 5          | 5          | 5          | 5          | 5          | 5          | 5          | 5          | 7          | 7          | 12         | 12         |
| No.                                        | 59         | 60         | 65         | 66         | 67         | 74         | 75         | 76         | 85         | 86         | 79         | 82         | 77         | 16         | 19         | 38         | 64         |
| SiO <sub>2</sub>                           | 46.6       | 47.1       | 48.2       | 51.7       | 48.8       | 51.9       | 55.6       | 54.0       | 59.1       | 58.5       | 58.3       | 56.6       | 50.7       | 50.0       | 49.4       | 47.3       | 43.8       |
| TiO <sub>2</sub>                           | 1.1        | 0.8        | 0.5        | 0.5        | 0.3        | 0.5        | 0.1        | 0.2        | 0.1        | 0.1        | 0.0        | 0.2        | 0.8        | 1.2        | 1.6        | 0.8        | 1.3        |
| Al <sub>2</sub> O <sub>3</sub>             | 10.1       | 10.3       | 9.4        | 6.5        | 8.6        | 6.5        | 2.9        | 4.7        | 0.2        | 0.2        | 0.1        | 0.4        | 7.4        | 6.5        | 6.9        | 8.6        | 12.0       |
| FeO                                        | 8.3        | 7.9        | 9.1        | 8.4        | 10.0       | 4.8        | 3.2        | 3.9        | 3.5        | 3.3        | 3.8        | 5.9        | 5.1        | 8.1        | 8.2        | 11.5       | 13.2       |
| MnO                                        | 0.1        | 0.1        | 0.2        | 0.1        | 0.2        | 0.1        | 0.1        | 0.0        | 0.3        | 0.3        | 0.2        | 0.2        | 0.1        | 0.2        | 0.2        | 0.3        | 0.2        |
| MgO                                        | 16.5       | 17.1       | 16.3       | 18.5       | 16.2       | 19.5       | 21.7       | 20.9       | 22.9       | 22.7       | 22.2       | 21.0       | 19.8       | 17.9       | 17.9       | 14.8       | 12.6       |
| CaO                                        | 12.1       | 11.6       | 11.5       | 11.1       | 11.5       | 12.5       | 13.0       | 12.4       | 12.5       | 12.6       | 11.6       | 12.5       | 12.4       | 11.6       | 11.2       | 11.7       | 11.6       |
| Na <sub>2</sub> O                          | 1.5        | 1.6        | 1.8        | 1.0        | 1.0        | 1.4        | 0.5        | 0.7        | 0.4        | 0.6        | 0.9        | 0.4        | 1.2        | 1.0        | 1.1        | 1.2        | 1.5        |
| K <sub>2</sub> O                           | 0.3        | 0.4        | 0.3        | 0.4        | 0.4        | 0.1        | 0.0        | 0.1        | 0.1        | 0.1        | 0.2        | 0.1        | 0.1        | 0.3        | 0.3        | 0.4        | 0.5        |
| F                                          | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cl                                         | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cr <sub>2</sub> O <sub>3</sub>             | 0.1        | 0.1        | 0.1        | 0.1        | 0.2        | 0.1        | 0.5        | 0.1        | 0.1        | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| NiO                                        | 0.1        | 0.1        | 0.0        | 0.1        | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        | 0.1        | 0.0        |
| V <sub>2</sub> O <sub>3</sub>              | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        | 0.1        | 0.0        | 0.1        | 0.1        | 0.0        | 0.0        | 0.0        | 0.2        | 0.2        | 0.1        | 0.1        |
| BaO                                        | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.1        | 0.0        | 0.1        | 0.0        |            |            |            |            |
| Total                                      | 96.8       | 97.1       | 97.5       | 98.3       | 97.4       | 97.5       | 97.8       | 97.1       | 99.3       | 98.5       | 97.4       | 97.3       | 97.6       | 97.1       | 97.2       | 96.7       | 96.7       |

## Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.

| Complex<br>Sequence<br>DrillCore<br>Sample | Amphibole  |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |
|--------------------------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
|                                            | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        |
|                                            | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          |
|                                            | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 |
|                                            | 12         | 12         | 12         | 12         | 12         | 12         | 12         | 12         | 16         | 16         | 16         | 16         | 16         | 18         | 18         | 18         | 18         |
| No.                                        | 39         | 58         | 70         | 63         | 40         | 41         | 35         | 36         | 31         | 29         | 26         | 27         | 8          | 111        | 88         | 93         | 109        |
| SiO <sub>2</sub>                           | 45.2       | 46.1       | 45.9       | 49.0       | 47.6       | 54.7       | 54.5       | 55.1       | 53.5       | 43.6       | 44.0       | 43.7       | 44.1       | 42.7       | 42.3       | 42.7       | 42.2       |
| TiO <sub>2</sub>                           | 1.1        | 1.4        | 1.5        | 0.8        | 1.2        | 0.0        | 0.0        | 0.0        | 0.1        | 1.7        | 1.5        | 1.5        | 1.4        | 2.0        | 2.0        | 1.9        | 2.0        |
| Al <sub>2</sub> O <sub>3</sub>             | 11.4       | 9.0        | 8.6        | 8.3        | 7.9        | 2.3        | 2.8        | 0.9        | 4.6        | 11.8       | 11.9       | 12.0       | 12.4       | 12.4       | 12.4       | 12.5       | 12.6       |
| FeO                                        | 12.7       | 13.5       | 14.2       | 11.2       | 13.3       | 10.3       | 10.1       | 17.6       | 14.7       | 11.2       | 11.4       | 10.6       | 11.1       | 13.0       | 13.4       | 13.1       | 13.4       |
| MnO                                        | 0.2        | 0.4        | 0.2        | 0.3        | 0.4        | 0.6        | 0.4        | 2.0        | 0.4        | 0.2        | 0.2        | 0.1        | 0.1        | 0.2        | 0.2        | 0.3        | 0.2        |
| MgO                                        | 13.4       | 14.1       | 13.7       | 15.3       | 15.4       | 17.6       | 18.0       | 20.4       | 21.9       | 14.5       | 14.6       | 14.7       | 14.0       | 12.5       | 12.4       | 12.9       | 12.7       |
| CaO                                        | 11.0       | 10.7       | 11.2       | 11.4       | 9.0        | 11.3       | 11.6       | 1.6        | 2.3        | 10.6       | 10.3       | 11.3       | 11.2       | 10.9       | 10.6       | 10.7       | 10.7       |
| Na <sub>2</sub> O                          | 1.6        | 1.1        | 1.5        | 1.1        | 1.0        | 0.6        | 0.6        | 0.1        | 0.5        | 1.9        | 1.9        | 1.8        | 1.7        | 2.4        | 2.2        | 2.2        | 2.5        |
| K <sub>2</sub> O                           | 0.5        | 0.5        | 0.3        | 0.3        | 0.5        | 0.0        | 0.1        | 0.0        | 0.0        | 0.4        | 0.4        | 0.5        | 0.4        | 0.4        | 0.4        | 0.4        | 0.4        |
| F                                          | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cl                                         | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cr <sub>2</sub> O <sub>3</sub>             | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| NiO                                        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.1        | 0.1        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        |
| V <sub>2</sub> O <sub>3</sub>              | 0.1        | 0.1        | 0.2        | 0.1        | 0.1        | 0.1        | 0.1        | 0.0        | 0.0        | 0.1        | 0.0        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        |
| BaO                                        |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |
| Total                                      | 97.3       | 97.0       | 97.4       | 97.7       | 96.5       | 97.7       | 98.2       | 97.8       | 98.1       | 96.1       | 96.3       | 96.4       | 96.3       | 96.7       | 96.1       | 96.7       | 96.8       |

## Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.

| Complex<br>Sequence<br>DrillCore<br>Sample | Amphibole  |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |
|--------------------------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
|                                            | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        |
|                                            | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          |
|                                            | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 |
|                                            | 18         | 18         | 18         | 18         | 18         | 18         | 18         | 18         | 19         | 19         | 19         | 19         | 19         | 19         | 19         | 19         | 19         |
| No.                                        | 98         | 113        | 112        | 110        | 106        | 92         | 107        | 89         | 53         | 58         | 63         | 39         | 41         | 65         | 66         | 64         | 60         |
| SiO <sub>2</sub>                           | 42.1       | 42.8       | 42.6       | 42.0       | 42.0       | 42.8       | 42.3       | 42.1       | 47.2       | 46.7       | 45.4       | 44.9       | 44.5       | 43.8       | 43.1       | 43.3       | 41.9       |
| TiO <sub>2</sub>                           | 2.1        | 1.6        | 1.7        | 1.9        | 2.2        | 1.9        | 2.0        | 1.9        | 1.0        | 1.4        | 1.3        | 1.5        | 0.8        | 1.6        | 1.6        | 1.6        | 1.8        |
| Al <sub>2</sub> O <sub>3</sub>             | 12.6       | 12.6       | 12.7       | 12.8       | 13.0       | 13.0       | 13.2       | 13.4       | 8.9        | 9.9        | 11.3       | 12.2       | 12.3       | 12.6       | 13.2       | 13.3       | 13.3       |
| FeO                                        | 13.1       | 13.1       | 13.1       | 13.3       | 13.3       | 13.5       | 13.2       | 12.9       | 9.5        | 8.5        | 8.5        | 9.2        | 6.2        | 10.1       | 9.8        | 10.4       | 10.3       |
| MnO                                        | 0.3        | 0.2        | 0.2        | 0.3        | 0.2        | 0.2        | 0.3        | 0.2        | 0.1        | 0.1        | 0.1        | 0.2        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        |
| MgO                                        | 12.4       | 12.6       | 12.6       | 12.3       | 12.1       | 12.9       | 12.2       | 12.1       | 16.2       | 16.9       | 16.0       | 15.3       | 18.1       | 15.0       | 14.7       | 14.4       | 14.2       |
| CaO                                        | 10.8       | 11.0       | 10.8       | 10.8       | 10.6       | 10.3       | 11.0       | 10.8       | 12.2       | 11.7       | 11.6       | 11.5       | 12.1       | 11.5       | 11.6       | 11.4       | 11.7       |
| Na <sub>2</sub> O                          | 2.3        | 2.3        | 2.3        | 2.4        | 2.2        | 2.1        | 2.3        | 2.3        | 1.3        | 1.5        | 1.9        | 2.0        | 2.2        | 2.1        | 2.1        | 2.4        | 2.3        |
| K <sub>2</sub> O                           | 0.5        | 0.4        | 0.4        | 0.4        | 0.4        | 0.4        | 0.4        | 0.4        | 0.1        | 0.3        | 0.3        | 0.3        | 0.4        | 0.4        | 0.3        | 0.4        | 0.4        |
| F                                          | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cl                                         | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cr <sub>2</sub> O <sub>3</sub>             | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.2        | 0.0        | 0.1        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.1        |
| NiO                                        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        | 0.2        | 0.0        | 0.1        | 0.1        | 0.0        | 0.1        | 0.0        |
| V <sub>2</sub> O <sub>3</sub>              | 0.1        | 0.1        | 0.0        | 0.1        | 0.1        | 0.1        | 0.1        | 0.0        | 0.0        | 0.1        | 0.1        | 0.1        | 0.0        | 0.1        | 0.1        | 0.1        | 0.1        |
| BaO                                        |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |
| Total                                      | 96.3       | 96.8       | 96.6       | 96.3       | 96.2       | 97.1       | 97.0       | 96.3       | 97.0       | 97.2       | 96.5       | 97.1       | 96.8       | 97.5       | 96.6       | 97.4       | 96.3       |

## Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.

| Complex<br>Sequence<br>DrillCore<br>Sample | Amphibole  |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |
|--------------------------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
|                                            | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        |
|                                            | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          |
|                                            | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 |
|                                            | 19         | 23         | 23         | 23         | 23         | 23         | 23         | 23         | 23         | 23         | 23         | 23         | 23         | 23         | 23         | 23         | 23         |
| No.                                        | 67         | 106        | 107        | 104        | 114        | 113        | 132        | 127        | 161        | 119        | 124        | 142        | 158        | 120        | 141        | 92         | 125        |
| SiO <sub>2</sub>                           | 41.8       | 52.1       | 53.5       | 48.4       | 50.8       | 47.9       | 49.7       | 52.9       | 50.0       | 50.1       | 50.8       | 46.8       | 44.9       | 50.1       | 48.2       | 43.9       | 50.3       |
| TiO <sub>2</sub>                           | 2.0        | 0.3        | 0.3        | 1.0        | 0.5        | 1.3        | 0.6        | 0.3        | 0.4        | 0.4        | 0.3        | 1.2        | 1.8        | 0.6        | 1.2        | 1.9        | 0.4        |
| Al <sub>2</sub> O <sub>3</sub>             | 13.4       | 4.7        | 3.5        | 9.3        | 7.5        | 9.5        | 8.9        | 5.7        | 8.3        | 8.2        | 7.2        | 9.8        | 11.7       | 7.0        | 9.3        | 12.2       | 7.3        |
| FeO                                        | 10.2       | 7.4        | 7.3        | 9.6        | 8.2        | 9.0        | 9.5        | 7.5        | 7.8        | 8.2        | 8.6        | 9.7        | 8.9        | 8.7        | 8.6        | 10.1       | 8.5        |
| MnO                                        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.2        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.2        |
| MgO                                        | 14.3       | 18.8       | 19.8       | 16.7       | 18.4       | 16.6       | 16.2       | 19.1       | 18.1       | 17.4       | 17.9       | 15.7       | 16.1       | 17.0       | 16.4       | 15.1       | 17.8       |
| CaO                                        | 11.3       | 11.9       | 11.9       | 11.5       | 11.5       | 11.9       | 11.8       | 11.8       | 11.9       | 12.4       | 11.5       | 11.9       | 11.3       | 12.7       | 11.7       | 11.5       | 11.7       |
| Na <sub>2</sub> O                          | 2.3        | 0.7        | 0.6        | 1.5        | 1.2        | 1.5        | 1.2        | 0.7        | 1.1        | 1.0        | 1.1        | 1.7        | 2.0        | 0.9        | 1.3        | 2.1        | 1.0        |
| K <sub>2</sub> O                           | 0.4        | 0.1        | 0.1        | 0.3        | 0.2        | 0.2        | 0.2        | 0.1        | 0.1        | 0.1        | 0.2        | 0.3        | 0.5        | 0.1        | 0.3        | 0.4        | 0.2        |
| F                                          | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cl                                         | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cr <sub>2</sub> O <sub>3</sub>             | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.2        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| NiO                                        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        | 0.1        | 0.1        | 0.1        | 0.0        | 0.0        | 0.0        | 0.1        | 0.2        | 0.0        | 0.1        | 0.0        | 0.0        |
| V <sub>2</sub> O <sub>3</sub>              | 0.1        | 0.0        | 0.0        | 0.1        | 0.1        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.0        |
| BaO                                        |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |
| Total                                      | 96.0       | 96.3       | 97.1       | 98.5       | 98.5       | 98.5       | 98.4       | 98.3       | 98.0       | 98.0       | 97.9       | 97.7       | 97.6       | 97.6       | 97.4       | 97.4       | 97.4       |

## Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.

| Complex<br>Sequence<br>DrillCore<br>Sample | Amphibole  |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |
|--------------------------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
|                                            | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        | AMB        |
|                                            | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          | S          |
|                                            | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 | AMB36<br>6 |
|                                            | 23         | 23         | 23         | 23         | 25         | 25         | 25         | 25         | 25         | 25         | 25         | 25         | 25         | 25         | 25         | 25         | 25         |
| No.                                        | 106        | 152        | 109        | 157        | 26         | 221        | 227        | 228        | 229        | 230        | 231        | 233        | 234        | 249        | 239        | 246        | 259        |
| SiO <sub>2</sub>                           | 49.0       | 44.0       | 47.7       | 44.0       | 53.9       | 47.7       | 48.3       | 53.8       | 45.2       | 45.8       | 54.3       | 44.7       | 44.6       | 53.1       | 54.2       | 48.4       | 47.4       |
| TiO <sub>2</sub>                           | 0.8        | 1.5        | 0.8        | 1.3        | 0.1        | 0.8        | 1.2        | 0.1        | 1.0        | 1.4        | 0.0        | 1.9        | 1.7        | 0.0        | 0.2        | 0.2        | 0.4        |
| Al <sub>2</sub> O <sub>3</sub>             | 8.2        | 12.0       | 9.4        | 12.1       | 2.2        | 9.3        | 9.5        | 2.3        | 12.1       | 10.8       | 3.0        | 12.5       | 12.4       | 2.4        | 3.1        | 30.6       | 9.9        |
| FeO                                        | 9.4        | 10.3       | 9.3        | 9.5        | 11.7       | 9.9        | 9.3        | 12.1       | 9.1        | 9.0        | 12.0       | 10.1       | 9.8        | 10.8       | 11.0       | 0.2        | 7.6        |
| MnO                                        | 0.2        | 0.1        | 0.1        | 0.1        | 0.4        | 0.1        | 0.2        | 0.4        | 0.1        | 0.1        | 0.3        | 0.1        | 0.1        | 0.3        | 0.4        | 0.0        | 0.1        |
| MgO                                        | 16.1       | 14.8       | 16.0       | 15.7       | 17.3       | 16.6       | 16.9       | 16.9       | 15.3       | 15.5       | 16.2       | 14.6       | 14.9       | 17.0       | 16.8       | 0.0        | 17.4       |
| CaO                                        | 12.1       | 11.8       | 11.6       | 10.8       | 10.0       | 10.6       | 11.2       | 11.7       | 11.6       | 11.6       | 11.4       | 11.5       | 11.3       | 11.8       | 11.8       | 16.2       | 12.0       |
| Na <sub>2</sub> O                          | 1.0        | 1.9        | 1.1        | 1.8        | 0.5        | 1.4        | 1.3        | 0.3        | 1.4        | 1.3        | 0.6        | 1.7        | 1.6        | 0.5        | 0.5        | 2.0        | 1.3        |
| K <sub>2</sub> O                           | 0.2        | 0.4        | 0.2        | 0.5        | 0.1        | 0.3        | 0.3        | 0.0        | 0.5        | 0.4        | 0.0        | 0.5        | 0.5        | 0.1        | 0.1        | 0.1        | 0.4        |
| F                                          | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cl                                         | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| Cr <sub>2</sub> O <sub>3</sub>             | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        |
| NiO                                        | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.0        | 0.1        | 0.0        | 0.0        | 0.0        |
| V <sub>2</sub> O <sub>3</sub>              | 0.1        | 0.1        | 0.1        | 0.1        | 0.0        | 0.1        | 0.1        | 0.1        | 0.1        | 0.1        | 0.0        | 0.1        | 0.1        | 0.0        | 0.0        | 0.0        | 0.1        |
| BaO                                        |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |            |
| Total                                      | 97.1       | 97.0       | 96.4       | 96.0       | 96.3       | 96.9       | 98.4       | 97.7       | 96.4       | 96.1       | 97.9       | 97.6       | 97.1       | 96.1       | 97.9       | 97.6       | 96.8       |

# Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.

| Complex                        | Amphibole |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|--------------------------------|-----------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                                | MN        | MN   | MN   | MN   | MN   | MN   | MN   | MN   | MN   | MN   | MN   | MN   | MN   | MN   | MN   |
| Sequence                       | N         | N    | N    | N    | N    | N    | N    | N    | N    | N    | N    | N    | N    | N    | N    |
| Sample                         | MNN0      | MNN0 | MNN0 | MNN1 | MNN1 | MNN1 | MNN1 | MNN1 | MNN1 | MNN1 | MNN1 | MNN1 | MNN1 | MNN1 | MNN1 |
|                                | 2         | 5    | 6    | 0    | 0    | 0    | 3    | 3    | 4    | 4    | 4    | 4    | 4    | 5    | 6    |
| No.                            | 1         | 1    | 1    | 2    | 3    | 4    | 1    | 2    | 1    | 2    | 3    | 4    | 1    | 2    | 6    |
| SiO <sub>2</sub>               | 42.5      | 43.2 | 41.8 | 48.6 | 49.9 | 49.3 | 51.4 | 49.1 | 44.4 | 53.3 | 53.2 | 53.7 | 46.6 | 47.3 | 43.2 |
| TiO <sub>2</sub>               | 4.0       | 0.3  | 0.3  | 0.8  | 0.5  | 0.3  | 0.7  | 0.7  | 1.2  | 0.3  | 0.3  | 0.3  | 0.6  | 0.7  | 0.1  |
| Al <sub>2</sub> O <sub>3</sub> | 12.2      | 15.5 | 18.5 | 8.0  | 7.2  | 7.6  | 4.8  | 6.4  | 13.7 | 4.5  | 4.5  | 4.1  | 12.7 | 12.2 | 17.6 |
| Cr <sub>2</sub> O <sub>3</sub> | 0.5       | 0.0  | 0.0  | 0.0  | 0.2  | 0.1  | 0.0  | 0.1  | 0.4  | 0.2  | 0.3  | 0.2  | 0.2  | 0.1  | 0.0  |
| FeO                            | 5.1       | 5.8  | 7.0  | 10.3 | 9.2  | 10.2 | 11.2 | 12.4 | 10.6 | 7.7  | 6.6  | 7.8  | 9.0  | 9.2  | 9.5  |
| MnO                            | 0.0       | 0.2  | 0.1  | 0.3  | 0.2  | 0.2  | 0.3  | 0.3  | 0.1  | 0.2  | 0.2  | 0.1  | 0.2  | 0.1  | 0.1  |
| MgO                            | 16.3      | 20.3 | 16.1 | 15.1 | 15.8 | 14.5 | 15.7 | 14.3 | 13.4 | 18.6 | 18.6 | 18.1 | 15.0 | 15.2 | 12.7 |
| CaO                            | 11.4      | 8.1  | 9.4  | 12.1 | 12.3 | 12.8 | 11.6 | 11.3 | 11.2 | 12.0 | 12.2 | 11.0 | 10.7 | 10.9 | 11.2 |
| Na <sub>2</sub> O              | 2.9       | 3.6  | 3.9  | 1.1  | 1.0  | 0.9  | 0.9  | 1.3  | 1.9  | 0.5  | 0.6  | 0.6  | 1.6  | 1.5  | 1.7  |
| K <sub>2</sub> O               | 1.4       | 0.3  | 0.2  | 0.3  | 0.2  | 0.2  | 0.2  | 0.3  | 0.5  | 0.1  | 0.0  | 0.0  | 0.2  | 0.2  | 0.5  |
| F                              | 0.0       | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |
| Cl                             | 0.0       | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |
| NiO                            | 0.1       | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.2  | 0.1  | 0.0  | 0.1  | 0.1  | 0.0  | 0.0  | 0.0  | 0.0  |
| V <sub>2</sub> O <sub>3</sub>  | 0.1       | 0.0  | 0.0  | 0.0  | 0.0  | 0.1  | 0.1  | 0.1  | 0.2  | 0.0  | 0.1  | 0.1  | 0.0  | 0.1  | 0.0  |
| P <sub>2</sub> O <sub>5</sub>  |           |      | 0.1  |      |      |      |      |      |      |      |      | 0.0  |      |      |      |
| Total                          | 96.5      | 97.6 | 97.5 | 96.7 | 96.6 | 96.4 | 97.2 | 96.3 | 97.7 | 97.5 | 96.8 | 96.1 | 96.9 | 97.5 | 96.6 |

# Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.

|                                | Amphibole |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|--------------------------------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Complex                        | MN        | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    |       |
| Sequence                       | N         | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     | N     |       |
| Sample                         | MNN16     | MNN16 | MNN16 | MNN16 | MNN16 | MNN16 | MNN16 | MNN16 | MNN16 | MNN16 | MNN16 | MNN16 | MNN15 | MNN15 | MNN15 |
| No.                            | 7         | 8     | 9     | 10    | 11    | 12    | 13    | 14    | 6     | 8     | 7     |       | 3.00  | 4.00  | 5.00  |
| SiO <sub>2</sub>               | 44.5      | 44.1  | 42.2  | 44.7  | 44.6  | 43.6  | 44.6  | 45.3  | 51.2  | 53.2  | 53.1  |       | 55.1  | 52.6  | 54.8  |
| TiO <sub>2</sub>               | 0.3       | 0.1   | 0.6   | 0.2   | 0.0   | 0.6   | 0.0   | 1.0   | 0.4   | 0.3   | 0.7   |       | 0.1   | 0.2   | 0.2   |
| Al <sub>2</sub> O <sub>3</sub> | 16.8      | 16.6  | 16.6  | 16.4  | 16.4  | 16.2  | 16.1  | 13.6  | 7.3   | 4.8   | 5.7   |       | 3.3   | 5.5   | 3.3   |
| Cr <sub>2</sub> O <sub>3</sub> | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.2   | 0.7   | 0.8   | 0.1   |       | 0.0   | 0.1   | 0.0   |
| FeO                            | 9.3       | 8.2   | 11.9  | 9.9   | 8.8   | 9.7   | 8.2   | 9.7   | 9.5   | 8.7   | 8.6   |       | 14.9  | 14.4  | 14.2  |
| MnO                            | 0.2       | 0.1   | 0.1   | 0.1   | 0.2   | 0.3   | 0.1   | 0.1   | 0.0   | 0.1   | 0.1   |       | 0.3   | 0.4   | 0.4   |
| MgO                            | 13.4      | 14.1  | 11.2  | 13.1  | 13.5  | 13.3  | 14.4  | 13.7  | 16.0  | 17.3  | 17.7  |       | 22.8  | 21.9  | 23.1  |
| CaO                            | 11.4      | 11.2  | 11.5  | 11.2  | 11.1  | 11.0  | 11.3  | 11.3  | 12.6  | 12.0  | 11.7  |       | 0.5   | 0.7   | 0.5   |
| Na <sub>2</sub> O              | 1.6       | 1.8   | 1.8   | 1.7   | 1.6   | 1.8   | 1.8   | 1.5   | 0.7   | 0.7   | 0.7   |       | 0.3   | 0.5   | 0.3   |
| K <sub>2</sub> O               | 0.5       | 0.5   | 0.5   | 0.5   | 0.4   | 0.5   | 0.5   | 0.5   | 0.2   | 0.1   | 0.2   |       | 0.0   | 0.0   | 0.0   |
| F                              | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |       | 0.0   | 0.0   | 0.0   |
| Cl                             | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |       | 0.0   | 0.0   | 0.0   |
| NiO                            | 0.0       | 0.0   | 0.1   | 0.0   | 0.1   | 0.1   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   |       | 0.0   | 0.1   | 0.0   |
| V <sub>2</sub> O <sub>3</sub>  | 0.0       | 0.0   | 0.1   | 0.0   | 0.0   | 0.1   | 0.0   | 0.1   | 0.1   | 0.1   | 0.0   |       | 0.0   | 0.0   | 0.0   |
| P <sub>2</sub> O <sub>5</sub>  |           |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Total                          | 97.9      | 96.7  | 96.7  | 97.8  | 96.6  | 97.2  | 97.1  | 97.0  | 98.7  | 98.1  | 98.5  |       | 97.2  | 96.3  | 96.8  |



# **Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.**

| Complex                        | Amphibole |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|--------------------------------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                | MN        | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    |
| Sequence                       | N         | N     | N     | N     | N     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     |
| Sample                         | MNN16     | MNN16 | MNN16 | MNN16 | MNN16 | MNS07 | MNS07 | MNS07 | MNS08 | MNS08 | MNS08 | MNS08 | MNS08 | MNS08 | MNS09 |
| No.                            | 1.00      | 2.00  | 3.00  | 4.00  | 5.00  | 1     | 2     | 3     | 1     | 2     | 3     | 4     | 5     | 6     | 1     |
| SiO <sub>2</sub>               | 42.2      | 42.2  | 42.9  | 42.1  | 43.2  | 50.8  | 52.0  | 52.0  | 46.8  | 46.2  | 46.4  | 45.1  | 45.9  | 45.8  | 51.6  |
| TiO <sub>2</sub>               | 0.0       | 0.1   | 0.3   | 0.1   | 0.4   | 1.0   | 0.7   | 0.5   | 0.4   | 0.4   | 0.4   | 0.3   | 0.6   | 0.5   | 0.3   |
| Al <sub>2</sub> O <sub>3</sub> | 20.7      | 20.5  | 19.9  | 19.7  | 19.4  | 6.5   | 6.1   | 6.1   | 13.3  | 14.0  | 13.7  | 15.3  | 13.6  | 14.0  | 7.4   |
| Cr <sub>2</sub> O <sub>3</sub> | 0.0       | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.2   | 0.2   | 0.2   | 0.1   | 0.2   | 0.0   | 0.0   | 0.0   | 0.3   |
| FeO                            | 13.5      | 12.5  | 13.7  | 12.4  | 13.8  | 7.9   | 7.4   | 7.8   | 9.2   | 9.1   | 8.8   | 9.2   | 10.0  | 8.9   | 7.0   |
| MnO                            | 0.2       | 0.3   | 0.3   | 0.3   | 0.3   | 0.1   | 0.1   | 0.2   | 0.3   | 0.3   | 0.2   | 0.2   | 0.2   | 0.1   | 0.2   |
| MgO                            | 17.6      | 19.3  | 17.7  | 19.0  | 17.4  | 17.6  | 18.6  | 18.2  | 14.6  | 14.1  | 14.1  | 13.3  | 13.7  | 13.9  | 17.9  |
| CaO                            | 0.6       | 0.5   | 0.6   | 0.5   | 0.6   | 12.0  | 11.4  | 11.9  | 10.5  | 10.6  | 11.2  | 11.5  | 10.5  | 11.2  | 11.8  |
| Na <sub>2</sub> O              | 2.3       | 2.5   | 2.4   | 2.3   | 2.1   | 0.8   | 0.5   | 0.5   | 1.9   | 2.0   | 1.6   | 1.6   | 1.8   | 1.7   | 0.7   |
| K <sub>2</sub> O               | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.4   | 0.2   | 0.2   | 0.2   | 0.2   | 0.2   | 0.2   | 0.2   | 0.2   | 0.2   |
| F                              | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Cl                             | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| NiO                            | 0.1       | 0.1   | 0.0   | 0.0   | 0.0   | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.0   | 0.0   | 0.1   |
| V <sub>2</sub> O <sub>3</sub>  | 0.1       | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.1   |
| P <sub>2</sub> O <sub>5</sub>  |           |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Total                          | 97.3      | 98.0  | 97.6  | 96.6  | 97.3  | 97.3  | 97.2  | 97.7  | 97.4  | 97.1  | 96.9  | 96.8  | 96.5  | 96.4  | 97.7  |

# **Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.**

| Complex                        | Amphibole |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|--------------------------------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                | MN        | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    |
| Sequence                       | S         | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     |
| Sample                         | MNS09     | MNS10 | MNS10 | MNS10 | MNS10 | MNS10 | MNS11 | MNS11 | MNS11 | MNS11 | MNS11 | MNS11 | MNS12 | MNS12 | MNS12 |
| No.                            | 2         | 1     | 2     | 3     | 4     | 5     | 1     | 2     | 3     | 4     | 6     | 7     | 1     | 2     | 3     |
| SiO <sub>2</sub>               | 54.3      | 46.3  | 44.8  | 46.0  | 46.8  | 47.6  | 47.1  | 49.8  | 51.5  | 51.9  | 53.0  | 53.3  | 44.6  | 46.1  | 46.8  |
| TiO <sub>2</sub>               | 0.2       | 0.4   | 0.3   | 0.2   | 0.1   | 0.3   | 0.7   | 0.5   | 0.1   | 0.2   | 0.0   | 0.3   | 0.2   | 0.5   | 0.5   |
| Al <sub>2</sub> O <sub>3</sub> | 3.6       | 13.8  | 14.1  | 14.2  | 13.0  | 11.8  | 10.9  | 8.5   | 8.3   | 8.1   | 6.8   | 5.0   | 14.3  | 13.3  | 12.8  |
| Cr <sub>2</sub> O <sub>3</sub> | 0.3       | 0.2   | 0.0   | 0.2   | 0.1   | 0.1   | 0.9   | 0.2   | 0.2   | 0.2   | 0.1   | 0.3   | 0.3   | 0.0   | 0.2   |
| FeO                            | 6.3       | 9.7   | 10.1  | 9.6   | 9.7   | 10.1  | 9.6   | 8.8   | 7.4   | 7.3   | 7.2   | 6.5   | 11.6  | 9.6   | 9.1   |
| MnO                            | 0.1       | 0.3   | 0.3   | 0.4   | 0.2   | 0.2   | 0.2   | 0.1   | 0.2   | 0.2   | 0.2   | 0.0   | 0.3   | 0.2   | 0.3   |
| MgO                            | 19.3      | 13.9  | 13.8  | 14.0  | 14.5  | 15.2  | 14.5  | 16.5  | 17.7  | 18.4  | 18.7  | 19.1  | 12.5  | 14.3  | 14.5  |
| CaO                            | 12.2      | 11.0  | 10.8  | 10.6  | 10.7  | 10.8  | 11.7  | 11.6  | 11.5  | 11.6  | 11.5  | 12.3  | 10.4  | 10.9  | 10.7  |
| Na <sub>2</sub> O              | 0.4       | 1.8   | 1.7   | 2.0   | 1.9   | 1.6   | 1.1   | 0.8   | 0.6   | 0.7   | 0.6   | 0.5   | 2.0   | 2.0   | 1.9   |
| K <sub>2</sub> O               | 0.1       | 0.2   | 0.2   | 0.2   | 0.2   | 0.2   | 0.4   | 0.2   | 0.2   | 0.2   | 0.2   | 0.1   | 0.2   | 0.3   | 0.2   |
| F                              | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Cl                             | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   |
| NiO                            | 0.1       | 0.0   | 0.0   | 0.1   | 0.0   | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.0   | 0.0   | 0.0   |
| V <sub>2</sub> O <sub>3</sub>  | 0.0       | 0.0   | 0.1   | 0.0   | 0.0   | 0.1   | 0.1   | 0.1   | 0.1   | 0.0   | 0.0   | 0.1   | 0.1   | 0.0   | 0.0   |
| P <sub>2</sub> O <sub>5</sub>  |           |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Total                          | 96.7      | 97.7  | 96.3  | 97.6  | 97.2  | 98.0  | 97.4  | 97.2  | 97.9  | 98.9  | 98.3  | 97.4  | 96.6  | 97.3  | 96.9  |

**Cont. Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.**

| Complex                        | Amphibole |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|--------------------------------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                | MN        | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    |
| Sequence                       | S         | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     |
| Sample                         | MNS12     | MNS13 | MNS13 | MNS13 | MNS13 | MNS13 | MNS13 | MNS13 | MNS13 | MNS13 | MNS14 | MNS14 | MNS15 | MNS15 | MNS15 |
| No.                            | 4         | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 7     | 1     | 1     | 2     | 3     |
| SiO <sub>2</sub>               | 45.0      | 53.1  | 49.3  | 45.9  | 47.8  | 46.9  | 47.7  | 54.2  | 47.3  | 54.9  | 46.8  | 42.3  | 43.7  | 45.7  | 46.0  |
| TiO <sub>2</sub>               | 0.1       | 0.4   | 0.6   | 1.0   | 0.8   | 1.3   | 1.0   | 0.0   | 0.9   | 0.0   | 2.3   | 0.0   | 1.4   | 1.7   | 1.5   |
| Al <sub>2</sub> O <sub>3</sub> | 13.6      | 3.7   | 7.4   | 10.7  | 9.3   | 9.5   | 9.4   | 3.2   | 9.6   | 2.4   | 9.8   | 17.5  | 12.1  | 10.6  | 10.7  |
| Cr <sub>2</sub> O <sub>3</sub> | 0.4       | 0.2   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.2   | 0.0   | 1.0   | 0.0   | 0.1   | 0.0   | 0.1   |
| FeO                            | 10.4      | 9.2   | 10.8  | 9.8   | 9.5   | 9.8   | 9.3   | 8.8   | 10.1  | 11.1  | 5.9   | 5.6   | 11.6  | 11.4  | 9.4   |
| MnO                            | 0.2       | 0.3   | 0.3   | 0.2   | 0.2   | 0.2   | 0.3   | 0.2   | 0.2   | 0.5   | 0.1   | 0.1   | 0.2   | 0.2   | 0.2   |
| MgO                            | 13.3      | 17.8  | 14.7  | 14.1  | 14.6  | 14.5  | 14.7  | 18.2  | 14.4  | 19.4  | 14.2  | 16.1  | 12.0  | 12.9  | 14.4  |
| CaO                            | 10.6      | 12.2  | 12.2  | 12.1  | 12.0  | 12.0  | 12.0  | 11.9  | 11.7  | 8.8   | 16.0  | 11.2  | 11.7  | 11.8  | 11.9  |
| Na <sub>2</sub> O              | 2.0       | 0.5   | 0.9   | 1.2   | 1.1   | 1.1   | 1.0   | 0.4   | 1.0   | 0.3   | 2.4   | 3.0   | 1.6   | 1.5   | 1.5   |
| K <sub>2</sub> O               | 0.3       | 0.2   | 0.3   | 0.7   | 0.6   | 0.6   | 0.5   | 0.1   | 0.5   | 0.0   | 0.2   | 0.5   | 1.1   | 0.8   | 0.8   |
| F                              | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Cl                             | 0.1       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| NiO                            | 0.1       | 0.2   | 0.1   | 0.2   | 0.2   | 0.1   | 0.1   | 0.1   | 0.0   | 0.1   | 0.1   | 0.0   | 0.1   | 0.1   | 0.2   |
| V <sub>2</sub> O <sub>3</sub>  | 0.0       | 0.0   | 0.1   | 0.3   | 0.2   | 0.2   | 0.2   | 0.1   | 0.1   | 0.0   | 0.1   | 0.0   | 0.2   | 0.1   | 0.1   |
| P <sub>2</sub> O <sub>5</sub>  |           |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Total                          | 96.1      | 97.7  | 96.6  | 96.2  | 96.4  | 96.2  | 96.1  | 97.2  | 96.1  | 97.6  | 98.9  | 96.4  | 96.0  | 96.7  | 96.8  |

**Cont. Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.**

| Complex                        | Amphibole |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|--------------------------------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                | MN        | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    |
| Sequence                       | S         | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     |
| Sample                         | MNS16     | MNS16 | MNS16 | MNS16 | MNS16 | MNS16 | MNS16 | MNS16 | MNS17 | MNS17 | MNS18 | MNS18 | MNS19 | MNS21 | MNN22 |
| No.                            | 2         | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 2     | 3     | 1     | 2     | 3     | 1     | 3     |
| SiO <sub>2</sub>               | 44.0      | 44.0  | 43.7  | 43.8  | 44.6  | 52.5  | 46.6  | 47.2  | 44.5  | 45.2  | 43.1  | 44.6  | 50.3  | 49.2  | 48.6  |
| TiO <sub>2</sub>               | 0.1       | 0.3   | 0.2   | 0.1   | 0.1   | 0.3   | 0.5   | 0.1   | 0.2   | 0.4   | 0.1   | 0.2   | 0.3   | 0.4   | 0.2   |
| Al <sub>2</sub> O <sub>3</sub> | 18.2      | 16.8  | 17.4  | 16.8  | 15.5  | 6.4   | 13.8  | 12.2  | 16.4  | 15.7  | 15.0  | 13.4  | 3.9   | 8.7   | 10.5  |
| Cr <sub>2</sub> O <sub>3</sub> | 0.0       | 0.0   | 0.0   | 0.0   | 0.1   | 0.8   | 0.4   | 0.2   | 0.0   | 0.0   | 0.0   | 0.1   | 0.2   | 0.1   | 0.1   |
| FeO                            | 6.4       | 6.2   | 6.9   | 6.4   | 6.4   | 6.3   | 6.9   | 7.5   | 7.7   | 7.6   | 6.7   | 6.8   | 4.1   | 6.1   | 8.3   |
| MnO                            | 0.1       | 0.1   | 0.1   | 0.1   | 0.0   | 0.1   | 0.1   | 0.2   | 0.1   | 0.2   | 0.2   | 0.1   | 0.0   | 0.2   | 0.2   |
| MgO                            | 14.1      | 15.2  | 15.4  | 15.1  | 15.5  | 19.1  | 15.9  | 17.1  | 14.0  | 13.9  | 17.3  | 17.0  | 17.9  | 18.8  | 16.1  |
| CaO                            | 12.0      | 11.7  | 11.6  | 11.6  | 11.5  | 11.4  | 11.0  | 10.3  | 11.1  | 11.4  | 11.6  | 11.5  | 19.3  | 12.1  | 10.4  |
| Na <sub>2</sub> O              | 1.7       | 1.7   | 1.8   | 1.7   | 1.9   | 0.7   | 1.9   | 1.6   | 1.8   | 1.9   | 2.6   | 2.8   | 0.8   | 1.9   | 1.5   |
| K <sub>2</sub> O               | 0.4       | 0.4   | 0.4   | 0.4   | 0.3   | 0.1   | 0.3   | 0.2   | 0.2   | 0.2   | 0.2   | 0.2   | 0.1   | 0.2   | 0.2   |
| F                              | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Cl                             | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| NiO                            | 0.1       | 0.2   | 0.2   | 0.2   | 0.2   | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.2   | 0.1   | 0.0   | 0.0   | 0.1   |
| V <sub>2</sub> O <sub>3</sub>  | 0.0       | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   |
| P <sub>2</sub> O <sub>5</sub>  |           |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Total                          | 97.1      | 96.7  | 97.7  | 96.1  | 96.2  | 97.8  | 97.5  | 96.7  | 96.1  | 96.7  | 97.0  | 96.6  | 97.1  | 97.6  | 96.2  |

**Cont. Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.**

|                                | Amphibole |       |       |       |       |       |       |       |       |        |       |       |       |       |       |
|--------------------------------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|
| Complex                        | MN        | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN     | MN    | MN    | MN    | MN    | MN    |
| Sequence                       | S         | S     | S     | S     | S     | S     | S     | S     | S     | S      | S     | S     | S     | S     | S     |
| Sample                         | MNS23     | MNS24 | MNS25 | MNS25 | MNS25 | MNS26 | MNS26 | MNS26 | MNS26 | Sample | MNS11 | MNS13 | MNS16 | MNS16 | MNS16 |
| No.                            | 1         | 1     | 2     | 3     | 5     | 1     | 2     | 3     | 4     | No.    | 5     | 10    | 11    | 12    | 13    |
| SiO <sub>2</sub>               | 44.8      | 49.3  | 47.4  | 47.6  | 46.8  | 49.5  | 54.2  | 54.0  | 48.4  | SiO2   | 50.3  | 53.0  | 47.5  | 45.7  | 41.6  |
| TiO <sub>2</sub>               | 0.3       | 0.2   | 0.4   | 0.3   | 0.5   | 0.4   | 0.4   | 0.1   | 0.8   | TiO2   | 0.2   | 0.7   | 0.2   | 0.3   | 0.0   |
| Al <sub>2</sub> O <sub>3</sub> | 12.7      | 8.4   | 12.3  | 11.9  | 12.5  | 6.8   | 3.5   | 3.7   | 10.6  | Al2O3  | 7.8   | 4.2   | 14.7  | 15.9  | 21.3  |
| Cr <sub>2</sub> O <sub>3</sub> | 0.1       | 0.2   | 0.1   | 0.1   | 0.3   | 0.2   | 0.0   | 0.1   | 0.2   | Cr2O3  | 0.2   | 0.1   | 0.1   | 0.2   | 0.1   |
| FeO                            | 10.2      | 5.9   | 8.6   | 9.0   | 8.0   | 8.8   | 8.3   | 8.3   | 9.5   | FeO    | 11.1  | 11.8  | 11.2  | 11.0  | 10.0  |
| MnO                            | 0.3       | 0.2   | 0.1   | 0.1   | 0.1   | 0.2   | 0.3   | 0.1   | 0.1   | MnO    | 0.2   | 0.3   | 0.3   | 0.4   | 0.3   |
| MgO                            | 14.4      | 18.6  | 15.0  | 15.3  | 15.0  | 14.5  | 18.2  | 18.3  | 16.6  | MgO    | 18.4  | 18.2  | 21.8  | 21.5  | 20.6  |
| CaO                            | 11.5      | 12.1  | 10.7  | 10.9  | 11.0  | 15.4  | 12.2  | 12.1  | 9.6   | CaO    | 7.5   | 7.7   | 0.8   | 0.6   | 0.5   |
| Na <sub>2</sub> O              | 2.0       | 1.3   | 1.8   | 1.7   | 1.8   | 0.8   | 0.4   | 0.3   | 1.0   | Na2O   | 0.5   | 0.6   | 1.8   | 2.1   | 2.5   |
| K <sub>2</sub> O               | 0.3       | 0.2   | 0.2   | 0.2   | 0.2   | 0.2   | 0.0   | 0.1   | 0.3   | K2O    | 0.3   | 0.2   | 0.0   | 0.0   | 0.0   |
| F                              | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | F      | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Cl                             | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | Cl     | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| NiO                            | 0.2       | 0.1   | 0.1   | 0.0   | 0.1   | 0.0   | 0.1   | 0.0   | 0.1   | NiO    | 0.1   | 0.1   | 0.2   | 0.1   | 0.1   |
| V <sub>2</sub> O <sub>3</sub>  | 0.0       | 0.0   | 0.1   | 0.0   | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | V2O3   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| P <sub>2</sub> O <sub>5</sub>  |           |       |       |       |       |       |       |       |       | P2O5   |       |       |       |       |       |
| Total                          | 96.6      | 96.6  | 96.7  | 97.1  | 96.3  | 96.9  | 97.7  | 97.0  | 97.2  | Total  | 96.7  | 97.1  | 98.6  | 97.7  | 97.0  |

**Cont. Appendix G: Mineral Chemistry of amphiboles of Americano do Brasil and Mangabal Complexes.**

| Complex                        | Amphibole |       |       |       |       |       |       |       |       |       |       |       |
|--------------------------------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                | MN        | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    | MN    |
| Sequence                       | S         | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     | S     |
| Sample                         | MNS17     | MNS17 | MNS22 | MNN22 | MNN22 | MNN22 | MNS25 | MNS25 | MNS26 | MNS26 | MNS26 | MNS26 |
| No.                            | 1         | 4     | 1     | 2     | 4     | 5     | 1     | 4     | 5     | 6     | 7     | 8     |
| SiO <sub>2</sub>               | 52.3      | 55.0  | 55.1  | 55.5  | 54.9  | 55.5  | 51.8  | 53.9  | 55.8  | 55.1  | 55.9  | 54.9  |
| TiO <sub>2</sub>               | 0.1       | 0.1   | 0.0   | 0.0   | 0.0   | 0.1   | 0.3   | 0.1   | 0.3   | 0.2   | 0.0   | 0.1   |
| Al <sub>2</sub> O <sub>3</sub> | 7.8       | 4.2   | 2.4   | 2.5   | 3.1   | 2.8   | 6.3   | 4.3   | 1.0   | 2.8   | 2.9   | 3.0   |
| Cr <sub>2</sub> O <sub>3</sub> | 0.0       | 0.3   | 0.1   | 0.0   | 0.1   | 0.0   | 0.3   | 0.3   | 0.0   | 0.2   | 0.2   | 0.1   |
| FeO                            | 12.1      | 12.8  | 14.7  | 15.2  | 14.7  | 14.4  | 12.5  | 10.6  | 15.2  | 15.1  | 14.5  | 15.2  |
| MnO                            | 0.1       | 0.2   | 0.4   | 0.4   | 0.3   | 0.3   | 0.3   | 0.2   | 0.5   | 0.4   | 0.4   | 0.3   |
| MgO                            | 22.8      | 23.5  | 23.2  | 23.2  | 22.6  | 22.6  | 20.0  | 20.3  | 22.1  | 23.2  | 23.7  | 22.5  |
| CaO                            | 0.6       | 0.5   | 0.5   | 0.6   | 0.5   | 0.8   | 4.7   | 6.7   | 1.2   | 0.5   | 0.5   | 0.4   |
| Na <sub>2</sub> O              | 0.7       | 0.4   | 0.2   | 0.2   | 0.3   | 0.3   | 0.8   | 0.7   | 0.1   | 0.2   | 0.1   | 0.3   |
| K <sub>2</sub> O               | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.1   | 0.1   | 0.0   | 0.0   | 0.0   | 0.0   |
| F                              | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| Cl                             | 0.0       | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| NiO                            | 0.0       | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.0   | 0.1   | 0.0   | 0.1   | 0.0   |
| V <sub>2</sub> O <sub>3</sub>  | 0.0       | 0.0   | 0.1   | 0.0   | 0.0   | 0.0   | 0.1   | 0.1   | 0.1   | 0.0   | 0.0   | 0.1   |
| P <sub>2</sub> O <sub>5</sub>  |           |       |       |       |       |       |       |       |       |       |       |       |
| Total                          | 96.6      | 97.0  | 96.6  | 97.8  | 96.6  | 97.0  | 97.3  | 97.3  | 96.3  | 97.7  | 98.3  | 96.9  |

**Appendix H: Pair amphibole-plagioclase and result for thermobarometer.**

| Sample Specimen                | MNN21<br>99 | MNN21<br>97 | MNN21<br>94 |
|--------------------------------|-------------|-------------|-------------|
| <b>Amph</b>                    |             |             |             |
| SiO <sub>2</sub>               | 46.63       | 46.63       | 46.42       |
| TiO <sub>2</sub>               | 0.5         | 0.66        | 0.66        |
| Al <sub>2</sub> O <sub>3</sub> | 14.36       | 15.68       | 14.73       |
| FeO*                           | 12.22       | 12.35       | 11.83       |
| MgO                            | 13.92       | 13.59       | 13.92       |
| <b>Plg</b>                     |             |             |             |
|                                | 98          | 96          | 95          |
| X <sub>Ab</sub>                | 48.45       | 51.24       | 54.64       |
| X <sub>An</sub>                | 51.55       | 48.76       | 45.36       |
| T (°C) HB2                     | 715.25      | 713.62      | 687.33      |
| P(Kb) HB2                      | 7.55        | 8.41        | 8.34        |

## Appendix I: Results (output file) from Theriak-Domino run

### Sample MNN03

SI(36.58)AL(7.18)FE(9.49)MG(39.84)CA(3.53)NA(1.6)K(0.24)O(?)H(20)O(0.01)

Bulk composition: O 147.720000

|    |           |
|----|-----------|
| AL | 7.180000  |
| CA | 3.530000  |
| FE | 9.490000  |
| H  | 20.000000 |
| K  | 0.240000  |
| MG | 39.840000 |
| NA | 1.600000  |
| SI | 36.580000 |
| E  | 0.000000  |

X: Temperature [C]

Y: Pressure [Bar]

MAXIMUM LEVEL: 6 PREC = 0.0050 WPREC = 0.0400

ASSEMBLAGE: 1: x,y = 4.00000000E+02 3.50000000E+03 OLIV BIO (2)ClAMg  
CHLR naph

assemblage: OLIV\_fo BIO\_phl ClAMg\_tr ClAMg\_parg CHLR\_clin naph

ASSEMBLAGE: 2: x,y = 6.00000000E+02 3.50000000E+03 OLIV BIO ClAMg CHLR  
naph

assemblage: OLIV\_fo BIO\_phl ClAMg\_tr CHLR\_clin naph

ASSEMBLAGE: 3: x,y = 7.00000000E+02 3.50000000E+03 OLIV BIO (2)ClAMg  
naph H2O

assemblage: OLIV\_fo BIO\_phl ClAMg\_parg ClAMg\_cumm naph H2O

ASSEMBLAGE: 4: x,y = 7.50000000E+02 3.50000000E+03 OLIV BIO ClAMg OPX6  
H2O

assemblage: OLIV\_fo BIO\_phl ClAMg\_parg OPX6\_en H2O

ASSEMBLAGE: 5: x,y = 6.75000000E+02 3.50000000E+03 OLIV BIO (2)ClAMg  
CHLR naph H2O

assemblage: OLIV\_fo BIO\_phl ClAMg\_parg ClAMg\_cumm CHLR\_clin naph H2O

ASSEMBLAGE: 6: x,y = 6.62500000E+02 3.50000000E+03 OLIV BIO ClAMg CHLR  
naph H2O

assemblage: OLIV\_fo BIO\_phl ClAMg\_tr CHLR\_clin naph H2O

ASSEMBLAGE: 7: x,y = 7.12500000E+02 3.50000000E+03 OLIV BIO ClAMg OPX6  
naph H2O

assemblage: OLIV\_fo BIO\_phl ClAMg\_parg OPX6\_en naph H2O

ASSEMBLAGE: 8: x,y = 7.08593750E+02 3.50000000E+03 OLIV BIO (2)ClAMg  
OPX6 H2O

assemblage: OLIV\_fo BIO\_phl ClAMg\_parg ClAMg\_cumm OPX6\_en H2O

ASSEMBLAGE: 9: x,y = 7.08398438E+02 3.50000000E+03 OLIV BIO (2)ClAMg  
H2O

assemblage: OLIV\_fo BIO\_phl ClAMg\_parg ClAMg\_cumm H2O

ASSEMBLAGE: 10: x,y = 7.08789062E+02 3.50000000E+03 OLIV BIO (2)ClAMg  
OPX6 naph H2O

assemblage: OLIV\_fo BIO\_phl ClAMg\_parg ClAMg\_cumm OPX6\_en naph H2O

REACTION: 1 1 = 2

position: 5.94043E+02 3.50000E+03 5.94141E+02 3.50000E+03

LABELLED WITH ASSEMBLAGES

REACTION: OLIV BIO (2)ClAMg CHLR naph = OLIV BIO ClAMg CHLR naph



REACTION: 2 2 = 6  
 position: 6.58887E+02 3.50000E+03 6.58984E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO ClAMg CHLR naph = OLIV BIO ClAMg CHLR naph H2O  
 REACTION: 3 6 = 5  
 position: 6.63574E+02 3.50000E+03 6.63672E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO ClAMg CHLR naph H2O = OLIV BIO (2)ClAMg CHLR naph H2O  
 REACTION: 4 5 = 3  
 position: 6.88086E+02 3.50000E+03 6.88184E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg CHLR naph H2O = OLIV BIO (2)ClAMg naph H2O  
 REACTION: 5 3 = 9  
 position: 7.08301E+02 3.50000E+03 7.08398E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg naph H2O = OLIV BIO (2)ClAMg H2O  
 REACTION: 6 9 = 8  
 position: 7.08496E+02 3.50000E+03 7.08594E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg H2O = OLIV BIO (2)ClAMg OPX6 H2O  
 REACTION: 7 8 = 10  
 position: 7.08594E+02 3.50000E+03 7.08691E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg OPX6 H2O = OLIV BIO (2)ClAMg OPX6 naph H2O  
 REACTION: 8 10 = 7  
 position: 7.08887E+02 3.50000E+03 7.08984E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg OPX6 naph H2O = OLIV BIO ClAMg OPX6 naph H2O  
 REACTION: 9 7 = 4  
 position: 7.14844E+02 3.50000E+03 7.14941E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO ClAMg OPX6 naph H2O = OLIV BIO ClAMg OPX6 H2O  
 65 65 Y = 3500.0000 , 9 REACTIONS: 1 2 3 4 5 6 7 8 9  
 REACTION: 10 8 = 7  
 position: 7.09766E+02 4.35000E+03 7.09863E+02 4.35000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg OPX6 H2O = OLIV BIO ClAMg OPX6 naph H2O  
 62 127 Y = 4350.0000 , 8 REACTIONS: 1 2 3 4 5 6 10 9  
 ASSEMBLAGE: 11: x,y = 7.09375000E+02 5.20000000E+03 OLIV BIO ClAMg OPX6 CHLR naph H2O  
 assemblage: OLIV\_fo BIO\_phl ClAMg\_parg OPX6\_en CHLR\_clin naph H2O  
 ASSEMBLAGE: 12: x,y = 7.08886719E+02 5.20000000E+03 OLIV BIO (2)ClAMg OPX6 CHLR naph H2O  
 assemblage: OLIV\_fo BIO\_phl ClAMg\_parg ClAMg\_cumm OPX6\_en CHLR\_clin naph H2O  
 ASSEMBLAGE: 13: x,y = 7.10937500E+02 5.20000000E+03 OLIV BIO ClAMg OPX6 CHLR H2O  
 assemblage: OLIV\_fo BIO\_phl ClAMg\_parg OPX6\_en CHLR\_clin H2O  
 REACTION: 11 5 = 12  
 position: 7.08789E+02 5.20000E+03 7.08887E+02 5.20000E+03

LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg CHLR naph H2O = OLIV BIO (2)ClAMg OPX6 CHLR naph H2O  
 REACTION: 12 12 = 11  
 position: 7.08887E+02 5.20000E+03 7.08984E+02 5.20000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg OPX6 CHLR naph H2O = OLIV BIO ClAMg OPX6 CHLR naph H2O  
 REACTION: 13 11 = 13  
 position: 7.09668E+02 5.20000E+03 7.09766E+02 5.20000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO ClAMg OPX6 CHLR naph H2O = OLIV BIO ClAMg OPX6 CHLR H2O  
 REACTION: 14 13 = 4  
 position: 7.11133E+02 5.20000E+03 7.11230E+02 5.20000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO ClAMg OPX6 CHLR H2O = OLIV BIO ClAMg OPX6 H2O  
 53 180 Y = 5200.0000 , 7 REACTIONS: 1 2 3 11 12 13 14  
 57 237 Y = 6050.0000 , 7 REACTIONS: 1 2 3 11 12 13 14  
 ASSEMBLAGE: 14: x,y = 4.00000000E+02 6.90000000E+03 OLIV BIO (2)ClAMg OPX6 CHLR naph  
 assemblage: OLIV\_fo BIO\_phl ClAMg\_tr ClAMg\_parg OPX6\_en CHLR\_clin naph  
 ASSEMBLAGE: 15: x,y = 6.00000000E+02 6.90000000E+03 OLIV BIO ClAMg OPX6 CHLR naph  
 assemblage: OLIV\_fo BIO\_phl ClAMg\_tr OPX6\_en CHLR\_clin naph  
 REACTION: 15 14 = 15  
 position: 5.89355E+02 6.90000E+03 5.89453E+02 6.90000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg OPX6 CHLR naph = OLIV BIO ClAMg OPX6 CHLR naph  
 REACTION: 16 15 = 2  
 position: 6.18945E+02 6.90000E+03 6.19043E+02 6.90000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO ClAMg OPX6 CHLR naph = OLIV BIO ClAMg CHLR naph  
 REACTION: 17 5 = 11  
 position: 7.07715E+02 6.90000E+03 7.07812E+02 6.90000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg CHLR naph H2O = OLIV BIO ClAMg OPX6 CHLR naph H2O  
 68 305 Y = 6900.0000 , 7 REACTIONS: 15 16 2 3 17 13 14  
 REACTION: 18 6 = 11  
 position: 7.06641E+02 7.75000E+03 7.06738E+02 7.75000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO ClAMg CHLR naph H2O = OLIV BIO ClAMg OPX6 CHLR naph H2O  
 59 364 Y = 7750.0000 , 6 REACTIONS: 15 16 2 18 13 14  
 58 422 Y = 8600.0000 , 6 REACTIONS: 15 16 2 18 13 14  
 57 479 Y = 9450.0000 , 6 REACTIONS: 15 16 2 18 13 14  
 REACTION: 19 15 = 11  
 position: 7.18164E+02 1.03000E+04 7.18262E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES

REACTION: OLIV BIO ClAMg OPX6 CHLR naph = OLIV BIO ClAMg OPX6 CHLR naph H2O

46 525 Y = 10300.0000 , 4 REACTIONS: 15 19 13 14

ASSEMBLAGE: 16: x,y = 4.00000000E+02 1.11500000E+04 OLIV BIO ClAMg CPXo OPX6 CHLR naph

assemblage: OLIV\_fo BIO\_phl ClAMg\_parg CPXo\_di OPX6\_en CHLR\_clin naph

ASSEMBLAGE: 17: x,y = 4.21875000E+02 1.11500000E+04 OLIV BIO (2)ClAMg CPXo OPX6 CHLR naph

assemblage: OLIV\_fo BIO\_phl ClAMg\_tr ClAMg\_parg CPXo\_di OPX6\_en CHLR\_clin naph

REACTION: 20 16 = 17

position: 4.20410E+02 1.11500E+04 4.20508E+02 1.11500E+04

LABELED WITH ASSEMBLAGES

REACTION: OLIV BIO ClAMg CPXo OPX6 CHLR naph = OLIV BIO (2)ClAMg CPXo OPX6 CHLR naph

REACTION: 21 17 = 14

position: 4.22266E+02 1.11500E+04 4.22363E+02 1.11500E+04

LABELED WITH ASSEMBLAGES

REACTION: OLIV BIO (2)ClAMg CPXo OPX6 CHLR naph = OLIV BIO (2)ClAMg OPX6 CHLR naph

60 585 Y = 11150.0000 , 6 REACTIONS: 20 21 15 19 13 14

61 646 Y = 12000.0000 , 6 REACTIONS: 20 21 15 19 13 14

REACTION: 22 1 = 14

position: 4.00000E+02 6.25586E+03 4.00000E+02 6.25752E+03

LABELED WITH ASSEMBLAGES

REACTION: OLIV BIO (2)ClAMg CHLR naph = OLIV BIO (2)ClAMg OPX6 CHLR naph

24 670 X = 400.0000 , 3 REACTIONS: 22 21 20

21 691 X = 450.0000 , 3 REACTIONS: 22 21 20

9 700 X = 500.0000 , 1 REACTIONS: 22

9 709 X = 550.0000 , 1 REACTIONS: 22

9 718 X = 600.0000 , 1 REACTIONS: 16

9 727 X = 650.0000 , 1 REACTIONS: 16

36 763 X = 700.0000 , 4 REACTIONS: 4 3 2 16

9 772 X = 750.0000 , 1 REACTIONS: 14

0 772 X = 800.0000 , 0 REACTIONS:

0 772 X = 850.0000 , 0 REACTIONS:

0 772 X = 900.0000 , 0 REACTIONS:

NUMBER OF LINES: 22 NUMBER OF POINTS: 87 max.ph.: 2121

LEVEL: 0 SQUARE: ( 4 , 4 ) LINE 1 REACTION 1: OPEN END

17 789 Y = 6475.0000 , 2 REACTIONS: 15 16

10 799 X = 575.0000 , 1 REACTIONS: 22

NUMBER OF LINES: 22 NUMBER OF POINTS: 90 max.ph.: 2044

LEVEL: 0 SQUARE: ( 7 , 8 ) LINE 2 REACTION 2: OPEN END

19 818 Y = 9875.0000 , 2 REACTIONS: 19 13

2 820 X = 725.0000 , 0 REACTIONS:

NUMBER OF LINES: 22 NUMBER OF POINTS: 92 max.ph.: 2241

LEVEL: 0 SQUARE: ( 7 , 5 ) LINE 3 REACTION 3: OPEN END

32 852 Y = 7325.0000 , 4 REACTIONS: 3 17 13 14

10 862 X = 725.0000 , 1 REACTIONS: 13

NUMBER OF LINES: 22 NUMBER OF POINTS: 97 max.ph.: 2094

LEVEL: 0 SQUARE: ( 7 , 2 ) LINE 4 REACTION 4: OPEN END

ASSEMBLAGE: 18: x,y = 7.06250000E+02 4.77500000E+03 OLIV BIO (2)ClAMg  
CHLR H2O

assemblage: OLIV\_fo BIO\_phl ClAMg\_parg ClAMg\_cumm CHLR\_clin H2O

REACTION: 23 5 = 18

position: 7.05371E+02 4.77500E+03 7.05469E+02 4.77500E+03

LABELED WITH ASSEMBLAGES

REACTION: OLIV BIO (2)ClAMg CHLR naph H2O = OLIV BIO (2)ClAMg CHLR H2O

REACTION: 24 18 = 9

position: 7.06738E+02 4.77500E+03 7.06836E+02 4.77500E+03

LABELED WITH ASSEMBLAGES

REACTION: OLIV BIO (2)ClAMg CHLR H2O = OLIV BIO (2)ClAMg H2O

REACTION: 25 8 = 4

position: 7.09082E+02 4.77500E+03 7.09180E+02 4.77500E+03

LABELED WITH ASSEMBLAGES

REACTION: OLIV BIO (2)ClAMg OPX6 H2O = OLIV BIO ClAMg OPX6 H2O

24 886 Y = 4775.0000, 4 REACTIONS: 23 24 6 25

2 888 X = 725.0000, 0 REACTIONS:

NUMBER OF LINES: 25 NUMBER OF POINTS: 101 max.ph.: 2145

LEVEL: 0 SQUARE: ( 7, 1 ) LINE 5 REACTION 5: TWO POINTS

31 919 Y = 3925.0000, 5 REACTIONS: 5 6 7 8 9

2 921 X = 725.0000, 0 REACTIONS:

NUMBER OF LINES: 25 NUMBER OF POINTS: 106 max.ph.: 2080

LEVEL: 0 SQUARE: ( 7, 4 ) LINE 11 REACTION 11: OPEN END

26 947 Y = 6475.0000, 4 REACTIONS: 11 12 13 14

10 957 X = 725.0000, 1 REACTIONS: 14

NUMBER OF LINES: 25 NUMBER OF POINTS: 111 max.ph.: 2135

LEVEL: 0 SQUARE: ( 5, 5 ) LINE 16 REACTION 16: BUMP

11 968 Y = 7325.0000, 1 REACTIONS: 16

10 978 X = 625.0000, 1 REACTIONS: 16

NUMBER OF LINES: 25 NUMBER OF POINTS: 113 max.ph.: 2052

LEVEL: 0 SQUARE: ( 6, 6 ) LINE 16 REACTION 16: BUMP

11 989 Y = 8175.0000, 1 REACTIONS: 16

10 999 X = 675.0000, 1 REACTIONS: 16

NUMBER OF LINES: 25 NUMBER OF POINTS: 115 max.ph.: 3125

LEVEL: 0 SQUARE: ( 3, 4 ) LINE 22 REACTION 22: BUMP

3 1002 Y = 6475.0000, 0 REACTIONS:

10 1012 X = 525.0000, 1 REACTIONS: 22

NUMBER OF LINES: 25 NUMBER OF POINTS: 116 max.ph.: 2004

LEVEL: 0 SQUARE: ( 2, 4 ) LINE 22 REACTION 22: BUMP

3 1015 Y = 6475.0000, 0 REACTIONS:

10 1025 X = 475.0000, 1 REACTIONS: 22

NUMBER OF LINES: 25 NUMBER OF POINTS: 117 max.ph.: 2079

LEVEL: 1 SQUARE: ( 8, 7 ) LINE 1 REACTION 1: OPEN END

10 1035 Y = 6262.5000, 1 REACTIONS: 1

9 1044 X = 587.5000, 1 REACTIONS: 22

NUMBER OF LINES: 25 NUMBER OF POINTS: 119 max.ph.: 2120

LEVEL: 1 SQUARE: ( 13, 15 ) LINE 2 REACTION 2: OPEN END

16 1060 Y = 9662.5000, 3 REACTIONS: 16 2 18

9 1069 X = 712.5000, 1 REACTIONS: 16

NUMBER OF LINES: 25 NUMBER OF POINTS: 123 max.ph.: 2227

LEVEL: 1 SQUARE: ( 13, 10 ) LINE 3 REACTION 3: OPEN END

15 1084 Y = 7537.5000, 2 REACTIONS: 2 18

2 1086 X = 712.5000, 0 REACTIONS:  
 NUMBER OF LINES: 25 NUMBER OF POINTS: 125 max.ph.: 2762  
 LEVEL: 1 SQUARE: (13, 3) LINE 4 REACTION 4: OPEN END  
 23 1109 Y = 4562.5000, 4 REACTIONS: 23 24 6 25  
 2 1111 X = 712.5000, 0 REACTIONS:  
 NUMBER OF LINES: 25 NUMBER OF POINTS: 129 max.ph.: 2082  
 LEVEL: 1 SQUARE: (13, 4) LINE 6 REACTION 6: OPEN END  
 REACTION: 26 18 = 8  
 position: 7.08398E+02 4.98750E+03 7.08496E+02 4.98750E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)CIAMg CHLR H2O = OLIV BIO (2)CIAMg OPX6 H2O  
 17 1128 Y = 4987.5000, 3 REACTIONS: 23 26 25  
 2 1130 X = 712.5000, 0 REACTIONS:  
 NUMBER OF LINES: 26 NUMBER OF POINTS: 132 max.ph.: 2238  
 LEVEL: 1 SQUARE: (13, 2) LINE 7 REACTION 7: OPEN END  
 25 1155 Y = 4137.5000, 5 REACTIONS: 5 6 7 8 9  
 9 1164 X = 712.5000, 1 REACTIONS: 9  
 NUMBER OF LINES: 26 NUMBER OF POINTS: 138 max.ph.: 2069  
 LEVEL: 1 SQUARE: (13, 8) LINE 11 REACTION 11: OPEN END  
 17 1181 Y = 6687.5000, 2 REACTIONS: 17 13  
 2 1183 X = 712.5000, 0 REACTIONS:  
 NUMBER OF LINES: 26 NUMBER OF POINTS: 140 max.ph.: 2082  
 LEVEL: 2 SQUARE: (16, 14) LINE 1 REACTION 1: OPEN END  
 14 1197 Y = 6368.7500, 2 REACTIONS: 22 1  
 8 1205 X = 593.7500, 1 REACTIONS: 16  
 NUMBER OF LINES: 26 NUMBER OF POINTS: 143 max.ph.: 2028  
 LEVEL: 2 SQUARE: (26, 30) LINE 2 REACTION 2: OPEN END  
 9 1214 Y = 9768.7500, 1 REACTIONS: 19  
 2 1216 X = 718.7500, 0 REACTIONS:  
 NUMBER OF LINES: 26 NUMBER OF POINTS: 144 max.ph.: 2140  
 LEVEL: 2 SQUARE: (25, 19) LINE 3 REACTION 3: OPEN END  
 17 1233 Y = 7431.2500, 3 REACTIONS: 2 3 17  
 8 1241 X = 706.2500, 1 REACTIONS: 17  
 NUMBER OF LINES: 26 NUMBER OF POINTS: 148 max.ph.: 2122  
 LEVEL: 0 SQUARE: (6, 5) LINE 2 REACTION 2: BUMP  
 11 1252 Y = 7325.0000, 1 REACTIONS: 2  
 2 1254 X = 675.0000, 0 REACTIONS:  
 NUMBER OF LINES: 26 NUMBER OF POINTS: 149 max.ph.: 3053  
 LEVEL: 2 SQUARE: (25, 5) LINE 4 REACTION 4: OPEN END  
 25 1279 Y = 4456.2500, 4 REACTIONS: 4 5 6 25  
 2 1281 X = 706.2500, 0 REACTIONS:  
 NUMBER OF LINES: 26 NUMBER OF POINTS: 153 max.ph.: 2104  
 LEVEL: 2 SQUARE: (25, 7) LINE 6 REACTION 6: OPEN END  
 16 1297 Y = 4881.2500, 3 REACTIONS: 23 26 25  
 8 1305 X = 706.2500, 1 REACTIONS: 23  
 NUMBER OF LINES: 26 NUMBER OF POINTS: 157 max.ph.: 2191  
 LEVEL: 2 SQUARE: (25, 4) LINE 7 REACTION 7: OPEN END  
 24 1329 Y = 4243.7500, 5 REACTIONS: 5 6 7 8 9  
 2 1331 X = 706.2500, 0 REACTIONS:  
 NUMBER OF LINES: 26 NUMBER OF POINTS: 162 max.ph.: 2123  
 LEVEL: 2 SQUARE: (25, 8) LINE 11 REACTION 11: OPEN END

ASSEMBLAGE: 19: x,y = 7.08691406E+02 5.09375000E+03 OLIV BIO (2)ClAMg  
OPX6 CHLR H2O

assemblage: OLIV\_fo BIO\_phl ClAMg\_parg ClAMg\_cumm OPX6\_en CHLR\_clin  
H2O

REACTION: 27 18 = 19

position: 7.08594E+02 5.09375E+03 7.08691E+02 5.09375E+03

LABELED WITH ASSEMBLAGES

REACTION: OLIV BIO (2)ClAMg CHLR H2O = OLIV BIO (2)ClAMg OPX6 CHLR H2O

REACTION: 28 19 = 13

position: 7.08691E+02 5.09375E+03 7.08789E+02 5.09375E+03

LABELED WITH ASSEMBLAGES

REACTION: OLIV BIO (2)ClAMg OPX6 CHLR H2O = OLIV BIO ClAMg OPX6 CHLR  
H2O

17 1348 Y = 5093.7500 , 4 REACTIONS: 23 27 28 14

2 1350 X = 706.2500 , 0 REACTIONS:

NUMBER OF LINES: 28 NUMBER OF POINTS: 166 max.ph.: 2090

LEVEL: 2 SQUARE: ( 25 , 15 ) LINE 11 REACTION 11: OPEN END

9 1359 Y = 6581.2500 , 1 REACTIONS: 17

2 1361 X = 706.2500 , 0 REACTIONS:

NUMBER OF LINES: 28 NUMBER OF POINTS: 167 max.ph.: 3072

LEVEL: 2 SQUARE: ( 25 , 6 ) LINE 24 REACTION 24: TWO POINTS

24 1385 Y = 4668.7500 , 4 REACTIONS: 23 24 6 25

8 1393 X = 706.2500 , 1 REACTIONS: 24

NUMBER OF LINES: 28 NUMBER OF POINTS: 172 max.ph.: 3199

LEVEL: 3 SQUARE: ( 31 , 28 ) LINE 1 REACTION 1: OPEN END

12 1405 Y = 6421.8750 , 2 REACTIONS: 15 16

7 1412 X = 590.6250 , 1 REACTIONS: 22

NUMBER OF LINES: 28 NUMBER OF POINTS: 175 max.ph.: 2155

LEVEL: 3 SQUARE: ( 51 , 59 ) LINE 2 REACTION 2: OPEN END

16 1428 Y = 9715.6250 , 3 REACTIONS: 16 2 18

16 1444 X = 715.6250 , 3 REACTIONS: 18 2 16

NUMBER OF LINES: 28 NUMBER OF POINTS: 181 max.ph.: 2102

LEVEL: 3 SQUARE: ( 49 , 38 ) LINE 3 REACTION 3: OPEN END

16 1460 Y = 7484.3750 , 3 REACTIONS: 2 3 17

2 1462 X = 703.1250 , 0 REACTIONS:

NUMBER OF LINES: 28 NUMBER OF POINTS: 184 max.ph.: 2054

LEVEL: 3 SQUARE: ( 49 , 10 ) LINE 4 REACTION 4: OPEN END

10 1472 Y = 4509.3750 , 2 REACTIONS: 4 5

16 1488 X = 703.1250 , 3 REACTIONS: 5 24 23

NUMBER OF LINES: 28 NUMBER OF POINTS: 189 max.ph.: 2070

LEVEL: 3 SQUARE: ( 50 , 13 ) LINE 6 REACTION 6: OPEN END

15 1503 Y = 4828.1250 , 3 REACTIONS: 24 6 25

2 1505 X = 709.3750 , 0 REACTIONS:

NUMBER OF LINES: 28 NUMBER OF POINTS: 192 max.ph.: 2175

LEVEL: 3 SQUARE: ( 50 , 8 ) LINE 7 REACTION 7: OPEN END

16 1521 Y = 4296.8750 , 4 REACTIONS: 6 7 8 9

2 1523 X = 709.3750 , 0 REACTIONS:

NUMBER OF LINES: 28 NUMBER OF POINTS: 196 max.ph.: 2033

LEVEL: 3 SQUARE: ( 50 , 9 ) LINE 9 REACTION 9: OPEN END

16 1539 Y = 4403.1250 , 3 REACTIONS: 6 10 9

2 1541 X = 709.3750 , 0 REACTIONS:

NUMBER OF LINES: 28 NUMBER OF POINTS: 199 max.ph.: 2078

LEVEL: 3 SQUARE: ( 50 , 16 ) LINE 11 REACTION 11: OPEN END  
 15 1556 Y = 5146.8750 , 3 REACTIONS: 17 13 14  
 7 1563 X = 709.3750 , 1 REACTIONS: 13  
 NUMBER OF LINES: 29 NUMBER OF POINTS: 203 max.ph.: 2112  
 LEVEL: 3 SQUARE: ( 50 , 29 ) LINE 11 REACTION 11: OPEN END  
 8 1571 Y = 6528.1250 , 1 REACTIONS: 17  
 2 1573 X = 709.3750 , 0 REACTIONS:  
 NUMBER OF LINES: 29 NUMBER OF POINTS: 204 max.ph.: 2130  
 LEVEL: 3 SQUARE: ( 50 , 15 ) LINE 14 REACTION 14: OPEN END  
 14 1587 Y = 5040.6250 , 4 REACTIONS: 23 27 28 14  
 7 1594 X = 709.3750 , 1 REACTIONS: 14  
 NUMBER OF LINES: 29 NUMBER OF POINTS: 209 max.ph.: 2096  
 LEVEL: 3 SQUARE: ( 50 , 14 ) LINE 26 REACTION 26: TWO POINTS  
 REACTION: 29 19 = 8  
 position: 7.08301E+02 4.93438E+03 7.08398E+02 4.93438E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg OPX6 CHLR H2O = OLIV BIO (2)ClAMg OPX6 H2O  
 15 1609 Y = 4934.3750 , 4 REACTIONS: 23 27 29 25  
 2 1611 X = 709.3750 , 0 REACTIONS:  
 NUMBER OF LINES: 32 NUMBER OF POINTS: 213 max.ph.: 2093  
 LEVEL: 4 SQUARE: ( 62 , 55 ) LINE 1 REACTION 1: OPEN END  
 10 1621 Y = 6395.3125 , 2 REACTIONS: 15 16  
 6 1627 X = 592.1875 , 1 REACTIONS: 16  
 NUMBER OF LINES: 32 NUMBER OF POINTS: 216 max.ph.: 2062  
 LEVEL: 4 SQUARE: ( 102 , 118 ) LINE 2 REACTION 2: OPEN END  
 7 1634 Y = 9742.1875 , 2 REACTIONS: 2 18  
 2 1636 X = 717.1875 , 0 REACTIONS:  
 NUMBER OF LINES: 32 NUMBER OF POINTS: 218 max.ph.: 3089  
 LEVEL: 4 SQUARE: ( 98 , 76 ) LINE 3 REACTION 3: OPEN END  
 10 1646 Y = 7510.9375 , 2 REACTIONS: 3 17  
 2 1648 X = 704.6875 , 0 REACTIONS:  
 NUMBER OF LINES: 32 NUMBER OF POINTS: 220 max.ph.: 2999  
 LEVEL: 4 SQUARE: ( 97 , 20 ) LINE 4 REACTION 4: OPEN END  
 7 1655 Y = 4535.9375 , 1 REACTIONS: 23  
 2 1657 X = 701.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 32 NUMBER OF POINTS: 221 max.ph.: 2016  
 LEVEL: 4 SQUARE: ( 99 , 26 ) LINE 6 REACTION 6: OPEN END  
 11 1668 Y = 4854.6875 , 3 REACTIONS: 24 6 25  
 6 1674 X = 707.8125 , 1 REACTIONS: 24  
 NUMBER OF LINES: 32 NUMBER OF POINTS: 225 max.ph.: 2097  
 LEVEL: 4 SQUARE: ( 100 , 16 ) LINE 7 REACTION 7: OPEN END  
 10 1684 Y = 4323.4375 , 3 REACTIONS: 7 8 9  
 2 1686 X = 710.9375 , 0 REACTIONS:  
 NUMBER OF LINES: 32 NUMBER OF POINTS: 228 max.ph.: 2055  
 LEVEL: 4 SQUARE: ( 100 , 18 ) LINE 9 REACTION 9: OPEN END  
 8 1694 Y = 4429.6875 , 2 REACTIONS: 10 9  
 2 1696 X = 710.9375 , 0 REACTIONS:  
 NUMBER OF LINES: 32 NUMBER OF POINTS: 230 max.ph.: 2139  
 LEVEL: 4 SQUARE: ( 99 , 32 ) LINE 11 REACTION 11: OPEN END  
 7 1703 Y = 5173.4375 , 1 REACTIONS: 17  
 2 1705 X = 707.8125 , 0 REACTIONS:  
 NUMBER OF LINES: 32 NUMBER OF POINTS: 231 max.ph.: 3526

LEVEL: 4 SQUARE: ( 99 , 57 ) LINE 11 REACTION 11: OPEN END  
 7 1712 Y = 6501.5625 , 1 REACTIONS: 17  
 2 1714 X = 707.8125 , 0 REACTIONS:  
 NUMBER OF LINES: 32 NUMBER OF POINTS: 232 max.ph.: 2134  
 LEVEL: 4 SQUARE: ( 99 , 31 ) LINE 13 REACTION 13: OPEN END  
 REACTION: 30 18 = 11  
 position: 7.08691E+02 5.12031E+03 7.08789E+02 5.12031E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg CHLR H2O = OLIV BIO ClAMg OPX6 CHLR naph  
 H2O  
 12 1726 Y = 5120.3125 , 3 REACTIONS: 23 30 13  
 2 1728 X = 707.8125 , 0 REACTIONS:  
 NUMBER OF LINES: 33 NUMBER OF POINTS: 235 max.ph.: 2057  
 LEVEL: 4 SQUARE: ( 99 , 29 ) LINE 14 REACTION 14: OPEN END  
 14 1742 Y = 5014.0625 , 4 REACTIONS: 23 27 28 14  
 6 1748 X = 707.8125 , 1 REACTIONS: 23  
 NUMBER OF LINES: 33 NUMBER OF POINTS: 240 max.ph.: 2101  
 LEVEL: 4 SQUARE: ( 99 , 27 ) LINE 26 REACTION 26: OPEN END  
 14 1762 Y = 4907.8125 , 3 REACTIONS: 23 26 25  
 2 1764 X = 707.8125 , 0 REACTIONS:  
 NUMBER OF LINES: 33 NUMBER OF POINTS: 243 max.ph.: 2035  
 LEVEL: 4 SQUARE: ( 99 , 28 ) LINE 27 REACTION 26: OPEN END  
 14 1778 Y = 4960.9375 , 3 REACTIONS: 23 26 25  
 2 1780 X = 707.8125 , 0 REACTIONS:  
 NUMBER OF LINES: 33 NUMBER OF POINTS: 246 max.ph.: 2118  
 LEVEL: 5 SQUARE: ( 123 , 109 ) LINE 1 REACTION 1: OPEN END  
 9 1789 Y = 6382.0312 , 2 REACTIONS: 22 1  
 7 1796 X = 591.4062 , 2 REACTIONS: 22 15  
 NUMBER OF LINES: 33 NUMBER OF POINTS: 250 max.ph.: 2051  
 LEVEL: 5 SQUARE: ( 203 , 236 ) LINE 2 REACTION 2: OPEN END  
 6 1802 Y = 9755.4688 , 1 REACTIONS: 19  
 2 1804 X = 716.4062 , 0 REACTIONS:  
 NUMBER OF LINES: 33 NUMBER OF POINTS: 251 max.ph.: 2858  
 LEVEL: 5 SQUARE: ( 196 , 152 ) LINE 3 REACTION 3: OPEN END  
 9 1813 Y = 7524.2188 , 2 REACTIONS: 3 17  
 5 1818 X = 705.4688 , 1 REACTIONS: 3  
 NUMBER OF LINES: 33 NUMBER OF POINTS: 254 max.ph.: 2851  
 LEVEL: 5 SQUARE: ( 194 , 39 ) LINE 4 REACTION 4: OPEN END  
 REACTION: 31 5 = 9  
 position: 7.02832E+02 4.52266E+03 7.02930E+02 4.52266E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)ClAMg CHLR naph H2O = OLIV BIO (2)ClAMg H2O  
 6 1824 Y = 4522.6562 , 1 REACTIONS: 31  
 2 1826 X = 702.3438 , 0 REACTIONS:  
 NUMBER OF LINES: 34 NUMBER OF POINTS: 255 max.ph.: 2068  
 LEVEL: 5 SQUARE: ( 198 , 52 ) LINE 6 REACTION 6: OPEN END  
 9 1835 Y = 4867.9688 , 2 REACTIONS: 26 25  
 2 1837 X = 708.5938 , 0 REACTIONS:  
 NUMBER OF LINES: 34 NUMBER OF POINTS: 257 max.ph.: 2126  
 LEVEL: 5 SQUARE: ( 199 , 32 ) LINE 7 REACTION 7: OPEN END  
 9 1846 Y = 4336.7188 , 3 REACTIONS: 7 8 9  
 2 1848 X = 710.1562 , 0 REACTIONS:



NUMBER OF LINES: 34 NUMBER OF POINTS: 260 max.ph.: 2066  
 LEVEL: 5 SQUARE: (199, 36) LINE 9 REACTION 9: OPEN END  
 6 1854 Y = 4442.9688, 2 REACTIONS: 10 9  
 2 1856 X = 710.1562, 0 REACTIONS:  
 NUMBER OF LINES: 34 NUMBER OF POINTS: 262 max.ph.: 2053  
 LEVEL: 5 SQUARE: (198, 64) LINE 11 REACTION 11: OPEN END  
 6 1862 Y = 5186.7188, 1 REACTIONS: 17  
 2 1864 X = 708.5938, 0 REACTIONS:  
 NUMBER OF LINES: 34 NUMBER OF POINTS: 263 max.ph.: 2751  
 LEVEL: 5 SQUARE: (198, 113) LINE 11 REACTION 11: OPEN END  
 6 1870 Y = 6488.2812, 1 REACTIONS: 17  
 2 1872 X = 708.5938, 0 REACTIONS:  
 NUMBER OF LINES: 34 NUMBER OF POINTS: 264 max.ph.: 2109  
 LEVEL: 5 SQUARE: (198, 61) LINE 13 REACTION 13: OPEN END  
 10 1882 Y = 5107.0312, 3 REACTIONS: 23 30 13  
 2 1884 X = 708.5938, 0 REACTIONS:  
 NUMBER OF LINES: 34 NUMBER OF POINTS: 267 max.ph.: 2089  
 LEVEL: 5 SQUARE: (198, 57) LINE 14 REACTION 14: OPEN END  
 REACTION: 32 19 = 4  
 position: 7.08496E+02 5.00078E+03 7.08594E+02 5.00078E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: OLIV BIO (2)CIAMg OPX6 CHLR H2O = OLIV BIO CIAMg OPX6 H2O  
 6 1890 Y = 5000.7812, 2 REACTIONS: 27 32  
 8 1898 X = 708.5938, 2 REACTIONS: 25 14  
 NUMBER OF LINES: 35 NUMBER OF POINTS: 271 max.ph.: 2116  
 LEVEL: 5 SQUARE: (198, 62) LINE 23 REACTION 23: OPEN END  
 9 1907 Y = 5133.5938, 3 REACTIONS: 11 12 13  
 5 1912 X = 708.5938, 1 REACTIONS: 23  
 NUMBER OF LINES: 37 NUMBER OF POINTS: 275 max.ph.: 2099  
 LEVEL: 5 SQUARE: (198, 54) LINE 26 REACTION 26: OPEN END  
 9 1921 Y = 4921.0938, 2 REACTIONS: 26 25  
 2 1923 X = 708.5938, 0 REACTIONS:  
 NUMBER OF LINES: 37 NUMBER OF POINTS: 277 max.ph.: 2159  
 LEVEL: 5 SQUARE: (198, 55) LINE 27 REACTION 26: OPEN END  
 9 1932 Y = 4947.6562, 2 REACTIONS: 26 25  
 2 1934 X = 708.5938, 0 REACTIONS:  
 NUMBER OF LINES: 37 NUMBER OF POINTS: 279 max.ph.: 2096  
 exit DOMINO  
 CPU time: 1h 37m 10.64s

**Sample MNN19**

SI(44.49)AL(18.08)FE(6.45)MG(12.88)CA(8.03)NA(4.85)K(0.84)O(?)H(100)O(0.01)

Bulk composition: O 196.315000

|    |            |
|----|------------|
| AL | 18.080000  |
| CA | 8.030000   |
| FE | 6.450000   |
| H  | 100.000000 |
| K  | 0.840000   |
| MG | 12.880000  |
| NA | 4.850000   |
| SI | 44.490000  |
| E  | 0.000000   |

X: Temperature [C]

Y: Pressure [Bar]

MAXIMUM LEVEL: 6 PREC = 0.0050 WPREC = 0.0400

ASSEMBLAGE: 1: x,y = 4.00000000E+02 3.50000000E+03 EPI BIO ClAMg CHLR  
ab q H2O

assemblage: EPI\_cz BIO\_ann2 ClAMg\_tr CHLR\_clin ab q H2O

ASSEMBLAGE: 2: x,y = 5.00000000E+02 3.50000000E+03 FSP BIO (2)ClAMg CHLR  
q H2O

assemblage: FSP\_abh BIO\_phl ClAMg\_tr ClAMg\_grun CHLR\_clin q H2O

ASSEMBLAGE: 3: x,y = 5.50000000E+02 3.50000000E+03 FSP BIO ClAMg CHLR  
q H2O

assemblage: FSP\_abh BIO\_phl ClAMg\_parg CHLR\_clin q H2O

ASSEMBLAGE: 4: x,y = 6.00000000E+02 3.50000000E+03 FSP BIO (2)ClAMg H2O

assemblage: FSP\_abh BIO\_phl ClAMg\_parg ClAMg\_bcam H2O

ASSEMBLAGE: 5: x,y = 7.50000000E+02 3.50000000E+03 FSP BIO (2)ClAMg OPX6  
H2O

assemblage: FSP\_anc1 BIO\_phl ClAMg\_parg ClAMg\_bcam OPX6\_fm H2O

ASSEMBLAGE: 6: x,y = 8.00000000E+02 3.50000000E+03 FSP BIO ClAMg OPX6  
H2O

assemblage: FSP\_anc1 BIO\_phl ClAMg\_parg OPX6\_fm H2O

ASSEMBLAGE: 7: x,y = 8.50000000E+02 3.50000000E+03 FSP BIO ClAMg CPXg  
OPX6 H2O

assemblage: FSP\_anc1 BIO\_phl ClAMg\_parg CPXg\_di OPX6\_fm H2O

ASSEMBLAGE: 8: x,y = 4.62500000E+02 3.50000000E+03 FSP EPI BIO ClAMg  
CHLR q H2O

assemblage: FSP\_abh EPI\_cz BIO\_ann2 ClAMg\_tr CHLR\_clin q H2O

ASSEMBLAGE: 9: x,y = 4.56445312E+02 3.50000000E+03 FSP EPI BIO ClAMg  
CHLR ab q H2O

assemblage: FSP\_abh EPI\_cz BIO\_ann2 ClAMg\_tr CHLR\_clin ab q H2O

ASSEMBLAGE: 10: x,y = 4.64062500E+02 3.50000000E+03 FSP EPI BIO (2)ClAMg  
CHLR q H2O

assemblage: FSP\_abh EPI\_cz BIO\_ann2 ClAMg\_tr ClAMg\_grun CHLR\_clin q H2O

ASSEMBLAGE: 11: x,y = 5.75000000E+02 3.50000000E+03 FSP BIO (2)ClAMg q  
H2O

assemblage: FSP\_abh BIO\_phl ClAMg\_parg ClAMg\_bcam q H2O

REACTION: 1 1 = 9

position: 4.56250E+02 3.50000E+03 4.56348E+02 3.50000E+03

LABELED WITH ASSEMBLAGES

REACTION: EPI BIO ClAMg CHLR ab q H2O = FSP EPI BIO ClAMg CHLR ab q H2O

REACTION: 2 9 = 8

position: 4.56543E+02 3.50000E+03 4.56641E+02 3.50000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP EPI BIO ClAMg CHLR ab q H2O = FSP EPI BIO ClAMg CHLR q H2O

REACTION: 3 8 = 10

position: 4.63867E+02 3.50000E+03 4.63965E+02 3.50000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP EPI BIO ClAMg CHLR q H2O = FSP EPI BIO (2)ClAMg CHLR q H2O

REACTION: 4 10 = 2

position: 4.64746E+02 3.50000E+03 4.64844E+02 3.50000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP EPI BIO (2)ClAMg CHLR q H2O = FSP BIO (2)ClAMg CHLR q H2O

REACTION: 5 2 = 3

position: 5.25488E+02 3.50000E+03 5.25586E+02 3.50000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO (2)ClAMg CHLR q H2O = FSP BIO ClAMg CHLR q H2O

REACTION: 6 2 = 11

position: 5.65918E+02 3.50000E+03 5.66016E+02 3.50000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO (2)ClAMg CHLR q H2O = FSP BIO (2)ClAMg q H2O

REACTION: 7 11 = 4

position: 5.95703E+02 3.50000E+03 5.95801E+02 3.50000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO (2)ClAMg q H2O = FSP BIO (2)ClAMg H2O

REACTION: 8 4 = 5

position: 7.47559E+02 3.50000E+03 7.47656E+02 3.50000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO (2)ClAMg H2O = FSP BIO (2)ClAMg OPX6 H2O

REACTION: 9 5 = 6

position: 7.51953E+02 3.50000E+03 7.52051E+02 3.50000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO (2)ClAMg OPX6 H2O = FSP BIO ClAMg OPX6 H2O

REACTION: 10 6 = 7

position: 8.44043E+02 3.50000E+03 8.44141E+02 3.50000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO ClAMg OPX6 H2O = FSP BIO ClAMg CPXg OPX6 H2O

92 92 Y = 3500.0000, 11 REACTIONS: 1 2 3 4 5 5 6 7 8 9 10

ASSEMBLAGE: 12: x,y = 4.75000000E+02 4.35000000E+03 FSP BIO ClAMg CHLR ab q H2O

assemblage: FSP\_abh BIO\_phl ClAMg\_parg CHLR\_clin ab q H2O

ASSEMBLAGE: 13: x,y = 4.71875000E+02 4.35000000E+03 EPI BIO (2)ClAMg CHLR ab q H2O

assemblage: EPI\_cz BIO\_phl ClAMg\_tr ClAMg\_grun CHLR\_clin ab q H2O

REACTION: 11 1 = 13

position: 4.69043E+02 4.35000E+03 4.69141E+02 4.35000E+03

LABELED WITH ASSEMBLAGES

REACTION: EPI BIO ClAMg CHLR ab q H2O = EPI BIO (2)ClAMg CHLR ab q H2O

REACTION: 12 9 = 12

position: 4.74805E+02 4.35000E+03 4.74902E+02 4.35000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP EPI BIO ClAMg CHLR ab q H2O = FSP BIO ClAMg CHLR ab q H2O

REACTION: 13 12 = 3

position: 4.98828E+02 4.35000E+03 4.98926E+02 4.35000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO ClAMg CHLR ab q H2O = FSP BIO ClAMg CHLR q H2O

86 178 Y = 4350.0000, 11 REACTIONS: 11 11 1 12 13 5 6 7 8  
9 10

ASSEMBLAGE: 14: x,y = 5.00000000E+02 5.20000000E+03 BIO ClAMg CHLR ab q  
H2O

assemblage: BIO\_phl ClAMg\_parg CHLR\_clin ab q H2O

ASSEMBLAGE: 15: x,y = 6.00000000E+02 5.20000000E+03 FSP BIO ClAMg q H2O

assemblage: FSP\_abh BIO\_phl ClAMg\_parg q H2O

REACTION: 14 1 = 14

position: 4.87695E+02 5.20000E+03 4.87793E+02 5.20000E+03

LABELED WITH ASSEMBLAGES

REACTION: EPI BIO ClAMg CHLR ab q H2O = BIO ClAMg CHLR ab q H2O

REACTION: 15 14 = 12

position: 5.04395E+02 5.20000E+03 5.04492E+02 5.20000E+03

LABELED WITH ASSEMBLAGES

REACTION: BIO ClAMg CHLR ab q H2O = FSP BIO ClAMg CHLR ab q H2O

REACTION: 16 3 = 15

position: 5.76660E+02 5.20000E+03 5.76758E+02 5.20000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO ClAMg CHLR q H2O = FSP BIO ClAMg q H2O

REACTION: 17 15 = 11

position: 6.02246E+02 5.20000E+03 6.02344E+02 5.20000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO ClAMg q H2O = FSP BIO (2)ClAMg q H2O

90 268 Y = 5200.0000, 9 REACTIONS: 14 15 13 16 17 7 8 9 10  
ASSEMBLAGE: 16: x,y = 7.89062500E+02 6.05000000E+03 FSP BIO ClAMg OPX6  
q H2O

assemblage: FSP\_anc1 BIO\_phl ClAMg\_parg OPX6\_fm q H2O

ASSEMBLAGE: 17: x,y = 7.88281250E+02 6.05000000E+03 FSP BIO (2)ClAMg  
OPX6 q H2O

assemblage: FSP\_anc1 BIO\_phl ClAMg\_parg ClAMg\_bcam OPX6\_fm q H2O

REACTION: 18 5 = 16

position: 7.88086E+02 6.05000E+03 7.88184E+02 6.05000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO (2)ClAMg OPX6 H2O = FSP BIO ClAMg OPX6 q H2O

REACTION: 19 16 = 17

position: 7.88184E+02 6.05000E+03 7.88281E+02 6.05000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO ClAMg OPX6 q H2O = FSP BIO (2)ClAMg OPX6 q H2O

REACTION: 20 16 = 6

position: 7.89062E+02 6.05000E+03 7.89160E+02 6.05000E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO ClAMg OPX6 q H2O = FSP BIO ClAMg OPX6 H2O

94 362 Y = 6050.0000, 12 REACTIONS: 14 15 13 16 17 7 8 18  
19 19 20 10

ASSEMBLAGE: 18: x,y = 4.00000000E+02 6.90000000E+03 EPI PHNG BIO ClAMg  
CHLR ab q H2O

assemblage: EPI\_cz PHNG\_mu BIO\_ann2 ClAMg\_tr CHLR\_clin ab q H2O  
 ASSEMBLAGE: 19: x,y = 5.62500000E+02 6.90000000E+03 BIO ClAMg ab q H2O  
 assemblage: BIO\_phl ClAMg\_parg ab q H2O  
 ASSEMBLAGE: 20: x,y = 5.68750000E+02 6.90000000E+03 FSP BIO ClAMg ab q H2O  
 assemblage: FSP\_abh BIO\_phl ClAMg\_parg ab q H2O  
 REACTION: 21 18 = 1  
 position: 4.00098E+02 6.90000E+03 4.00195E+02 6.90000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG BIO ClAMg CHLR ab q H2O = EPI BIO ClAMg CHLR ab q H2O  
 REACTION: 22 14 = 19  
 position: 5.51172E+02 6.90000E+03 5.51270E+02 6.90000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: BIO ClAMg CHLR ab q H2O = BIO ClAMg ab q H2O  
 REACTION: 23 19 = 20  
 position: 5.65039E+02 6.90000E+03 5.65137E+02 6.90000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: BIO ClAMg ab q H2O = FSP BIO ClAMg ab q H2O  
 REACTION: 24 20 = 15  
 position: 5.74121E+02 6.90000E+03 5.74219E+02 6.90000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO ClAMg ab q H2O = FSP BIO ClAMg q H2O  
 REACTION: 25 15 = 16  
 position: 7.92578E+02 6.90000E+03 7.92676E+02 6.90000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO ClAMg q H2O = FSP BIO ClAMg OPX6 q H2O  
 78 440 Y = 6900.0000 , 8 REACTIONS: 21 14 22 23 24 25 20 10  
 ASSEMBLAGE: 21: x,y = 4.00000000E+02 7.75000000E+03 EPI PHNG ClAMg CHLR  
 ab q H2O  
 assemblage: EPI\_cz PHNG\_mu ClAMg\_tr CHLR\_clin ab q H2O  
 ASSEMBLAGE: 22: x,y = 9.00000000E+02 7.75000000E+03 (2)FSP BIO ClAMg  
 OPX6 H2O  
 assemblage: FSP\_san FSP\_anc1 BIO\_phl ClAMg\_parg OPX6\_en H2O  
 ASSEMBLAGE: 23: x,y = 5.12500000E+02 7.75000000E+03 PHNG BIO ClAMg  
 CHLR ab q H2O  
 assemblage: PHNG\_mu BIO\_phl ClAMg\_parg CHLR\_clin ab q H2O  
 REACTION: 26 21 = 18  
 position: 4.16504E+02 7.75000E+03 4.16602E+02 7.75000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG ClAMg CHLR ab q H2O = EPI PHNG BIO ClAMg CHLR ab q  
 H2O  
 REACTION: 27 1 = 23  
 position: 5.00293E+02 7.75000E+03 5.00391E+02 7.75000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI BIO ClAMg CHLR ab q H2O = PHNG BIO ClAMg CHLR ab q H2O  
 REACTION: 28 23 = 14  
 position: 5.16504E+02 7.75000E+03 5.16602E+02 7.75000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: PHNG BIO ClAMg CHLR ab q H2O = BIO ClAMg CHLR ab q H2O  
 REACTION: 29 6 = 22  
 position: 8.89648E+02 7.75000E+03 8.89746E+02 7.75000E+03  
 LABELED WITH ASSEMBLAGES

REACTION: FSP BIO ClAMg OPX6 H2O = (2)FSP BIO ClAMg OPX6 H2O  
93 533 Y = 7750.0000 , 10 REACTIONS: 26 21 27 28 22 23 24 25  
20 29  
ASSEMBLAGE: 24: x,y = 5.00000000E+02 8.60000000E+03 PHNG ClAMg CHLR ab  
q H2O  
assemblage: PHNG\_mu ClAMg\_parg CHLR\_clin ab q H2O  
ASSEMBLAGE: 25: x,y = 9.00000000E+02 8.60000000E+03 (2)FSP ClAMg OPX6  
H2O  
assemblage: FSP\_san FSP\_anc1 ClAMg\_parg OPX6\_fm H2O  
ASSEMBLAGE: 26: x,y = 5.25000000E+02 8.60000000E+03 PHNG BIO ClAMg ab q  
H2O  
assemblage: PHNG\_mu BIO\_phl ClAMg\_parg ab q H2O  
ASSEMBLAGE: 27: x,y = 8.75000000E+02 8.60000000E+03 (2)FSP ClAMg OPX6 q  
H2O  
assemblage: FSP\_san FSP\_abh ClAMg\_parg OPX6\_fm q H2O  
ASSEMBLAGE: 28: x,y = 8.67187500E+02 8.60000000E+03 (2)FSP BIO ClAMg  
OPX6 q H2O  
assemblage: FSP\_san FSP\_abh BIO\_phl ClAMg\_parg OPX6\_fm q H2O  
REACTION: 30 1 = 21  
position: 4.95410E+02 8.60000E+03 4.95508E+02 8.60000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: EPI BIO ClAMg CHLR ab q H2O = EPI PHNG ClAMg CHLR ab q H2O  
REACTION: 31 21 = 24  
position: 4.97949E+02 8.60000E+03 4.98047E+02 8.60000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: EPI PHNG ClAMg CHLR ab q H2O = PHNG ClAMg CHLR ab q H2O  
REACTION: 32 24 = 23  
position: 5.00977E+02 8.60000E+03 5.01074E+02 8.60000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: PHNG ClAMg CHLR ab q H2O = PHNG BIO ClAMg CHLR ab q H2O  
REACTION: 33 23 = 26  
position: 5.24512E+02 8.60000E+03 5.24609E+02 8.60000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: PHNG BIO ClAMg CHLR ab q H2O = PHNG BIO ClAMg ab q H2O  
REACTION: 34 26 = 19  
position: 5.45020E+02 8.60000E+03 5.45117E+02 8.60000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: PHNG BIO ClAMg ab q H2O = BIO ClAMg ab q H2O  
REACTION: 35 16 = 28  
position: 8.66699E+02 8.60000E+03 8.66797E+02 8.60000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP BIO ClAMg OPX6 q H2O = (2)FSP BIO ClAMg OPX6 q H2O  
REACTION: 36 28 = 27  
position: 8.67383E+02 8.60000E+03 8.67480E+02 8.60000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: (2)FSP BIO ClAMg OPX6 q H2O = (2)FSP ClAMg OPX6 q H2O  
REACTION: 37 27 = 25  
position: 8.80762E+02 8.60000E+03 8.80859E+02 8.60000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: (2)FSP ClAMg OPX6 q H2O = (2)FSP ClAMg OPX6 H2O  
122 655 Y = 8600.0000 , 15 REACTIONS: 26 21 11 11 30 31 32 33  
34 23 24 25 35 36 37

ASSEMBLAGE: 29: x,y = 4.00000000E+02 9.45000000E+03 EPI PHNG (2)ClAMg CHLR q H2O  
 assemblage: EPI\_cz PHNG\_mu ClAMg\_tr ClAMg\_gl CHLR\_clin q H2O  
 ASSEMBLAGE: 30: x,y = 5.00000000E+02 9.45000000E+03 EPI PHNG ClAMg CHLR q H2O  
 assemblage: EPI\_cz PHNG\_mu ClAMg\_parg CHLR\_clin q H2O  
 ASSEMBLAGE: 31: x,y = 5.50000000E+02 9.45000000E+03 PHNG BIO ClAMg q H2O  
 assemblage: PHNG\_mu BIO\_phl ClAMg\_parg q H2O  
 ASSEMBLAGE: 32: x,y = 4.43750000E+02 9.45000000E+03 EPI PHNG (2)ClAMg CHLR ab q H2O  
 assemblage: EPI\_cz PHNG\_mu ClAMg\_tr ClAMg\_gl CHLR\_clin ab q H2O  
 ASSEMBLAGE: 33: x,y = 5.25000000E+02 9.45000000E+03 PHNG BIO ClAMg CHLR q H2O  
 assemblage: PHNG\_mu BIO\_phl ClAMg\_parg CHLR\_clin q H2O  
 ASSEMBLAGE: 34: x,y = 5.12500000E+02 9.45000000E+03 PHNG ClAMg CHLR q H2O  
 assemblage: PHNG\_mu ClAMg\_parg CHLR\_clin q H2O  
 ASSEMBLAGE: 35: x,y = 8.62500000E+02 9.45000000E+03 (2)FSP BIO ClAMg q H2O  
 assemblage: FSP\_san FSP\_abh BIO\_phl ClAMg\_parg q H2O  
 ASSEMBLAGE: 36: x,y = 8.68750000E+02 9.45000000E+03 (2)FSP ClAMg q H2O  
 assemblage: FSP\_san FSP\_abh ClAMg\_parg q H2O  
 REACTION: 38 29 = 32  
 position: 4.43457E+02 9.45000E+03 4.43555E+02 9.45000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)ClAMg CHLR q H2O = EPI PHNG (2)ClAMg CHLR ab q H2O  
 REACTION: 39 32 = 21  
 position: 4.48340E+02 9.45000E+03 4.48438E+02 9.45000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)ClAMg CHLR ab q H2O = EPI PHNG ClAMg CHLR ab q H2O  
 REACTION: 40 21 = 30  
 position: 4.94629E+02 9.45000E+03 4.94727E+02 9.45000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG ClAMg CHLR ab q H2O = EPI PHNG ClAMg CHLR q H2O  
 REACTION: 41 30 = 34  
 position: 5.06250E+02 9.45000E+03 5.06348E+02 9.45000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG ClAMg CHLR q H2O = PHNG ClAMg CHLR q H2O  
 REACTION: 42 34 = 33  
 position: 5.18164E+02 9.45000E+03 5.18262E+02 9.45000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: PHNG ClAMg CHLR q H2O = PHNG BIO ClAMg CHLR q H2O  
 REACTION: 43 33 = 31  
 position: 5.31836E+02 9.45000E+03 5.31934E+02 9.45000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: PHNG BIO ClAMg CHLR q H2O = PHNG BIO ClAMg q H2O  
 REACTION: 44 31 = 26  
 position: 5.57617E+02 9.45000E+03 5.57715E+02 9.45000E+03  
 LABELED WITH ASSEMBLAGES

REACTION: PHNG BIO ClAMg q H2O = PHNG BIO ClAMg ab q H2O  
 REACTION: 45 15 = 35  
 position: 8.61523E+02 9.45000E+03 8.61621E+02 9.45000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO ClAMg q H2O = (2)FSP BIO ClAMg q H2O  
 REACTION: 46 35 = 36  
 position: 8.62695E+02 9.45000E+03 8.62793E+02 9.45000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: (2)FSP BIO ClAMg q H2O = (2)FSP ClAMg q H2O  
 REACTION: 47 36 = 27  
 position: 8.73535E+02 9.45000E+03 8.73633E+02 9.45000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: (2)FSP ClAMg q H2O = (2)FSP ClAMg OPX6 q H2O  
 122 777 Y = 9450.0000, 15 REACTIONS: 38 39 39 39 40 41 42 43  
 44 34 23 24 45 46 47  
 ASSEMBLAGE: 37: x,y = 4.87500000E+02 1.03000000E+04 EPI (2)PHNG (2)ClAMg  
 CHLR q H2O  
 assemblage: EPI\_cz PHNG\_mu PHNG\_pa ClAMg\_tr ClAMg\_grun CHLR\_clin q H2O  
 ASSEMBLAGE: 38: x,y = 4.86523438E+02 1.03000000E+04 EPI (2)PHNG (3)ClAMg  
 CHLR q H2O  
 assemblage: EPI\_cz PHNG\_mu PHNG\_pa ClAMg\_tr ClAMg\_gl ClAMg\_grun  
 CHLR\_clin q H2O  
 ASSEMBLAGE: 39: x,y = 6.25000000E+02 1.03000000E+04 FSP PHNG BIO ClAMg  
 q H2O  
 assemblage: FSP\_abh PHNG\_mu BIO\_phl ClAMg\_parg q H2O  
 REACTION: 48 29 = 38  
 position: 4.86426E+02 1.03000E+04 4.86523E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)ClAMg CHLR q H2O = EPI (2)PHNG (3)ClAMg CHLR q  
 H2O  
 REACTION: 49 38 = 37  
 position: 4.86523E+02 1.03000E+04 4.86621E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI (2)PHNG (3)ClAMg CHLR q H2O = EPI (2)PHNG (2)ClAMg CHLR q  
 H2O  
 REACTION: 50 37 = 29  
 position: 4.90820E+02 1.03000E+04 4.90918E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI (2)PHNG (2)ClAMg CHLR q H2O = EPI PHNG (2)ClAMg CHLR q  
 H2O  
 REACTION: 51 29 = 30  
 position: 4.96582E+02 1.03000E+04 4.96680E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)ClAMg CHLR q H2O = EPI PHNG ClAMg CHLR q H2O  
 REACTION: 52 26 = 39  
 position: 6.08887E+02 1.03000E+04 6.08984E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: PHNG BIO ClAMg ab q H2O = FSP PHNG BIO ClAMg q H2O  
 REACTION: 53 39 = 15  
 position: 6.25684E+02 1.03000E+04 6.25781E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP PHNG BIO ClAMg q H2O = FSP BIO ClAMg q H2O



89 866 Y = 10300.0000 , 12 REACTIONS: 48 49 50 51 41 42 43 44  
52 53 45 46  
ASSEMBLAGE: 40: x,y = 4.00000000E+02 1.11500000E+04 PHNG (2)ClAMg CPXg  
CHLR law H2O  
assemblage: PHNG\_mu ClAMg\_tr ClAMg\_gl CPXg\_di CHLR\_clin law H2O  
ASSEMBLAGE: 41: x,y = 9.00000000E+02 1.11500000E+04 GRT (2)FSP ClAMg q  
H2O  
assemblage: GRT\_alm FSP\_san FSP\_abh ClAMg\_parg q H2O  
ASSEMBLAGE: 42: x,y = 4.07812500E+02 1.11500000E+04 EPI PHNG (2)ClAMg  
CHLR law H2O  
assemblage: EPI\_cz PHNG\_mu ClAMg\_tr ClAMg\_gl CHLR\_clin law H2O  
ASSEMBLAGE: 43: x,y = 4.07519531E+02 1.11500000E+04 EPI PHNG (2)ClAMg  
CPXg CHLR law H2O  
assemblage: EPI\_cz PHNG\_mu ClAMg\_tr ClAMg\_gl CPXg\_di CHLR\_clin law H2O  
ASSEMBLAGE: 44: x,y = 4.07910156E+02 1.11500000E+04 EPI PHNG (2)ClAMg  
CHLR law q H2O  
assemblage: EPI\_cz PHNG\_mu ClAMg\_tr ClAMg\_gl CHLR\_clin law q H2O  
REACTION: 54 40 = 43  
position: 4.07422E+02 1.11500E+04 4.07520E+02 1.11500E+04  
LABELED WITH ASSEMBLAGES  
REACTION: PHNG (2)ClAMg CPXg CHLR law H2O = EPI PHNG (2)ClAMg CPXg  
CHLR law H2O  
REACTION: 55 43 = 42  
position: 4.07520E+02 1.11500E+04 4.07617E+02 1.11500E+04  
LABELED WITH ASSEMBLAGES  
REACTION: EPI PHNG (2)ClAMg CPXg CHLR law H2O = EPI PHNG (2)ClAMg CHLR  
law H2O  
REACTION: 56 42 = 44  
position: 4.07812E+02 1.11500E+04 4.07910E+02 1.11500E+04  
LABELED WITH ASSEMBLAGES  
REACTION: EPI PHNG (2)ClAMg CHLR law H2O = EPI PHNG (2)ClAMg CHLR law q  
H2O  
REACTION: 57 44 = 29  
position: 4.07910E+02 1.11500E+04 4.08008E+02 1.11500E+04  
LABELED WITH ASSEMBLAGES  
REACTION: EPI PHNG (2)ClAMg CHLR law q H2O = EPI PHNG (2)ClAMg CHLR q  
H2O  
REACTION: 58 31 = 39  
position: 6.46191E+02 1.11500E+04 6.46289E+02 1.11500E+04  
LABELED WITH ASSEMBLAGES  
REACTION: PHNG BIO ClAMg q H2O = FSP PHNG BIO ClAMg q H2O  
REACTION: 59 36 = 41  
position: 8.58887E+02 1.11500E+04 8.58984E+02 1.11500E+04  
LABELED WITH ASSEMBLAGES  
REACTION: (2)FSP ClAMg q H2O = GRT (2)FSP ClAMg q H2O  
98 964 Y = 11150.0000 , 13 REACTIONS: 54 55 56 57 51 41 42 43  
58 53 45 46 59  
WARNING: loops reached maximum: 301 X,Y = 421.679688 12000.000000 G(-)  
)= 2.09634E-02 dist = 2.10445E-03  
ASSEMBLAGE: 45: x,y = 5.06250000E+02 1.20000000E+04 EPI PHNG (3)ClAMg  
CHLR q H2O

assemblage: EPI\_cz PHNG\_mu ClAMg\_tr ClAMg\_gl ClAMg\_grun CHLR\_clin q H2O  
 ASSEMBLAGE: 46: x,y = 5.75000000E+02 1.20000000E+04 PHNG ClAMg q H2O  
 assemblage: PHNG\_mu ClAMg\_parg q H2O  
 REACTION: 60 29 = 45  
 position: 5.06152E+02 1.20000E+04 5.06250E+02 1.20000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)ClAMg CHLR q H2O = EPI PHNG (3)ClAMg CHLR q H2O  
 REACTION: 61 34 = 46  
 position: 5.60449E+02 1.20000E+04 5.60547E+02 1.20000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: PHNG ClAMg CHLR q H2O = PHNG ClAMg q H2O  
 REACTION: 62 46 = 31  
 position: 5.96387E+02 1.20000E+04 5.96484E+02 1.20000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: PHNG ClAMg q H2O = PHNG BIO ClAMg q H2O  
 116 1080 Y = 12000.0000, 15 REACTIONS: 54 55 56 57 60 60 51 41  
 61 62 58 53 45 46 59  
 ASSEMBLAGE: 47: x,y = 4.00000000E+02 1.07250000E+04 PHNG (2)ClAMg CPXg  
 CHLR law q H2O  
 assemblage: PHNG\_mu ClAMg\_tr ClAMg\_gl CPXg\_di CHLR\_clin law q H2O  
 ASSEMBLAGE: 48: x,y = 4.00000000E+02 1.06187500E+04 EPI PHNG (2)ClAMg  
 CPXg CHLR q H2O  
 assemblage: EPI\_cz PHNG\_mu ClAMg\_tr ClAMg\_gl CPXg\_di CHLR\_clin q H2O  
 ASSEMBLAGE: 49: x,y = 4.00000000E+02 1.07050781E+04 EPI PHNG (2)ClAMg  
 CPXg CHLR law q H2O  
 assemblage: EPI\_cz PHNG\_mu ClAMg\_tr ClAMg\_gl CPXg\_di CHLR\_clin law q H2O  
 ASSEMBLAGE: 50: x,y = 4.00000000E+02 1.07083984E+04 EPI PHNG ClAMg CPXg  
 CHLR law q H2O  
 assemblage: EPI\_cz PHNG\_mu ClAMg\_gl CPXg\_di CHLR\_clin law q H2O  
 ASSEMBLAGE: 51: x,y = 4.00000000E+02 1.07150391E+04 PHNG ClAMg CPXg  
 CHLR law q H2O  
 assemblage: PHNG\_mu ClAMg\_gl CPXg\_di CHLR\_clin law q H2O  
  
 WARNING: loops reached maximum: 301 X,Y = 400.000000 10831.250000 G(-)  
 ) = 2.81363E-04 dist = 4.08050E-07  
 REACTION: 63 29 = 48  
 position: 4.00000E+02 1.05656E+04 4.00000E+02 1.05673E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)ClAMg CHLR q H2O = EPI PHNG (2)ClAMg CPXg CHLR q  
 H2O  
 REACTION: 64 48 = 49  
 position: 4.00000E+02 1.07018E+04 4.00000E+02 1.07034E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)ClAMg CPXg CHLR q H2O = EPI PHNG (2)ClAMg CPXg  
 CHLR law q H2O  
 REACTION: 65 49 = 50  
 position: 4.00000E+02 1.07067E+04 4.00000E+02 1.07084E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)ClAMg CPXg CHLR law q H2O = EPI PHNG ClAMg CPXg  
 CHLR law q H2O  
 REACTION: 66 50 = 44  
 position: 4.00000E+02 1.07101E+04 4.00000E+02 1.07117E+04

LABELED WITH ASSEMBLAGES

REACTION: EPI PHNG ClAMg CPXg CHLR law q H2O = EPI PHNG (2)ClAMg CHLR law q H2O

REACTION: 67 44 = 51

position: 4.00000E+02 1.07117E+04 4.00000E+02 1.07134E+04

LABELED WITH ASSEMBLAGES

REACTION: EPI PHNG (2)ClAMg CHLR law q H2O = PHNG ClAMg CPXg CHLR law q H2O

REACTION: 68 51 = 47

position: 4.00000E+02 1.07167E+04 4.00000E+02 1.07184E+04

LABELED WITH ASSEMBLAGES

REACTION: PHNG ClAMg CPXg CHLR law q H2O = PHNG (2)ClAMg CPXg CHLR law q H2O

REACTION: 69 47 = 40

position: 4.00000E+02 1.08263E+04 4.00000E+02 1.08279E+04

LABELED WITH ASSEMBLAGES

REACTION: PHNG (2)ClAMg CPXg CHLR law q H2O = PHNG (2)ClAMg CPXg CHLR law H2O

63 1143 X = 400.0000 , 11 REACTIONS: 21 26 39 38 63 64 65 66 67 68 69

32 1175 X = 450.0000 , 4 REACTIONS: 21 26 39 38

REACTION: 70 18 = 23

position: 5.00000E+02 7.86123E+03 5.00000E+02 7.86289E+03

LABELED WITH ASSEMBLAGES

REACTION: EPI PHNG BIO ClAMg CHLR ab q H2O = PHNG BIO ClAMg CHLR ab q H2O

REACTION: 71 24 = 34

position: 5.00000E+02 8.99346E+03 5.00000E+02 8.99512E+03

LABELED WITH ASSEMBLAGES

REACTION: PHNG ClAMg CHLR ab q H2O = PHNG ClAMg CHLR q H2O

78 1253 X = 500.0000 , 10 REACTIONS: 5 13 15 14 21 70 32 71 41 51

61 1314 X = 550.0000 , 7 REACTIONS: 13 15 22 34 44 43 42

ASSEMBLAGE: 52: x,y = 6.00000000E+02 9.84179688E+03 FSP PHNG BIO ClAMg ab q H2O

assemblage: FSP\_abh PHNG\_mu BIO\_phl ClAMg\_parg ab q H2O

REACTION: 72 39 = 52

position: 6.00000E+02 9.83682E+03 6.00000E+02 9.83848E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP PHNG BIO ClAMg q H2O = FSP PHNG BIO ClAMg ab q H2O

REACTION: 73 52 = 26

position: 6.00000E+02 9.84678E+03 6.00000E+02 9.84844E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP PHNG BIO ClAMg ab q H2O = PHNG BIO ClAMg ab q H2O

43 1357 X = 600.0000 , 6 REACTIONS: 7 17 53 72 73 44

36 1393 X = 650.0000 , 4 REACTIONS: 7 17 53 58

27 1420 X = 700.0000 , 3 REACTIONS: 7 17 53

27 1447 X = 750.0000 , 3 REACTIONS: 8 7 17

27 1474 X = 800.0000 , 3 REACTIONS: 20 25 45

51 1525 X = 850.0000 , 6 REACTIONS: 10 20 25 45 46 59

REACTION: 74 22 = 25

position: 9.00000E+02 7.78486E+03 9.00000E+02 7.78652E+03

LABELED WITH ASSEMBLAGES

REACTION: (2)FSP BIO ClAMg OPX6 H2O = (2)FSP ClAMg OPX6 H2O

52 1577 X = 900.0000 , 6 REACTIONS: 10 29 74 37 47 59

NUMBER OF LINES: 77 NUMBER OF POINTS: 194 max.ph.: 2084

LEVEL: 0 SQUARE: ( 2 , 2 ) LINE 1 REACTION 1: OPEN END

REACTION: 75 1 = 12

position: 4.82812E+02 4.77500E+03 4.82910E+02 4.77500E+03

LABELED WITH ASSEMBLAGES

REACTION: EPI BIO ClAMg CHLR ab q H2O = FSP BIO ClAMg CHLR ab q H2O

25 1602 Y = 4775.0000 , 3 REACTIONS: 11 11 75

25 1627 X = 475.0000 , 4 REACTIONS: 12 1 11 11

NUMBER OF LINES: 78 NUMBER OF POINTS: 201 max.ph.: 2087

LEVEL: 0 SQUARE: ( 2 , 1 ) LINE 2 REACTION 2: OPEN END

ASSEMBLAGE: 53: x,y = 4.65820312E+02 3.92500000E+03 FSP EPI BIO (2)ClAMg CHLR ab q H2O

assemblage: FSP\_abh EPI\_cz BIO\_ann2 ClAMg\_tr ClAMg\_grun CHLR\_clin ab q H2O

REACTION: 76 13 = 53

position: 4.65723E+02 3.92500E+03 4.65820E+02 3.92500E+03

LABELED WITH ASSEMBLAGES

REACTION: EPI BIO (2)ClAMg CHLR ab q H2O = FSP EPI BIO (2)ClAMg CHLR ab q H2O

REACTION: 77 53 = 10

position: 4.65918E+02 3.92500E+03 4.66016E+02 3.92500E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP EPI BIO (2)ClAMg CHLR ab q H2O = FSP EPI BIO (2)ClAMg CHLR q H2O

21 1648 Y = 3925.0000 , 4 REACTIONS: 11 76 77 4

ASSEMBLAGE: 54: x,y = 4.75000000E+02 4.24375000E+03 FSP BIO (2)ClAMg CHLR ab q H2O

assemblage: FSP\_abh BIO\_phl ClAMg\_tr ClAMg\_parg CHLR\_clin ab q H2O

REACTION: 78 2 = 54

position: 4.75000E+02 4.15244E+03 4.75000E+02 4.15410E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO (2)ClAMg CHLR q H2O = FSP BIO (2)ClAMg CHLR ab q H2O

REACTION: 79 54 = 12

position: 4.75000E+02 4.27031E+03 4.75000E+02 4.27197E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO (2)ClAMg CHLR ab q H2O = FSP BIO ClAMg CHLR ab q H2O

16 1664 X = 475.0000 , 2 REACTIONS: 78 79

NUMBER OF LINES: 83 NUMBER OF POINTS: 207 max.ph.: 3148

LEVEL: 0 SQUARE: ( 3 , 1 ) LINE 6 REACTION 5: TWO POINTS

11 1675 Y = 3925.0000 , 1 REACTIONS: 5

10 1685 X = 525.0000 , 1 REACTIONS: 5

NUMBER OF LINES: 83 NUMBER OF POINTS: 209 max.ph.: 2088

LEVEL: 0 SQUARE: ( 4 , 2 ) LINE 7 REACTION 5: OPEN END

19 1704 Y = 4775.0000 , 2 REACTIONS: 5 6

18 1722 X = 575.0000 , 2 REACTIONS: 6 5

NUMBER OF LINES: 83 NUMBER OF POINTS: 213 max.ph.: 2080

LEVEL: 0 SQUARE: ( 8 , 4 ) LINE 9 REACTION 7: OPEN END

REACTION: 80 11 = 17

position: 7.86328E+02 6.47500E+03 7.86426E+02 6.47500E+03

LABELED WITH ASSEMBLAGES

REACTION: FSP BIO (2)ClAMg q H2O = FSP BIO (2)ClAMg OPX6 q H2O  
 14 1736 Y = 6475.0000 , 2 REACTIONS: 80 19  
 18 1754 X = 775.0000 , 2 REACTIONS: 7 17  
 NUMBER OF LINES: 84 NUMBER OF POINTS: 217 max.ph.: 2083  
 LEVEL: 0 SQUARE: ( 8 , 3 ) LINE 11 REACTION 9: OPEN END  
 17 1771 Y = 5625.0000 , 2 REACTIONS: 8 9  
 10 1781 X = 775.0000 , 1 REACTIONS: 8  
 NUMBER OF LINES: 84 NUMBER OF POINTS: 220 max.ph.: 2123  
 LEVEL: 0 SQUARE: ( 4 , 4 ) LINE 15 REACTION 13: OPEN END  
 24 1805 Y = 6475.0000 , 3 REACTIONS: 22 23 24  
 2 1807 X = 575.0000 , 0 REACTIONS:  
 NUMBER OF LINES: 84 NUMBER OF POINTS: 223 max.ph.: 2050  
 LEVEL: 0 SQUARE: ( 3 , 5 ) LINE 16 REACTION 14: OPEN END  
 25 1832 Y = 7325.0000 , 4 REACTIONS: 21 70 28 22  
 2 1834 X = 525.0000 , 0 REACTIONS:  
 NUMBER OF LINES: 86 NUMBER OF POINTS: 227 max.ph.: 2176  
 LEVEL: 0 SQUARE: ( 4 , 3 ) LINE 18 REACTION 16: TWO POINTS  
 11 1845 Y = 5625.0000 , 1 REACTIONS: 16  
 10 1855 X = 575.0000 , 1 REACTIONS: 16  
 NUMBER OF LINES: 86 NUMBER OF POINTS: 229 max.ph.: 2133  
 LEVEL: 0 SQUARE: ( 10 , 6 ) LINE 22 REACTION 20: OPEN END  
 REACTION: 81 28 = 22  
 position: 8.65918E+02 8.17500E+03 8.66016E+02 8.17500E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: (2)FSP BIO ClAMg OPX6 q H2O = (2)FSP BIO ClAMg OPX6 H2O  
 22 1877 Y = 8175.0000 , 3 REACTIONS: 35 81 74  
 25 1902 X = 875.0000 , 3 REACTIONS: 29 74 37  
 NUMBER OF LINES: 87 NUMBER OF POINTS: 235 max.ph.: 2058  
 LEVEL: 0 SQUARE: ( 2 , 7 ) LINE 23 REACTION 21: OPEN END  
 REACTION: 82 13 = 32  
 position: 4.91113E+02 9.02500E+03 4.91211E+02 9.02500E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI BIO (2)ClAMg CHLR ab q H2O = EPI PHNG (2)ClAMg CHLR ab q H2O  
 44 1946 Y = 9025.0000 , 7 REACTIONS: 26 21 11 82 39 40 41  
 18 1964 X = 475.0000 , 2 REACTIONS: 21 26  
 NUMBER OF LINES: 89 NUMBER OF POINTS: 244 max.ph.: 2102  
 LEVEL: 0 SQUARE: ( 1 , 5 ) LINE 23 REACTION 21: BUMP  
 18 1982 Y = 7325.0000 , 2 REACTIONS: 26 21  
 10 1992 X = 425.0000 , 1 REACTIONS: 21  
 NUMBER OF LINES: 89 NUMBER OF POINTS: 247 max.ph.: 2600  
 LEVEL: 0 SQUARE: ( 3 , 6 ) LINE 24 REACTION 22: OPEN END  
 16 2008 Y = 8175.0000 , 2 REACTIONS: 28 22  
 18 2026 X = 525.0000 , 2 REACTIONS: 28 33  
 NUMBER OF LINES: 89 NUMBER OF POINTS: 251 max.ph.: 2234  
 LEVEL: 0 SQUARE: ( 4 , 8 ) LINE 25 REACTION 23: OPEN END  
 11 2037 Y = 9875.0000 , 1 REACTIONS: 44  
 10 2047 X = 575.0000 , 1 REACTIONS: 44  
 NUMBER OF LINES: 89 NUMBER OF POINTS: 253 max.ph.: 2138  
 LEVEL: 0 SQUARE: ( 10 , 7 ) LINE 27 REACTION 25: OPEN END  
 30 2077 Y = 9025.0000 , 4 REACTIONS: 25 35 36 37  
 2 2079 X = 875.0000 , 0 REACTIONS:

NUMBER OF LINES: 89 NUMBER OF POINTS: 257 max.ph.: 3019  
 LEVEL: 0 SQUARE: ( 1 , 6 ) LINE 28 REACTION 26: BUMP  
 18 2097 Y = 8175.0000 , 2 REACTIONS: 26 21  
 10 2107 X = 425.0000 , 1 REACTIONS: 26  
 NUMBER OF LINES: 89 NUMBER OF POINTS: 260 max.ph.: 3019  
 LEVEL: 0 SQUARE: ( 2 , 6 ) LINE 33 REACTION 30: OPEN END  
 11 2118 Y = 8175.0000 , 1 REACTIONS: 27  
 2 2120 X = 475.0000 , 0 REACTIONS:  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 261 max.ph.: 2046  
 LEVEL: 0 SQUARE: ( 3 , 7 ) LINE 35 REACTION 32: OPEN END  
 25 2145 Y = 9025.0000 , 3 REACTIONS: 42 43 44  
 16 2161 X = 525.0000 , 2 REACTIONS: 44 43  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 266 max.ph.: 2235  
 LEVEL: 0 SQUARE: ( 2 , 8 ) LINE 41 REACTION 38: OPEN END  
 24 2185 Y = 9875.0000 , 3 REACTIONS: 38 38 51  
 18 2203 X = 475.0000 , 2 REACTIONS: 39 38  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 271 max.ph.: 2111  
 LEVEL: 0 SQUARE: ( 4 , 10 ) LINE 46 REACTION 42: OPEN END  
 18 2221 Y = 11575.0000 , 2 REACTIONS: 61 62  
 10 2231 X = 575.0000 , 1 REACTIONS: 62  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 274 max.ph.: 2171  
 LEVEL: 0 SQUARE: ( 5 , 9 ) LINE 48 REACTION 44: OPEN END  
 18 2249 Y = 10725.0000 , 2 REACTIONS: 58 53  
 10 2259 X = 625.0000 , 1 REACTIONS: 58  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 277 max.ph.: 2225  
 LEVEL: 0 SQUARE: ( 10 , 8 ) LINE 51 REACTION 47: TWO POINTS  
 24 2283 Y = 9875.0000 , 3 REACTIONS: 45 46 47  
 10 2293 X = 875.0000 , 1 REACTIONS: 47  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 281 max.ph.: 2056  
 LEVEL: 0 SQUARE: ( 2 , 9 ) LINE 52 REACTION 48: OPEN END  
 3 2296 Y = 10725.0000 , 0 REACTIONS:  
 2 2298 X = 475.0000 , 0 REACTIONS:  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 281 max.ph.: 2153  
 LEVEL: 0 SQUARE: ( 5 , 8 ) LINE 56 REACTION 52: OPEN END  
 17 2315 Y = 9875.0000 , 3 REACTIONS: 73 72 53  
 10 2325 X = 625.0000 , 1 REACTIONS: 53  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 285 max.ph.: 2140  
 LEVEL: 0 SQUARE: ( 1 , 9 ) LINE 58 REACTION 54: OPEN END  
 REACTION: 83 47 = 49  
 position: 4.00195E+02 1.07250E+04 4.00293E+02 1.07250E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: PHNG (2)CIAMg CPXg CHLR law q H2O = EPI PHNG (2)CIAMg CPXg  
 CHLR law q H2O  
 14 2339 Y = 10725.0000 , 3 REACTIONS: 83 64 63  
 2 2341 X = 425.0000 , 0 REACTIONS:  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 288 max.ph.: 2049  
 LEVEL: 0 SQUARE: ( 1 , 10 ) LINE 58 REACTION 54: TWO POINTS  
  
 WARNING: loops reached maximum: 301 X,Y = 400.000000 11575.000000 G(-  
 ) = 3.42775E-04 dist = 4.66500E-08

WARNING: loops reached maximum: 301 X,Y = 412.500000 11575.000000 G(-)  
 ) = 7.04693E-04 dist = 9.37000E-08

15 2356 Y = 11575.0000, 4 REACTIONS: 54 55 56 57  
 2 2358 X = 425.0000, 0 REACTIONS:  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 292 max.ph.: 2120  
 LEVEL: 0 SQUARE: ( 10, 9 ) LINE 63 REACTION 59: BUMP  
 3 2361 Y = 10725.0000, 0 REACTIONS:  
 10 2371 X = 875.0000, 1 REACTIONS: 59  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 293 max.ph.: 2091  
 LEVEL: 0 SQUARE: ( 9, 10 ) LINE 63 REACTION 59: BUMP  
 25 2396 Y = 11575.0000, 3 REACTIONS: 45 46 59  
 10 2406 X = 825.0000, 1 REACTIONS: 59  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 297 max.ph.: 2035  
 LEVEL: 1 SQUARE: ( 3, 1 ) LINE 1 REACTION 1: OPEN END  
 23 2429 Y = 3712.5000, 4 REACTIONS: 1 2 3 4  
 14 2443 X = 462.5000, 2 REACTIONS: 2 1  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 303 max.ph.: 2114  
 LEVEL: 1 SQUARE: ( 3, 2 ) LINE 2 REACTION 1: OPEN END  
 REACTION: 84 53 = 54  
 position: 4.70410E+02 4.13750E+03 4.70508E+02 4.13750E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP EPI BIO (2)CIAMg CHLR ab q H2O = FSP BIO (2)CIAMg CHLR ab q  
 H2O

21 2464 Y = 4137.5000, 4 REACTIONS: 11 76 84 78  
 2 2466 X = 462.5000, 0 REACTIONS:  
 NUMBER OF LINES: 92 NUMBER OF POINTS: 307 max.ph.: 2047  
 LEVEL: 1 SQUARE: ( 4, 3 ) LINE 2 REACTION 1: OPEN END  
 15 2481 Y = 4562.5000, 2 REACTIONS: 11 75  
 2 2483 X = 487.5000, 0 REACTIONS:  
 NUMBER OF LINES: 92 NUMBER OF POINTS: 309 max.ph.: 2210  
 LEVEL: 1 SQUARE: ( 3, 3 ) LINE 2 REACTION 1: TWO POINTS  
 10 2493 Y = 4562.5000, 1 REACTIONS: 11  
 2 2495 X = 462.5000, 0 REACTIONS:  
 NUMBER OF LINES: 92 NUMBER OF POINTS: 310 max.ph.: 2109  
 LEVEL: 1 SQUARE: ( 4, 2 ) LINE 6 REACTION 5: OPEN END  
 3 2498 Y = 4137.5000, 0 REACTIONS:  
 15 2513 X = 487.5000, 2 REACTIONS: 78 79  
 NUMBER OF LINES: 92 NUMBER OF POINTS: 312 max.ph.: 2934  
 LEVEL: 1 SQUARE: ( 8, 4 ) LINE 7 REACTION 5: OPEN END  
 15 2528 Y = 4987.5000, 2 REACTIONS: 16 17  
 9 2537 X = 587.5000, 1 REACTIONS: 17  
 NUMBER OF LINES: 92 NUMBER OF POINTS: 315 max.ph.: 2064  
 LEVEL: 1 SQUARE: ( 7, 3 ) LINE 7 REACTION 5: BUMP  
 10 2547 Y = 4562.5000, 1 REACTIONS: 5  
 2 2549 X = 562.5000, 0 REACTIONS:  
 NUMBER OF LINES: 92 NUMBER OF POINTS: 316 max.ph.: 2107  
 LEVEL: 1 SQUARE: ( 16, 7 ) LINE 9 REACTION 7: OPEN END  
 23 2572 Y = 6262.5000, 3 REACTIONS: 80 19 20  
 REACTION: 85 5 = 17  
 position: 7.87500E+02 6.10146E+03 7.87500E+02 6.10312E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)CIAMg OPX6 H2O = FSP BIO (2)CIAMg OPX6 q H2O

16 2588 X = 787.5000 , 2 REACTIONS: 85 19  
 NUMBER OF LINES: 93 NUMBER OF POINTS: 321 max.ph.: 2095  
 LEVEL: 1 SQUARE: ( 16 , 6 ) LINE 11 REACTION 9: OPEN END  
 15 2603 Y = 5837.5000 , 2 REACTIONS: 8 9  
 9 2612 X = 787.5000 , 1 REACTIONS: 9  
 NUMBER OF LINES: 93 NUMBER OF POINTS: 324 max.ph.: 2138  
 LEVEL: 1 SQUARE: ( 3 , 4 ) LINE 13 REACTION 11: BUMP  
 10 2622 Y = 4987.5000 , 1 REACTIONS: 11  
 2 2624 X = 462.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 93 NUMBER OF POINTS: 325 max.ph.: 2122  
 LEVEL: 1 SQUARE: ( 4 , 4 ) LINE 13 REACTION 11: BUMP  
 23 2647 Y = 4987.5000 , 3 REACTIONS: 11 14 15  
 16 2663 X = 487.5000 , 2 REACTIONS: 15 14  
 NUMBER OF LINES: 93 NUMBER OF POINTS: 330 max.ph.: 2149  
 LEVEL: 1 SQUARE: ( 7 , 7 ) LINE 15 REACTION 13: OPEN END  
 23 2686 Y = 6262.5000 , 3 REACTIONS: 22 23 24  
 REACTION: 86 12 = 20  
 position: 5.62500E+02 6.22764E+03 5.62500E+02 6.22930E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO ClAMg CHLR ab q H2O = FSP BIO ClAMg ab q H2O  
 15 2701 X = 562.5000 , 2 REACTIONS: 13 86  
 NUMBER OF LINES: 94 NUMBER OF POINTS: 335 max.ph.: 2123  
 LEVEL: 1 SQUARE: ( 5 , 9 ) LINE 16 REACTION 14: OPEN END  
 15 2716 Y = 7112.5000 , 2 REACTIONS: 27 28  
 2 2718 X = 512.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 95 NUMBER OF POINTS: 337 max.ph.: 3283  
 LEVEL: 1 SQUARE: ( 16 , 8 ) LINE 19 REACTION 17: OPEN END  
 15 2733 Y = 6687.5000 , 3 REACTIONS: 17 80 19  
 9 2742 X = 787.5000 , 1 REACTIONS: 25  
 NUMBER OF LINES: 95 NUMBER OF POINTS: 341 max.ph.: 3184  
 LEVEL: 1 SQUARE: ( 19 , 11 ) LINE 22 REACTION 20: OPEN END  
 17 2759 Y = 7962.5000 , 2 REACTIONS: 20 29  
 9 2768 X = 862.5000 , 1 REACTIONS: 20  
 NUMBER OF LINES: 95 NUMBER OF POINTS: 344 max.ph.: 2016  
 LEVEL: 1 SQUARE: ( 4 , 14 ) LINE 23 REACTION 21: OPEN END  
 REACTION: 87 18 = 32  
 position: 4.88477E+02 9.23750E+03 4.88574E+02 9.23750E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG BIO ClAMg CHLR ab q H2O = EPI PHNG (2)ClAMg CHLR ab  
 q H2O  
 28 2796 Y = 9237.5000 , 4 REACTIONS: 26 87 39 40  
 16 2812 X = 487.5000 , 2 REACTIONS: 21 87  
 NUMBER OF LINES: 96 NUMBER OF POINTS: 350 max.ph.: 2553  
 LEVEL: 1 SQUARE: ( 6 , 12 ) LINE 24 REACTION 22: OPEN END  
 16 2828 Y = 8387.5000 , 2 REACTIONS: 33 34  
 9 2837 X = 537.5000 , 1 REACTIONS: 34  
 NUMBER OF LINES: 96 NUMBER OF POINTS: 353 max.ph.: 2225  
 LEVEL: 1 SQUARE: ( 6 , 11 ) LINE 24 REACTION 22: BUMP  
 10 2847 Y = 7962.5000 , 1 REACTIONS: 22  
 9 2856 X = 537.5000 , 1 REACTIONS: 22  
 NUMBER OF LINES: 96 NUMBER OF POINTS: 355 max.ph.: 2236  
 LEVEL: 1 SQUARE: ( 8 , 15 ) LINE 25 REACTION 23: OPEN END



REACTION: 88 52 = 15  
position: 5.96484E+02 9.66250E+03 5.96582E+02 9.66250E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP PHNG BIO ClAMg ab q H2O = FSP BIO ClAMg q H2O  
12 2868 Y = 9662.5000, 2 REACTIONS: 73 88  
2 2870 X = 587.5000, 0 REACTIONS:  
NUMBER OF LINES: 97 NUMBER OF POINTS: 357 max.ph.: 2159  
LEVEL: 1 SQUARE: ( 19 , 14 ) LINE 27 REACTION 25: OPEN END  
REACTION: 89 35 = 27  
position: 8.66699E+02 9.23750E+03 8.66797E+02 9.23750E+03  
LABELED WITH ASSEMBLAGES  
REACTION: (2)FSP BIO ClAMg q H2O = (2)FSP ClAMg OPX6 q H2O  
13 2883 Y = 9237.5000, 2 REACTIONS: 45 89  
16 2899 X = 862.5000, 2 REACTIONS: 25 45  
NUMBER OF LINES: 98 NUMBER OF POINTS: 361 max.ph.: 2087  
LEVEL: 1 SQUARE: ( 5 , 10 ) LINE 29 REACTION 27: OPEN END  
16 2915 Y = 7537.5000, 2 REACTIONS: 27 28  
9 2924 X = 512.5000, 1 REACTIONS: 28  
NUMBER OF LINES: 98 NUMBER OF POINTS: 364 max.ph.: 2235  
LEVEL: 1 SQUARE: ( 5 , 11 ) LINE 29 REACTION 27: OPEN END  
10 2934 Y = 7962.5000, 1 REACTIONS: 28  
2 2936 X = 512.5000, 0 REACTIONS:  
NUMBER OF LINES: 98 NUMBER OF POINTS: 365 max.ph.: 2163  
LEVEL: 1 SQUARE: ( 4 , 13 ) LINE 32 REACTION 11: OPEN END  
23 2959 Y = 8812.5000, 4 REACTIONS: 11 82 39 31  
2 2961 X = 487.5000, 0 REACTIONS:  
NUMBER OF LINES: 98 NUMBER OF POINTS: 369 max.ph.: 2099  
LEVEL: 1 SQUARE: ( 4 , 12 ) LINE 33 REACTION 30: OPEN END  
REACTION: 90 1 = 24  
position: 4.97168E+02 8.38750E+03 4.97266E+02 8.38750E+03  
LABELED WITH ASSEMBLAGES  
REACTION: EPI BIO ClAMg CHLR ab q H2O = PHNG ClAMg CHLR ab q H2O  
23 2984 Y = 8387.5000, 4 REACTIONS: 11 11 90 32  
2 2986 X = 487.5000, 0 REACTIONS:  
NUMBER OF LINES: 99 NUMBER OF POINTS: 373 max.ph.: 2127  
LEVEL: 1 SQUARE: ( 5 , 13 ) LINE 35 REACTION 32: OPEN END  
17 3003 Y = 8812.5000, 2 REACTIONS: 32 33  
REACTION: 91 23 = 33  
position: 5.12500E+02 8.90215E+03 5.12500E+02 8.90381E+03  
LABELED WITH ASSEMBLAGES  
REACTION: PHNG BIO ClAMg CHLR ab q H2O = PHNG BIO ClAMg CHLR q H2O  
9 3012 X = 512.5000, 1 REACTIONS: 91  
NUMBER OF LINES: 100 NUMBER OF POINTS: 376 max.ph.: 2166  
LEVEL: 1 SQUARE: ( 19 , 12 ) LINE 39 REACTION 36: OPEN END  
19 3031 Y = 8387.5000, 3 REACTIONS: 35 36 37  
2 3033 X = 862.5000, 0 REACTIONS:  
NUMBER OF LINES: 100 NUMBER OF POINTS: 379 max.ph.: 2015  
LEVEL: 1 SQUARE: ( 4 , 15 ) LINE 41 REACTION 38: OPEN END  
20 3053 Y = 9662.5000, 3 REACTIONS: 39 39 40  
2 3055 X = 487.5000, 0 REACTIONS:  
NUMBER OF LINES: 100 NUMBER OF POINTS: 382 max.ph.: 2133  
LEVEL: 1 SQUARE: ( 4 , 16 ) LINE 41 REACTION 38: BUMP

23 3078 Y = 10087.5000 , 3 REACTIONS: 50 50 51  
 REACTION: 92 32 = 37  
 position: 4.87500E+02 9.92480E+03 4.87500E+02 9.92646E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)ClAMg CHLR ab q H2O = EPI (2)PHNG (2)ClAMg CHLR q H2O  
 9 3087 X = 487.5000 , 1 REACTIONS: 92  
 NUMBER OF LINES: 103 NUMBER OF POINTS: 386 max.ph.: 2620  
 LEVEL: 1 SQUARE: ( 3 , 15 ) LINE 43 REACTION 39: BUMP  
 15 3102 Y = 9662.5000 , 2 REACTIONS: 38 39  
 14 3116 X = 462.5000 , 2 REACTIONS: 39 38  
 NUMBER OF LINES: 103 NUMBER OF POINTS: 390 max.ph.: 2075  
 LEVEL: 1 SQUARE: ( 7 , 19 ) LINE 47 REACTION 42: OPEN END  
 11 3127 Y = 11362.5000 , 2 REACTIONS: 42 43  
 9 3136 X = 562.5000 , 1 REACTIONS: 62  
 NUMBER OF LINES: 103 NUMBER OF POINTS: 393 max.ph.: 2242  
 LEVEL: 1 SQUARE: ( 9 , 17 ) LINE 49 REACTION 44: OPEN END  
 10 3146 Y = 10512.5000 , 1 REACTIONS: 58  
 9 3155 X = 612.5000 , 1 REACTIONS: 58  
 NUMBER OF LINES: 103 NUMBER OF POINTS: 395 max.ph.: 2119  
 LEVEL: 1 SQUARE: ( 4 , 17 ) LINE 53 REACTION 48: OPEN END  
 10 3165 Y = 10512.5000 , 1 REACTIONS: 51  
 9 3174 X = 487.5000 , 1 REACTIONS: 50  
 NUMBER OF LINES: 103 NUMBER OF POINTS: 397 max.ph.: 2109  
 LEVEL: 1 SQUARE: ( 9 , 16 ) LINE 57 REACTION 52: OPEN END  
 17 3191 Y = 10087.5000 , 3 REACTIONS: 73 72 53  
 9 3200 X = 612.5000 , 1 REACTIONS: 53  
 NUMBER OF LINES: 103 NUMBER OF POINTS: 401 max.ph.: 2071  
 LEVEL: 1 SQUARE: ( 1 , 18 ) LINE 59 REACTION 54: OPEN END  
 REACTION: 93 43 = 44  
 position: 4.04004E+02 1.09375E+04 4.04102E+02 1.09375E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)ClAMg CPXg CHLR law H2O = EPI PHNG (2)ClAMg CHLR law q H2O  
 14 3214 Y = 10937.5000 , 3 REACTIONS: 54 93 57  
 2 3216 X = 412.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 104 NUMBER OF POINTS: 404 max.ph.: 2078  
 LEVEL: 1 SQUARE: ( 20 , 18 ) LINE 64 REACTION 59: BUMP  
 10 3226 Y = 10937.5000 , 1 REACTIONS: 59  
 9 3235 X = 887.5000 , 1 REACTIONS: 59  
 NUMBER OF LINES: 104 NUMBER OF POINTS: 406 max.ph.: 2087  
 LEVEL: 1 SQUARE: ( 1 , 17 ) LINE 68 REACTION 63: TWO POINTS  
 3 3238 Y = 10512.5000 , 0 REACTIONS:  
 2 3240 X = 412.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 104 NUMBER OF POINTS: 406 max.ph.: 2091  
 LEVEL: 1 SQUARE: ( 4 , 11 ) LINE 75 REACTION 21: OPEN END  
 10 3250 Y = 7962.5000 , 1 REACTIONS: 27  
 2 3252 X = 487.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 104 NUMBER OF POINTS: 407 max.ph.: 2060  
 LEVEL: 2 SQUARE: ( 6 , 2 ) LINE 1 REACTION 1: OPEN END  
 20 3272 Y = 3818.7500 , 4 REACTIONS: 1 2 3 4  
 2 3274 X = 468.7500 , 0 REACTIONS:

NUMBER OF LINES: 104 NUMBER OF POINTS: 411 max.ph.: 2161  
 LEVEL: 2 SQUARE: ( 6 , 4 ) LINE 2 REACTION 1: OPEN END  
 REACTION: 94 13 = 54  
 position: 4.72656E+02 4.24375E+03 4.72754E+02 4.24375E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI BIO (2)ClAMg CHLR ab q H2O = FSP BIO (2)ClAMg CHLR ab q H2O  
 15 3289 Y = 4243.7500 , 2 REACTIONS: 11 94  
 8 3297 X = 468.7500 , 1 REACTIONS: 11  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 414 max.ph.: 2126  
 LEVEL: 2 SQUARE: ( 7 , 5 ) LINE 2 REACTION 1: OPEN END  
 9 3306 Y = 4456.2500 , 2 REACTIONS: 1 12  
 2 3308 X = 481.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 416 max.ph.: 2135  
 LEVEL: 2 SQUARE: ( 6 , 3 ) LINE 5 REACTION 4: OPEN END  
 20 3328 Y = 4031.2500 , 4 REACTIONS: 11 76 77 4  
 18 3346 X = 468.7500 , 3 REACTIONS: 4 77 76  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 423 max.ph.: 2137  
 LEVEL: 2 SQUARE: ( 8 , 4 ) LINE 6 REACTION 5: OPEN END  
 9 3355 Y = 4243.7500 , 1 REACTIONS: 78  
 13 3368 X = 493.7500 , 2 REACTIONS: 78 79  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 426 max.ph.: 2723  
 LEVEL: 2 SQUARE: ( 15 , 7 ) LINE 7 REACTION 5: OPEN END  
 12 3380 Y = 4881.2500 , 2 REACTIONS: 5 6  
 2 3382 X = 581.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 428 max.ph.: 2131  
 LEVEL: 2 SQUARE: ( 14 , 6 ) LINE 7 REACTION 5: BUMP  
 9 3391 Y = 4668.7500 , 1 REACTIONS: 5  
 2 3393 X = 568.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 429 max.ph.: 2080  
 LEVEL: 2 SQUARE: ( 31 , 13 ) LINE 9 REACTION 7: OPEN END  
 17 3410 Y = 6156.2500 , 3 REACTIONS: 7 8 85  
 8 3418 X = 781.2500 , 1 REACTIONS: 7  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 433 max.ph.: 3184  
 LEVEL: 2 SQUARE: ( 32 , 12 ) LINE 11 REACTION 9: OPEN END  
 3 3421 Y = 5943.7500 , 0 REACTIONS:  
 2 3423 X = 793.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 433 max.ph.: 2076  
 LEVEL: 2 SQUARE: ( 7 , 8 ) LINE 13 REACTION 11: BUMP  
 9 3432 Y = 5093.7500 , 1 REACTIONS: 14  
 2 3434 X = 481.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 434 max.ph.: 2118  
 LEVEL: 2 SQUARE: ( 7 , 7 ) LINE 13 REACTION 11: BUMP  
 15 3449 Y = 4881.2500 , 2 REACTIONS: 11 75  
 2 3451 X = 481.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 436 max.ph.: 3206  
 LEVEL: 2 SQUARE: ( 14 , 13 ) LINE 15 REACTION 13: OPEN END  
 14 3465 Y = 6156.2500 , 2 REACTIONS: 13 16  
 8 3473 X = 568.7500 , 1 REACTIONS: 16  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 439 max.ph.: 2136  
 LEVEL: 2 SQUARE: ( 9 , 17 ) LINE 16 REACTION 14: OPEN END  
 13 3486 Y = 7006.2500 , 2 REACTIONS: 27 28  
 2 3488 X = 506.2500 , 0 REACTIONS:

NUMBER OF LINES: 105 NUMBER OF POINTS: 441 max.ph.: 2156  
 LEVEL: 2 SQUARE: ( 13 , 13 ) LINE 17 REACTION 15: OPEN END  
 9 3497 Y = 6156.2500 , 1 REACTIONS: 15  
 11 3508 X = 556.2500 , 2 REACTIONS: 86 23  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 444 max.ph.: 2129  
 LEVEL: 2 SQUARE: ( 31 , 16 ) LINE 19 REACTION 17: OPEN END  
 3 3511 Y = 6793.7500 , 0 REACTIONS:  
 2 3513 X = 781.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 444 max.ph.: 2108  
 LEVEL: 2 SQUARE: ( 32 , 13 ) LINE 20 REACTION 18: OPEN END  
 14 3527 Y = 6156.2500 , 2 REACTIONS: 19 20  
 8 3535 X = 793.7500 , 1 REACTIONS: 20  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 447 max.ph.: 2131  
 LEVEL: 2 SQUARE: ( 38 , 22 ) LINE 22 REACTION 20: OPEN END  
 9 3544 Y = 8068.7500 , 2 REACTIONS: 35 81  
 8 3552 X = 868.7500 , 1 REACTIONS: 29  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 450 max.ph.: 2161  
 LEVEL: 2 SQUARE: ( 8 , 27 ) LINE 23 REACTION 21: OPEN END  
 23 3575 Y = 9131.2500 , 4 REACTIONS: 11 82 39 40  
 2 3577 X = 493.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 454 max.ph.: 2162  
 LEVEL: 2 SQUARE: ( 11 , 23 ) LINE 24 REACTION 22: OPEN END  
 14 3591 Y = 8281.2500 , 2 REACTIONS: 33 34  
 8 3599 X = 531.2500 , 1 REACTIONS: 34  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 457 max.ph.: 2244  
 LEVEL: 2 SQUARE: ( 16 , 29 ) LINE 25 REACTION 23: OPEN END  
 REACTION: 95 52 = 20  
 position: 5.94238E+02 9.55625E+03 5.94336E+02 9.55625E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP PHNG BIO ClAMg ab q H2O = FSP BIO ClAMg ab q H2O  
 15 3614 Y = 9556.2500 , 3 REACTIONS: 73 95 24  
 10 3624 X = 593.7500 , 2 REACTIONS: 95 73  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 462 max.ph.: 2112  
 LEVEL: 2 SQUARE: ( 38 , 27 ) LINE 27 REACTION 25: OPEN END  
 16 3640 Y = 9131.2500 , 3 REACTIONS: 25 35 36  
 2 3642 X = 868.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 465 max.ph.: 2062  
 LEVEL: 2 SQUARE: ( 7 , 28 ) LINE 28 REACTION 26: OPEN END  
 13 3655 Y = 9343.7500 , 2 REACTIONS: 26 87  
 8 3663 X = 481.2500 , 1 REACTIONS: 26  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 468 max.ph.: 2583  
 LEVEL: 2 SQUARE: ( 9 , 19 ) LINE 29 REACTION 27: OPEN END  
 15 3678 Y = 7431.2500 , 2 REACTIONS: 27 28  
 2 3680 X = 506.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 470 max.ph.: 2161  
 LEVEL: 2 SQUARE: ( 9 , 21 ) LINE 29 REACTION 27: OPEN END  
 9 3689 Y = 7856.2500 , 1 REACTIONS: 27  
 2 3691 X = 506.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 471 max.ph.: 2222  
 LEVEL: 2 SQUARE: ( 8 , 25 ) LINE 32 REACTION 11: OPEN END  
 22 3713 Y = 8706.2500 , 5 REACTIONS: 11 11 21 26 31  
 REACTION: 96 13 = 18

position: 4.93750E+02 8.76934E+03 4.93750E+02 8.77100E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI BIO (2)CIAMg CHLR ab q H2O = EPI PHNG BIO CIAMg CHLR ab q  
 H2O

8 3721 X = 493.7500, 2 REACTIONS: 96 26  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 478 max.ph.: 2092  
 LEVEL: 2 SQUARE: ( 8, 24 ) LINE 32 REACTION 11: BUMP  
 28 3749 Y = 8493.7500, 5 REACTIONS: 11 11 30 31 32  
 2 3751 X = 493.7500, 0 REACTIONS:  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 483 max.ph.: 2743  
 LEVEL: 2 SQUARE: ( 8, 26 ) LINE 34 REACTION 31: OPEN END  
 23 3774 Y = 8918.7500, 4 REACTIONS: 11 82 39 31  
 2 3776 X = 493.7500, 0 REACTIONS:  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 487 max.ph.: 2141  
 LEVEL: 2 SQUARE: ( 8, 23 ) LINE 35 REACTION 32: OPEN END  
 9 3785 Y = 8281.2500, 1 REACTIONS: 27  
 8 3793 X = 493.7500, 1 REACTIONS: 11  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 489 max.ph.: 2087  
 LEVEL: 2 SQUARE: ( 9, 26 ) LINE 35 REACTION 32: OPEN END  
 14 3807 Y = 8918.7500, 2 REACTIONS: 32 91  
 14 3821 X = 506.2500, 2 REACTIONS: 32 71  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 493 max.ph.: 2094  
 LEVEL: 2 SQUARE: ( 10, 26 ) LINE 36 REACTION 33: OPEN END  
 9 3830 Y = 8918.7500, 1 REACTIONS: 43  
 8 3838 X = 518.7500, 1 REACTIONS: 91  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 495 max.ph.: 2163  
 LEVEL: 2 SQUARE: ( 38, 23 ) LINE 39 REACTION 36: OPEN END  
 16 3854 Y = 8281.2500, 3 REACTIONS: 35 36 37  
 14 3868 X = 868.7500, 2 REACTIONS: 74 37  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 500 max.ph.: 2062  
 LEVEL: 2 SQUARE: ( 7, 31 ) LINE 41 REACTION 38: OPEN END  
 15 3883 Y = 9981.2500, 2 REACTIONS: 38 92  
 19 3902 X = 481.2500, 3 REACTIONS: 39 92 50  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 505 max.ph.: 2085  
 LEVEL: 2 SQUARE: ( 8, 31 ) LINE 42 REACTION 38: OPEN END  
 14 3916 Y = 9981.2500, 2 REACTIONS: 50 51  
 8 3924 X = 493.7500, 1 REACTIONS: 51  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 508 max.ph.: 2128  
 LEVEL: 2 SQUARE: ( 8, 30 ) LINE 42 REACTION 38: OPEN END  
 14 3938 Y = 9768.7500, 2 REACTIONS: 38 51  
 2 3940 X = 493.7500, 0 REACTIONS:  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 510 max.ph.: 2158  
 LEVEL: 2 SQUARE: ( 6, 30 ) LINE 43 REACTION 39: BUMP  
 14 3954 Y = 9768.7500, 2 REACTIONS: 38 39  
 13 3967 X = 468.7500, 2 REACTIONS: 39 38  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 514 max.ph.: 2064  
 LEVEL: 2 SQUARE: ( 7, 30 ) LINE 43 REACTION 39: BUMP  
 9 3976 Y = 9768.7500, 1 REACTIONS: 39  
 2 3978 X = 481.2500, 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 515 max.ph.: 2105  
 LEVEL: 2 SQUARE: ( 13, 38 ) LINE 48 REACTION 42: OPEN END  
 9 3987 Y = 11468.7500, 1 REACTIONS: 61

2 3989 X = 556.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 516 max.ph.: 2188  
 LEVEL: 2 SQUARE: ( 17 , 33 ) LINE 50 REACTION 44: OPEN END  
 3 3992 Y = 10406.2500 , 0 REACTIONS:  
 2 3994 X = 606.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 516 max.ph.: 2137  
 LEVEL: 2 SQUARE: ( 38 , 28 ) LINE 52 REACTION 46: OPEN END  
 19 4013 Y = 9343.7500 , 3 REACTIONS: 45 46 47  
 8 4021 X = 868.7500 , 1 REACTIONS: 47  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 520 max.ph.: 2129  
 LEVEL: 2 SQUARE: ( 7 , 32 ) LINE 54 REACTION 48: OPEN END  
 9 4030 Y = 10193.7500 , 1 REACTIONS: 50  
 2 4032 X = 481.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 521 max.ph.: 3043  
 LEVEL: 2 SQUARE: ( 7 , 33 ) LINE 54 REACTION 48: OPEN END  
 9 4041 Y = 10406.2500 , 1 REACTIONS: 50  
 2 4043 X = 481.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 522 max.ph.: 2168  
 LEVEL: 2 SQUARE: ( 8 , 32 ) LINE 56 REACTION 50: BUMP  
 15 4058 Y = 10193.7500 , 2 REACTIONS: 50 51  
 2 4060 X = 493.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 524 max.ph.: 2138  
 LEVEL: 2 SQUARE: ( 8 , 33 ) LINE 56 REACTION 50: BUMP  
 15 4075 Y = 10406.2500 , 2 REACTIONS: 50 51  
 2 4077 X = 493.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 526 max.ph.: 2198  
 LEVEL: 2 SQUARE: ( 17 , 32 ) LINE 58 REACTION 52: OPEN END  
 15 4092 Y = 10193.7500 , 2 REACTIONS: 44 52  
 16 4108 X = 606.2500 , 3 REACTIONS: 72 73 44  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 531 max.ph.: 2110  
 LEVEL: 2 SQUARE: ( 16 , 30 ) LINE 59 REACTION 53: OPEN END  
 13 4121 Y = 9768.7500 , 2 REACTIONS: 73 72  
 2 4123 X = 593.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 533 max.ph.: 2126  
 LEVEL: 2 SQUARE: ( 1 , 35 ) LINE 60 REACTION 54: OPEN END

WARNING: loops reached maximum: 301 X,Y = 400.000000 10831.250000 G(-)  
 ) = 2.81363E-04 dist = 4.08050E-07

17 4140 Y = 10831.2500 , 4 REACTIONS: 69 83 64 63  
 2 4142 X = 406.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 537 max.ph.: 3040  
 LEVEL: 2 SQUARE: ( 1 , 36 ) LINE 61 REACTION 55: OPEN END

WARNING: loops reached maximum: 301 X,Y = 405.761719 11043.750000 G(-)  
 ) = 7.15443E-04 dist = 6.81008E-07

11 4153 Y = 11043.7500 , 4 REACTIONS: 54 55 56 57

WARNING: loops reached maximum: 301 X,Y = 406.250000 11071.972656 G(-)  
 ) = 1.79279E-04 dist = 1.59848E-06

17 4170 X = 406.2500 , 4 REACTIONS: 57 56 55 54  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 545 max.ph.: 2142  
 LEVEL: 2 SQUARE: ( 1 , 34 ) LINE 71 REACTION 65: OPEN END

9 4179 Y = 10618.7500 , 1 REACTIONS: 63  
 2 4181 X = 406.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 546 max.ph.: 2055  
 LEVEL: 2 SQUARE: ( 8 , 21 ) LINE 76 REACTION 21: OPEN END  
 3 4184 Y = 7856.2500 , 0 REACTIONS:  
 2 4186 X = 493.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 546 max.ph.: 2069  
 LEVEL: 2 SQUARE: ( 9 , 18 ) LINE 88 REACTION 21: OPEN END  
 15 4201 Y = 7218.7500 , 3 REACTIONS: 21 70 28  
 8 4209 X = 506.2500 , 1 REACTIONS: 28  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 550 max.ph.: 3369  
 LEVEL: 3 SQUARE: ( 11 , 4 ) LINE 1 REACTION 1: OPEN END  
 REACTION: 97 9 = 53  
 position: 4.64648E+02 3.87188E+03 4.64746E+02 3.87188E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP EPI BIO ClAMg CHLR ab q H2O = FSP EPI BIO (2)ClAMg CHLR ab  
 q H2O  
 14 4223 Y = 3871.8750 , 4 REACTIONS: 1 97 77 4  
 10 4233 X = 465.6250 , 2 REACTIONS: 77 76  
 NUMBER OF LINES: 112 NUMBER OF POINTS: 556 max.ph.: 2090  
 LEVEL: 3 SQUARE: ( 12 , 8 ) LINE 2 REACTION 1: OPEN END  
 12 4245 Y = 4296.8750 , 3 REACTIONS: 11 1 12  
 2 4247 X = 471.8750 , 0 REACTIONS:  
 NUMBER OF LINES: 112 NUMBER OF POINTS: 559 max.ph.: 2142  
 LEVEL: 3 SQUARE: ( 13 , 10 ) LINE 2 REACTION 1: OPEN END  
 8 4255 Y = 4509.3750 , 1 REACTIONS: 75  
 10 4265 X = 478.1250 , 2 REACTIONS: 12 1  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 562 max.ph.: 2155  
 LEVEL: 3 SQUARE: ( 12 , 6 ) LINE 5 REACTION 4: OPEN END  
 12 4277 Y = 4084.3750 , 3 REACTIONS: 76 77 4  
 7 4284 X = 471.8750 , 1 REACTIONS: 78  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 566 max.ph.: 2189  
 LEVEL: 3 SQUARE: ( 16 , 8 ) LINE 6 REACTION 5: OPEN END  
 13 4297 Y = 4296.8750 , 2 REACTIONS: 78 5  
 8 4305 X = 496.8750 , 2 REACTIONS: 78 79  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 570 max.ph.: 2117  
 LEVEL: 3 SQUARE: ( 29 , 14 ) LINE 7 REACTION 5: OPEN END  
 10 4315 Y = 4934.3750 , 2 REACTIONS: 5 6  
 7 4322 X = 578.1250 , 1 REACTIONS: 17  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 573 max.ph.: 2120  
 LEVEL: 3 SQUARE: ( 62 , 26 ) LINE 9 REACTION 7: OPEN END  
 8 4330 Y = 6209.3750 , 1 REACTIONS: 80  
 7 4337 X = 784.3750 , 1 REACTIONS: 7  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 575 max.ph.: 2093  
 LEVEL: 3 SQUARE: ( 63 , 24 ) LINE 11 REACTION 9: OPEN END  
 8 4345 Y = 5996.8750 , 1 REACTIONS: 9  
 2 4347 X = 790.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 576 max.ph.: 2067  
 LEVEL: 3 SQUARE: ( 13 , 15 ) LINE 13 REACTION 11: BUMP  
 8 4355 Y = 5040.6250 , 1 REACTIONS: 11  
 2 4357 X = 478.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 577 max.ph.: 2739

LEVEL: 3 SQUARE: ( 27 , 26 ) LINE 16 REACTION 13: OPEN END  
 12 4369 Y = 6209.3750 , 2 REACTIONS: 13 16  
 12 4381 X = 565.6250 , 2 REACTIONS: 13 86  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 581 max.ph.: 2104  
 LEVEL: 3 SQUARE: ( 14 , 14 ) LINE 17 REACTION 14: OPEN END  
 8 4389 Y = 4934.3750 , 1 REACTIONS: 14  
 2 4391 X = 484.3750 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 582 max.ph.: 2132  
 LEVEL: 3 SQUARE: ( 17 , 33 ) LINE 17 REACTION 14: OPEN END  
 8 4399 Y = 6953.1250 , 1 REACTIONS: 14  
 2 4401 X = 503.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 583 max.ph.: 2251  
 LEVEL: 3 SQUARE: ( 25 , 26 ) LINE 18 REACTION 15: OPEN END  
 8 4409 Y = 6209.3750 , 1 REACTIONS: 15  
 2 4411 X = 553.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 584 max.ph.: 2161  
 LEVEL: 3 SQUARE: ( 62 , 31 ) LINE 20 REACTION 17: OPEN END  
 3 4414 Y = 6740.6250 , 0 REACTIONS:  
 7 4421 X = 784.3750 , 1 REACTIONS: 17  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 585 max.ph.: 3181  
 LEVEL: 3 SQUARE: ( 63 , 25 ) LINE 21 REACTION 18: OPEN END  
 13 4434 Y = 6103.1250 , 2 REACTIONS: 19 20  
 7 4441 X = 790.6250 , 1 REACTIONS: 20  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 588 max.ph.: 2082  
 LEVEL: 3 SQUARE: ( 75 , 43 ) LINE 23 REACTION 20: OPEN END  
 13 4454 Y = 8015.6250 , 2 REACTIONS: 20 29  
 7 4461 X = 865.6250 , 1 REACTIONS: 29  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 591 max.ph.: 2068  
 LEVEL: 3 SQUARE: ( 15 , 54 ) LINE 24 REACTION 21: OPEN END  
 REACTION: 98 1 = 32  
 position: 4.89160E+02 9.18438E+03 4.89258E+02 9.18438E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI BIO CIAMg CHLR ab q H2O = EPI PHNG (2)CIAMg CHLR ab q H2O  
 13 4474 Y = 9184.3750 , 3 REACTIONS: 21 98 39  
 2 4476 X = 490.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 594 max.ph.: 2141  
 LEVEL: 3 SQUARE: ( 21 , 45 ) LINE 25 REACTION 22: OPEN END  
 11 4487 Y = 8228.1250 , 2 REACTIONS: 28 22  
 12 4499 X = 528.1250 , 2 REACTIONS: 22 34  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 598 max.ph.: 2219  
 LEVEL: 3 SQUARE: ( 31 , 57 ) LINE 26 REACTION 23: OPEN END  
 8 4507 Y = 9503.1250 , 2 REACTIONS: 73 95  
 7 4514 X = 590.6250 , 1 REACTIONS: 34  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 601 max.ph.: 2127  
 LEVEL: 3 SQUARE: ( 32 , 58 ) LINE 27 REACTION 24: OPEN END  
 15 4529 Y = 9609.3750 , 3 REACTIONS: 73 95 24  
 2 4531 X = 596.8750 , 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 604 max.ph.: 4165  
 LEVEL: 3 SQUARE: ( 75 , 54 ) LINE 28 REACTION 25: OPEN END  
 13 4544 Y = 9184.3750 , 3 REACTIONS: 25 35 36  
 7 4551 X = 865.6250 , 1 REACTIONS: 25  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 608 max.ph.: 2051



LEVEL: 3 SQUARE: ( 14 , 56 ) LINE 29 REACTION 26: OPEN END  
 8 4559 Y = 9396.8750 , 1 REACTIONS: 39  
 2 4561 X = 484.3750 , 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 609 max.ph.: 2140  
 LEVEL: 3 SQUARE: ( 17 , 37 ) LINE 30 REACTION 27: OPEN END  
 8 4569 Y = 7378.1250 , 1 REACTIONS: 27  
 2 4571 X = 503.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 610 max.ph.: 2202  
 LEVEL: 3 SQUARE: ( 17 , 42 ) LINE 30 REACTION 27: OPEN END  
 3 4574 Y = 7909.3750 , 0 REACTIONS:  
 2 4576 X = 503.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 610 max.ph.: 2293  
 LEVEL: 3 SQUARE: ( 16 , 50 ) LINE 33 REACTION 11: OPEN END  
 REACTION: 99 13 = 21  
 position: 4.93848E+02 8.75938E+03 4.93945E+02 8.75938E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI BIO (2)CIAMg CHLR ab q H2O = EPI PHNG CIAMg CHLR ab q H2O  
 13 4589 Y = 8759.3750 , 2 REACTIONS: 99 31  
 2 4591 X = 496.8750 , 0 REACTIONS:  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 612 max.ph.: 3107  
 LEVEL: 3 SQUARE: ( 15 , 47 ) LINE 33 REACTION 11: BUMP  
 8 4599 Y = 8440.6250 , 1 REACTIONS: 11  
 2 4601 X = 490.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 613 max.ph.: 2084  
 LEVEL: 3 SQUARE: ( 15 , 46 ) LINE 33 REACTION 11: BUMP  
 8 4609 Y = 8334.3750 , 1 REACTIONS: 11  
 2 4611 X = 490.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 120 NUMBER OF POINTS: 614 max.ph.: 2060  
 LEVEL: 3 SQUARE: ( 16 , 47 ) LINE 35 REACTION 30: OPEN END  
 20 4631 Y = 8440.6250 , 4 REACTIONS: 11 30 31 32  
 7 4638 X = 496.8750 , 2 REACTIONS: 21 26  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 620 max.ph.: 3090  
 LEVEL: 3 SQUARE: ( 16 , 49 ) LINE 35 REACTION 30: OPEN END  
 16 4654 Y = 8653.1250 , 3 REACTIONS: 11 30 31  
 2 4656 X = 496.8750 , 0 REACTIONS:  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 623 max.ph.: 2151  
 LEVEL: 3 SQUARE: ( 16 , 52 ) LINE 36 REACTION 31: OPEN END  
 8 4664 Y = 8971.8750 , 1 REACTIONS: 31  
 2 4666 X = 496.8750 , 0 REACTIONS:  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 624 max.ph.: 3021  
 LEVEL: 3 SQUARE: ( 16 , 46 ) LINE 37 REACTION 32: OPEN END  
 13 4679 Y = 8334.3750 , 2 REACTIONS: 11 27  
 2 4681 X = 496.8750 , 0 REACTIONS:  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 626 max.ph.: 2081  
 LEVEL: 3 SQUARE: ( 18 , 52 ) LINE 37 REACTION 32: OPEN END  
 8 4689 Y = 8971.8750 , 1 REACTIONS: 42  
 7 4696 X = 509.3750 , 1 REACTIONS: 91  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 628 max.ph.: 2140  
 LEVEL: 3 SQUARE: ( 20 , 51 ) LINE 38 REACTION 33: OPEN END  
 12 4708 Y = 8865.6250 , 2 REACTIONS: 43 44  
 7 4715 X = 521.8750 , 1 REACTIONS: 91  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 631 max.ph.: 2196

LEVEL: 0 SQUARE: ( 4 , 7 ) LINE 39 REACTION 34: BUMP  
 24 4739 Y = 9025.0000 , 3 REACTIONS: 34 23 24  
 10 4749 X = 575.0000 , 1 REACTIONS: 34  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 635 max.ph.: 2189  
 LEVEL: 1 SQUARE: ( 8 , 14 ) LINE 39 REACTION 34: BUMP  
 23 4772 Y = 9237.5000 , 3 REACTIONS: 34 23 24  
 9 4781 X = 587.5000 , 1 REACTIONS: 34  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 639 max.ph.: 2161  
 LEVEL: 3 SQUARE: ( 75 , 45 ) LINE 41 REACTION 36: OPEN END  
 14 4795 Y = 8228.1250 , 3 REACTIONS: 35 36 37  
 7 4802 X = 865.6250 , 1 REACTIONS: 35  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 643 max.ph.: 2055  
 LEVEL: 3 SQUARE: ( 13 , 62 ) LINE 43 REACTION 38: OPEN END  
 8 4810 Y = 10034.3750 , 1 REACTIONS: 50  
 2 4812 X = 478.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 644 max.ph.: 2057  
 LEVEL: 3 SQUARE: ( 15 , 61 ) LINE 44 REACTION 38: OPEN END  
 13 4825 Y = 9928.1250 , 2 REACTIONS: 50 51  
 2 4827 X = 490.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 646 max.ph.: 2129  
 LEVEL: 3 SQUARE: ( 15 , 59 ) LINE 44 REACTION 38: OPEN END  
 10 4837 Y = 9715.6250 , 2 REACTIONS: 38 51  
 7 4844 X = 490.6250 , 1 REACTIONS: 38  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 649 max.ph.: 3075  
 LEVEL: 3 SQUARE: ( 13 , 60 ) LINE 45 REACTION 39: OPEN END  
 3 4847 Y = 9821.8750 , 0 REACTIONS:  
 2 4849 X = 478.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 649 max.ph.: 3058  
 LEVEL: 3 SQUARE: ( 14 , 60 ) LINE 46 REACTION 39: OPEN END  
 8 4857 Y = 9821.8750 , 1 REACTIONS: 39  
 2 4859 X = 484.3750 , 0 REACTIONS:  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 650 max.ph.: 2746  
 LEVEL: 3 SQUARE: ( 15 , 50 ) LINE 47 REACTION 39: OPEN END  
 8 4867 Y = 8759.3750 , 1 REACTIONS: 11  
 2 4869 X = 490.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 651 max.ph.: 2064  
 LEVEL: 3 SQUARE: ( 26 , 75 ) LINE 50 REACTION 42: OPEN END  
 12 4881 Y = 11415.6250 , 2 REACTIONS: 61 62  
 9 4890 X = 559.3750 , 2 REACTIONS: 43 42  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 655 max.ph.: 2217  
 LEVEL: 2 SQUARE: ( 13 , 37 ) LINE 51 REACTION 43: BUMP  
 13 4903 Y = 11256.2500 , 2 REACTIONS: 42 43  
 8 4911 X = 556.2500 , 1 REACTIONS: 42  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 658 max.ph.: 2257  
 LEVEL: 3 SQUARE: ( 34 , 65 ) LINE 52 REACTION 44: OPEN END  
 8 4919 Y = 10353.1250 , 1 REACTIONS: 58  
 7 4926 X = 609.3750 , 1 REACTIONS: 58  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 660 max.ph.: 2102  
 LEVEL: 3 SQUARE: ( 75 , 55 ) LINE 54 REACTION 46: OPEN END  
 17 4943 Y = 9290.6250 , 3 REACTIONS: 45 46 47  
 12 4955 X = 865.6250 , 2 REACTIONS: 45 46  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 665 max.ph.: 2998

LEVEL: 3 SQUARE: ( 14 , 64 ) LINE 56 REACTION 48: OPEN END  
 8 4963 Y = 10246.8750 , 1 REACTIONS: 50  
 7 4970 X = 484.3750 , 1 REACTIONS: 50  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 667 max.ph.: 3792  
 LEVEL: 3 SQUARE: ( 14 , 65 ) LINE 56 REACTION 48: OPEN END  
 8 4978 Y = 10353.1250 , 1 REACTIONS: 50  
 2 4980 X = 484.3750 , 0 REACTIONS:  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 668 max.ph.: 3072  
 LEVEL: 3 SQUARE: ( 15 , 65 ) LINE 58 REACTION 50: BUMP  
 8 4988 Y = 10353.1250 , 1 REACTIONS: 50  
 2 4990 X = 490.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 122 NUMBER OF POINTS: 669 max.ph.: 2107  
 LEVEL: 3 SQUARE: ( 15 , 66 ) LINE 58 REACTION 50: BUMP  
 13 5003 Y = 10459.3750 , 2 REACTIONS: 50 50  
 2 5005 X = 490.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 671 max.ph.: 2095  
 LEVEL: 3 SQUARE: ( 34 , 63 ) LINE 61 REACTION 52: OPEN END  
 3 5008 Y = 10140.6250 , 0 REACTIONS:  
 2 5010 X = 609.3750 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 671 max.ph.: 2121  
 LEVEL: 3 SQUARE: ( 34 , 64 ) LINE 61 REACTION 52: TWO POINTS  
 8 5018 Y = 10246.8750 , 1 REACTIONS: 52  
 2 5020 X = 609.3750 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 672 max.ph.: 2089  
 LEVEL: 3 SQUARE: ( 32 , 59 ) LINE 62 REACTION 53: OPEN END  
 13 5033 Y = 9715.6250 , 3 REACTIONS: 73 72 53  
 14 5047 X = 596.8750 , 3 REACTIONS: 53 72 73  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 678 max.ph.: 2078  
 LEVEL: 3 SQUARE: ( 1 , 70 ) LINE 63 REACTION 54: OPEN END  
 REACTION: 100 40 = 49  
 position: 4.02930E+02 1.08844E+04 4.03027E+02 1.08844E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: PHNG (2)CIAMg CPXg CHLR law H2O = EPI PHNG (2)CIAMg CPXg  
 CHLR law q H2O  
 REACTION: 101 49 = 44  
 position: 4.03027E+02 1.08844E+04 4.03125E+02 1.08844E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)CIAMg CPXg CHLR law q H2O = EPI PHNG (2)CIAMg  
 CHLR law q H2O  
 13 5060 Y = 10884.3750 , 3 REACTIONS: 100 101 57  
 REACTION: 102 29 = 49  
 position: 4.03125E+02 1.08811E+04 4.03125E+02 1.08827E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)CIAMg CHLR q H2O = EPI PHNG (2)CIAMg CPXg CHLR  
 law q H2O  
 REACTION: 103 49 = 43  
 position: 4.03125E+02 1.08894E+04 4.03125E+02 1.08910E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (2)CIAMg CPXg CHLR law q H2O = EPI PHNG (2)CIAMg  
 CPXg CHLR law H2O  
 15 5075 X = 403.1250 , 5 REACTIONS: 102 101 101 103 54  
 NUMBER OF LINES: 127 NUMBER OF POINTS: 686 max.ph.: 2177

LEVEL: 3 SQUARE: ( 1 , 71 ) LINE 64 REACTION 55: OPEN END

WARNING: loops reached maximum: 301 X,Y = 404.882812 10990.625000 G(-)  
)= 5.94231E-04 dist = 7.81440E-07

11 5086 Y = 10990.6250 , 4 REACTIONS: 54 55 56 57

2 5088 X = 403.1250 , 0 REACTIONS:

NUMBER OF LINES: 127 NUMBER OF POINTS: 690 max.ph.: 2170

LEVEL: 3 SQUARE: ( 1 , 68 ) LINE 74 REACTION 65: OPEN END

8 5096 Y = 10671.8750 , 1 REACTIONS: 63

2 5098 X = 403.1250 , 0 REACTIONS:

NUMBER OF LINES: 127 NUMBER OF POINTS: 691 max.ph.: 2102

LEVEL: 3 SQUARE: ( 1 , 69 ) LINE 78 REACTION 69: TWO POINTS

14 5112 Y = 10778.1250 , 3 REACTIONS: 83 64 63

2 5114 X = 403.1250 , 0 REACTIONS:

NUMBER OF LINES: 127 NUMBER OF POINTS: 694 max.ph.: 2111

LEVEL: 3 SQUARE: ( 16 , 42 ) LINE 79 REACTION 21: OPEN END

8 5122 Y = 7909.3750 , 1 REACTIONS: 27

2 5124 X = 496.8750 , 0 REACTIONS:

NUMBER OF LINES: 127 NUMBER OF POINTS: 695 max.ph.: 2090

LEVEL: 3 SQUARE: ( 17 , 52 ) LINE 81 REACTION 71: TWO POINTS

8 5132 Y = 8971.8750 , 1 REACTIONS: 71

7 5139 X = 503.1250 , 1 REACTIONS: 71

NUMBER OF LINES: 127 NUMBER OF POINTS: 697 max.ph.: 2161

LEVEL: 3 SQUARE: ( 12 , 7 ) LINE 86 REACTION 76: OPEN END

8 5147 Y = 4190.6250 , 2 REACTIONS: 76 84

7 5154 X = 471.8750 , 2 REACTIONS: 84 76

NUMBER OF LINES: 127 NUMBER OF POINTS: 701 max.ph.: 2129

LEVEL: 3 SQUARE: ( 17 , 35 ) LINE 91 REACTION 21: OPEN END

13 5167 Y = 7165.6250 , 2 REACTIONS: 27 28

2 5169 X = 503.1250 , 0 REACTIONS:

NUMBER OF LINES: 127 NUMBER OF POINTS: 703 max.ph.: 2214

LEVEL: 3 SQUARE: ( 17 , 36 ) LINE 91 REACTION 21: TWO POINTS

8 5177 Y = 7271.8750 , 1 REACTIONS: 27

2 5179 X = 503.1250 , 0 REACTIONS:

NUMBER OF LINES: 130 NUMBER OF POINTS: 704 max.ph.: 2179

LEVEL: 3 SQUARE: ( 75 , 44 ) LINE 95 REACTION 81: TWO POINTS

10 5189 Y = 8121.8750 , 2 REACTIONS: 35 81

7 5196 X = 865.6250 , 1 REACTIONS: 81

NUMBER OF LINES: 130 NUMBER OF POINTS: 707 max.ph.: 3119

LEVEL: 3 SQUARE: ( 62 , 25 ) LINE 100 REACTION 85: TWO POINTS

12 5208 Y = 6103.1250 , 2 REACTIONS: 8 85

2 5210 X = 784.3750 , 0 REACTIONS:

NUMBER OF LINES: 130 NUMBER OF POINTS: 709 max.ph.: 2088

LEVEL: 3 SQUARE: ( 13 , 61 ) LINE 117 REACTION 39: OPEN END

8 5218 Y = 9928.1250 , 1 REACTIONS: 39

12 5230 X = 478.1250 , 2 REACTIONS: 39 38

NUMBER OF LINES: 130 NUMBER OF POINTS: 712 max.ph.: 2083

LEVEL: 3 SQUARE: ( 14 , 61 ) LINE 117 REACTION 39: OPEN END

13 5243 Y = 9928.1250 , 2 REACTIONS: 39 92

7 5250 X = 484.3750 , 1 REACTIONS: 92

NUMBER OF LINES: 130 NUMBER OF POINTS: 715 max.ph.: 2093

LEVEL: 4 SQUARE: ( 21 , 8 ) LINE 1 REACTION 1: OPEN END

9 5259 Y = 3898.4375 , 3 REACTIONS: 11 76 77  
 2 5261 X = 464.0625 , 0 REACTIONS:  
 NUMBER OF LINES: 130 NUMBER OF POINTS: 718 max.ph.: 2111  
 LEVEL: 4 SQUARE: ( 24 , 15 ) LINE 2 REACTION 1: OPEN END  
 14 5275 Y = 4270.3125 , 4 REACTIONS: 11 1 12 79  
 11 5286 X = 473.4375 , 3 REACTIONS: 79 12 1  
 NUMBER OF LINES: 130 NUMBER OF POINTS: 725 max.ph.: 2163  
 LEVEL: 4 SQUARE: ( 25 , 19 ) LINE 2 REACTION 1: OPEN END  
 10 5296 Y = 4482.8125 , 2 REACTIONS: 1 12  
 2 5298 X = 476.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 130 NUMBER OF POINTS: 727 max.ph.: 2129  
 LEVEL: 4 SQUARE: ( 21 , 7 ) LINE 3 REACTION 2: OPEN END  
 13 5311 Y = 3845.3125 , 3 REACTIONS: 1 2 3  
 10 5321 X = 464.0625 , 2 REACTIONS: 2 1  
 NUMBER OF LINES: 130 NUMBER OF POINTS: 732 max.ph.: 2148  
 LEVEL: 4 SQUARE: ( 23 , 12 ) LINE 5 REACTION 4: OPEN END  
 9 5330 Y = 4110.9375 , 3 REACTIONS: 76 77 4  
 11 5341 X = 470.3125 , 3 REACTIONS: 78 84 76  
 NUMBER OF LINES: 130 NUMBER OF POINTS: 738 max.ph.: 2182  
 LEVEL: 4 SQUARE: ( 32 , 16 ) LINE 6 REACTION 5: OPEN END  
 7 5348 Y = 4323.4375 , 1 REACTIONS: 13  
 6 5354 X = 498.4375 , 1 REACTIONS: 13  
 NUMBER OF LINES: 130 NUMBER OF POINTS: 740 max.ph.: 2239  
 LEVEL: 4 SQUARE: ( 57 , 28 ) LINE 7 REACTION 5: OPEN END  
 REACTION: 104 3 = 11  
 position: 5.77930E+02 4.96094E+03 5.78027E+02 4.96094E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO ClAMg CHLR q H2O = FSP BIO (2)ClAMg q H2O  
 7 5361 Y = 4960.9375 , 1 REACTIONS: 104  
 2 5363 X = 576.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 741 max.ph.: 2137  
 LEVEL: 4 SQUARE: ( 124 , 51 ) LINE 9 REACTION 7: OPEN END  
 10 5373 Y = 6182.8125 , 3 REACTIONS: 7 8 85  
 6 5379 X = 785.9375 , 1 REACTIONS: 7  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 745 max.ph.: 2058  
 LEVEL: 4 SQUARE: ( 125 , 48 ) LINE 11 REACTION 9: OPEN END  
 7 5386 Y = 6023.4375 , 1 REACTIONS: 9  
 6 5392 X = 789.0625 , 1 REACTIONS: 20  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 747 max.ph.: 2097  
 LEVEL: 4 SQUARE: ( 25 , 30 ) LINE 13 REACTION 11: OPEN END  
 3 5395 Y = 5067.1875 , 0 REACTIONS:  
 2 5397 X = 476.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 747 max.ph.: 2090  
 LEVEL: 4 SQUARE: ( 26 , 30 ) LINE 14 REACTION 11: OPEN END  
 7 5404 Y = 5067.1875 , 1 REACTIONS: 11  
 2 5406 X = 479.6875 , 0 REACTIONS:  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 748 max.ph.: 2893  
 LEVEL: 4 SQUARE: ( 54 , 52 ) LINE 16 REACTION 13: OPEN END  
 7 5413 Y = 6235.9375 , 1 REACTIONS: 24  
 8 5421 X = 567.1875 , 2 REACTIONS: 16 24  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 751 max.ph.: 2138  
 LEVEL: 4 SQUARE: ( 28 , 27 ) LINE 17 REACTION 14: OPEN END

11 5432 Y = 4907.8125 , 2 REACTIONS: 14 15  
 6 5438 X = 485.9375 , 1 REACTIONS: 15  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 754 max.ph.: 2126  
 LEVEL: 4 SQUARE: ( 33 , 66 ) LINE 17 REACTION 14: OPEN END  
 7 5445 Y = 6979.6875 , 1 REACTIONS: 14  
 6 5451 X = 501.5625 , 1 REACTIONS: 28  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 756 max.ph.: 2183  
 LEVEL: 4 SQUARE: ( 50 , 52 ) LINE 18 REACTION 15: OPEN END  
 7 5458 Y = 6235.9375 , 1 REACTIONS: 22  
 2 5460 X = 554.6875 , 0 REACTIONS:  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 757 max.ph.: 2128  
 LEVEL: 4 SQUARE: (124 , 61 ) LINE 20 REACTION 17: OPEN END  
 7 5467 Y = 6714.0625 , 1 REACTIONS: 25  
 6 5473 X = 785.9375 , 1 REACTIONS: 17  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 759 max.ph.: 2104  
 LEVEL: 4 SQUARE: (125 , 49 ) LINE 21 REACTION 18: OPEN END  
 14 5487 Y = 6076.5625 , 3 REACTIONS: 85 19 20  
 2 5489 X = 789.0625 , 0 REACTIONS:  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 762 max.ph.: 2182  
 LEVEL: 4 SQUARE: (149 , 86 ) LINE 23 REACTION 20: OPEN END  
 7 5496 Y = 8042.1875 , 2 REACTIONS: 35 81  
 2 5498 X = 864.0625 , 0 REACTIONS:  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 764 max.ph.: 2040  
 LEVEL: 4 SQUARE: ( 29 , 108 ) LINE 24 REACTION 21: OPEN END  
 7 5505 Y = 9210.9375 , 1 REACTIONS: 87  
 6 5511 X = 489.0625 , 1 REACTIONS: 87  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 766 max.ph.: 2609  
 LEVEL: 4 SQUARE: ( 41 , 90 ) LINE 25 REACTION 22: OPEN END  
 10 5521 Y = 8254.6875 , 2 REACTIONS: 33 34  
 2 5523 X = 526.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 768 max.ph.: 2206  
 LEVEL: 4 SQUARE: ( 62 , 113 ) LINE 26 REACTION 23: OPEN END  
 11 5534 Y = 9476.5625 , 2 REACTIONS: 34 23  
 6 5540 X = 592.1875 , 1 REACTIONS: 34  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 771 max.ph.: 2135  
 LEVEL: 4 SQUARE: ( 63 , 116 ) LINE 27 REACTION 24: OPEN END  
 11 5551 Y = 9635.9375 , 3 REACTIONS: 73 95 24  
 6 5557 X = 595.3125 , 1 REACTIONS: 73  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 775 max.ph.: 2121  
 LEVEL: 4 SQUARE: (150 , 108 ) LINE 28 REACTION 25: OPEN END  
 REACTION: 105 35 = 28  
 position: 8.66504E+02 9.21094E+03 8.66602E+02 9.21094E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: (2)FSP BIO ClAMg q H2O = (2)FSP BIO ClAMg OPX6 q H2O  
 12 5569 Y = 9210.9375 , 3 REACTIONS: 45 105 36  
 2 5571 X = 867.1875 , 0 REACTIONS:  
 NUMBER OF LINES: 132 NUMBER OF POINTS: 778 max.ph.: 2038  
 LEVEL: 4 SQUARE: ( 28 , 111 ) LINE 29 REACTION 26: OPEN END  
 9 5580 Y = 9370.3125 , 2 REACTIONS: 26 87  
 6 5586 X = 485.9375 , 1 REACTIONS: 26  
 NUMBER OF LINES: 132 NUMBER OF POINTS: 781 max.ph.: 2641  
 LEVEL: 4 SQUARE: ( 33 , 73 ) LINE 30 REACTION 27: OPEN END

7 5593 Y = 7351.5625 , 1 REACTIONS: 27  
 2 5595 X = 501.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 132 NUMBER OF POINTS: 782 max.ph.: 2201  
 LEVEL: 4 SQUARE: ( 33 , 83 ) LINE 30 REACTION 27: OPEN END  
 3 5598 Y = 7882.8125 , 0 REACTIONS:  
 2 5600 X = 501.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 132 NUMBER OF POINTS: 782 max.ph.: 2181  
 LEVEL: 4 SQUARE: ( 29 , 107 ) LINE 33 REACTION 11: OPEN END  
 9 5609 Y = 9157.8125 , 2 REACTIONS: 11 82  
 6 5615 X = 489.0625 , 1 REACTIONS: 21  
 NUMBER OF LINES: 132 NUMBER OF POINTS: 785 max.ph.: 2132  
 LEVEL: 4 SQUARE: ( 29 , 91 ) LINE 33 REACTION 11: OPEN END  
 7 5622 Y = 8307.8125 , 1 REACTIONS: 11  
 2 5624 X = 489.0625 , 0 REACTIONS:  
 NUMBER OF LINES: 132 NUMBER OF POINTS: 786 max.ph.: 2053  
 LEVEL: 4 SQUARE: ( 30 , 91 ) LINE 34 REACTION 11: OPEN END  
 7 5631 Y = 8307.8125 , 1 REACTIONS: 11  
 2 5633 X = 492.1875 , 0 REACTIONS:  
 NUMBER OF LINES: 132 NUMBER OF POINTS: 787 max.ph.: 2961  
 LEVEL: 4 SQUARE: ( 31 , 99 ) LINE 34 REACTION 11: OPEN END  
 10 5643 Y = 8732.8125 , 3 REACTIONS: 11 21 26  
 2 5645 X = 495.3125 , 0 REACTIONS:  
 NUMBER OF LINES: 132 NUMBER OF POINTS: 790 max.ph.: 2149  
 LEVEL: 4 SQUARE: ( 31 , 93 ) LINE 35 REACTION 30: OPEN END  
 7 5652 Y = 8414.0625 , 1 REACTIONS: 11  
 2 5654 X = 495.3125 , 0 REACTIONS:  
 NUMBER OF LINES: 132 NUMBER OF POINTS: 791 max.ph.: 2059  
 LEVEL: 4 SQUARE: ( 31 , 98 ) LINE 35 REACTION 30: OPEN END  
 11 5665 Y = 8679.6875 , 3 REACTIONS: 11 21 26  
 2 5667 X = 495.3125 , 0 REACTIONS:  
 NUMBER OF LINES: 132 NUMBER OF POINTS: 794 max.ph.: 4187  
 LEVEL: 4 SQUARE: ( 32 , 93 ) LINE 36 REACTION 31: OPEN END  
 12 5679 Y = 8414.0625 , 3 REACTIONS: 30 31 32  
 2 5681 X = 498.4375 , 0 REACTIONS:  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 797 max.ph.: 2170  
 LEVEL: 4 SQUARE: ( 32 , 104 ) LINE 36 REACTION 31: OPEN END  
 10 5691 Y = 8998.4375 , 2 REACTIONS: 31 71  
 2 5693 X = 498.4375 , 0 REACTIONS:  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 799 max.ph.: 2145  
 LEVEL: 4 SQUARE: ( 32 , 92 ) LINE 37 REACTION 32: OPEN END  
 7 5700 Y = 8360.9375 , 1 REACTIONS: 27  
 2 5702 X = 498.4375 , 0 REACTIONS:  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 800 max.ph.: 2199  
 LEVEL: 4 SQUARE: ( 35 , 103 ) LINE 37 REACTION 32: OPEN END  
 9 5711 Y = 8945.3125 , 2 REACTIONS: 71 42  
 10 5721 X = 507.8125 , 2 REACTIONS: 91 42  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 804 max.ph.: 2201  
 LEVEL: 4 SQUARE: ( 40 , 101 ) LINE 38 REACTION 33: OPEN END  
 10 5731 Y = 8839.0625 , 2 REACTIONS: 43 44  
 6 5737 X = 523.4375 , 1 REACTIONS: 44  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 807 max.ph.: 3428  
 LEVEL: 4 SQUARE: ( 150 , 89 ) LINE 41 REACTION 36: OPEN END

11 5748 Y = 8201.5625 , 2 REACTIONS: 81 74  
 6 5754 X = 867.1875 , 1 REACTIONS: 74  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 810 max.ph.: 2161  
 LEVEL: 4 SQUARE: ( 26 ,123 ) LINE 43 REACTION 38: OPEN END  
 7 5761 Y = 10007.8125 , 1 REACTIONS: 50  
 10 5771 X = 479.6875 , 2 REACTIONS: 92 50  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 813 max.ph.: 2036  
 LEVEL: 4 SQUARE: ( 29 ,121 ) LINE 44 REACTION 38: OPEN END  
 7 5778 Y = 9901.5625 , 2 REACTIONS: 92 50  
 10 5788 X = 489.0625 , 2 REACTIONS: 38 50  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 817 max.ph.: 2118  
 LEVEL: 4 SQUARE: ( 30 ,117 ) LINE 44 REACTION 38: OPEN END  
 7 5795 Y = 9689.0625 , 2 REACTIONS: 39 40  
 2 5797 X = 492.1875 , 0 REACTIONS:  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 819 max.ph.: 2890  
 LEVEL: 4 SQUARE: ( 25 ,120 ) LINE 45 REACTION 39: OPEN END  
 3 5800 Y = 9848.4375 , 0 REACTIONS:  
 2 5802 X = 476.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 819 max.ph.: 3136  
 LEVEL: 4 SQUARE: ( 27 ,120 ) LINE 46 REACTION 39: OPEN END  
 7 5809 Y = 9848.4375 , 1 REACTIONS: 39  
 6 5815 X = 482.8125 , 1 REACTIONS: 39  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 821 max.ph.: 2120  
 LEVEL: 4 SQUARE: ( 30 ,100 ) LINE 47 REACTION 39: OPEN END  
 7 5822 Y = 8785.9375 , 1 REACTIONS: 99  
 2 5824 X = 492.1875 , 0 REACTIONS:  
 NUMBER OF LINES: 134 NUMBER OF POINTS: 822 max.ph.: 2645  
 LEVEL: 4 SQUARE: ( 52 ,149 ) LINE 50 REACTION 42: OPEN END  
 9 5833 Y = 11389.0625 , 2 REACTIONS: 61 62  
 6 5839 X = 560.9375 , 1 REACTIONS: 62  
 NUMBER OF LINES: 134 NUMBER OF POINTS: 825 max.ph.: 2197  
 LEVEL: 4 SQUARE: ( 67 ,129 ) LINE 52 REACTION 44: OPEN END  
 3 5842 Y = 10326.5625 , 0 REACTIONS:  
 2 5844 X = 607.8125 , 0 REACTIONS:  
 NUMBER OF LINES: 134 NUMBER OF POINTS: 825 max.ph.: 2179  
 LEVEL: 4 SQUARE: (150 ,109 ) LINE 54 REACTION 46: OPEN END  
 11 5855 Y = 9264.0625 , 2 REACTIONS: 46 47  
 6 5861 X = 867.1875 , 1 REACTIONS: 47  
 NUMBER OF LINES: 134 NUMBER OF POINTS: 828 max.ph.: 2036  
 LEVEL: 4 SQUARE: ( 28 ,128 ) LINE 56 REACTION 48: OPEN END  
 7 5868 Y = 10273.4375 , 1 REACTIONS: 50  
 6 5874 X = 485.9375 , 1 REACTIONS: 50  
 NUMBER OF LINES: 134 NUMBER OF POINTS: 830 max.ph.: 2562  
 LEVEL: 4 SQUARE: ( 28 ,129 ) LINE 56 REACTION 48: OPEN END  
 7 5881 Y = 10326.5625 , 1 REACTIONS: 50  
 6 5887 X = 485.9375 , 1 REACTIONS: 50  
 NUMBER OF LINES: 134 NUMBER OF POINTS: 832 max.ph.: 2069  
 LEVEL: 4 SQUARE: ( 30 ,132 ) LINE 58 REACTION 50: OPEN END  
 7 5894 Y = 10485.9375 , 1 REACTIONS: 50  
 2 5896 X = 492.1875 , 0 REACTIONS:  
 NUMBER OF LINES: 134 NUMBER OF POINTS: 833 max.ph.: 2123  
 LEVEL: 4 SQUARE: ( 29 ,132 ) LINE 59 REACTION 50: OPEN END



REACTION: 106 37 = 45  
 position: 4.88770E+02 1.04859E+04 4.88867E+02 1.04859E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI (2)PHNG (2)CIAMg CHLR q H2O = EPI PHNG (3)CIAMg CHLR q H2O  
 REACTION: 107 45 = 38  
 position: 4.89062E+02 1.04859E+04 4.89160E+02 1.04859E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI PHNG (3)CIAMg CHLR q H2O = EPI (2)PHNG (3)CIAMg CHLR q H2O  
 11 5907 Y = 10485.9375 , 4 REACTIONS: 50 106 107 49  
 10 5917 X = 489.0625 , 2 REACTIONS: 106 106  
 NUMBER OF LINES: 137 NUMBER OF POINTS: 839 max.ph.: 2065  
 LEVEL: 4 SQUARE: ( 28 ,130 ) LINE 59 REACTION 50: BUMP  
 12 5929 Y = 10379.6875 , 4 REACTIONS: 50 50 50 106  
 6 5935 X = 485.9375 , 1 REACTIONS: 50  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 844 max.ph.: 2129  
 LEVEL: 4 SQUARE: ( 67 ,126 ) LINE 62 REACTION 52: OPEN END  
 7 5942 Y = 10167.1875 , 2 REACTIONS: 73 72  
 2 5944 X = 607.8125 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 846 max.ph.: 2087  
 LEVEL: 4 SQUARE: ( 63 ,117 ) LINE 63 REACTION 53: OPEN END  
 7 5951 Y = 9689.0625 , 1 REACTIONS: 73  
 2 5953 X = 595.3125 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 847 max.ph.: 2144  
 LEVEL: 4 SQUARE: ( 1 ,140 ) LINE 64 REACTION 54: OPEN END  
 3 5956 Y = 10910.9375 , 0 REACTIONS:  
 2 5958 X = 401.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 847 max.ph.: 2136  
 LEVEL: 4 SQUARE: ( 2 ,141 ) LINE 65 REACTION 55: OPEN END  
 8 5966 Y = 10964.0625 , 4 REACTIONS: 54 55 56 57  
 11 5977 X = 404.6875 , 4 REACTIONS: 57 56 55 54  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 855 max.ph.: 2190  
 LEVEL: 4 SQUARE: ( 2 ,139 ) LINE 67 REACTION 57: OPEN END  
 3 5980 Y = 10857.8125 , 0 REACTIONS:  
 2 5982 X = 404.6875 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 855 max.ph.: 2142  
 LEVEL: 4 SQUARE: ( 1 ,139 ) LINE 73 REACTION 63: OPEN END  
  
 WARNING: loops reached maximum: 301 X,Y = 401.953125 10857.812500 G(-)  
 ) = 9.39935E-04 dist = 9.58602E-07  
  
 WARNING: loops reached maximum: 300 X,Y = 402.636719 10857.812500 G(-)  
 ) = 3.12004E-11 dist = 0.00000E+00  
 11 5993 Y = 10857.8125 , 3 REACTIONS: 69 83 102  
 6 5999 X = 401.5625 , 1 REACTIONS: 69  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 859 max.ph.: 2166  
 LEVEL: 4 SQUARE: ( 1 ,136 ) LINE 75 REACTION 65: OPEN END  
 7 6006 Y = 10698.4375 , 1 REACTIONS: 63  
 2 6008 X = 401.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 860 max.ph.: 2190  
 LEVEL: 4 SQUARE: ( 32 , 83 ) LINE 80 REACTION 21: OPEN END

7 6015 Y = 7882.8125 , 1 REACTIONS: 27  
 2 6017 X = 498.4375 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 861 max.ph.: 2094  
 LEVEL: 4 SQUARE: ( 26 , 20 ) LINE 86 REACTION 75: OPEN END  
 7 6024 Y = 4535.9375 , 1 REACTIONS: 75  
 2 6026 X = 479.6875 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 862 max.ph.: 2118  
 LEVEL: 4 SQUARE: ( 24 , 14 ) LINE 87 REACTION 76: OPEN END  
 7 6033 Y = 4217.1875 , 1 REACTIONS: 94  
 2 6035 X = 473.4375 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 863 max.ph.: 2103  
 LEVEL: 4 SQUARE: ( 33 , 70 ) LINE 92 REACTION 21: OPEN END  
 7 6042 Y = 7192.1875 , 1 REACTIONS: 27  
 2 6044 X = 501.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 864 max.ph.: 2291  
 LEVEL: 4 SQUARE: ( 33 , 71 ) LINE 92 REACTION 21: OPEN END  
 7 6051 Y = 7245.3125 , 1 REACTIONS: 27  
 2 6053 X = 501.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 865 max.ph.: 2203  
 LEVEL: 4 SQUARE: ( 33 , 72 ) LINE 93 REACTION 21: OPEN END  
 7 6060 Y = 7298.4375 , 1 REACTIONS: 27  
 2 6062 X = 501.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 866 max.ph.: 2229  
 LEVEL: 4 SQUARE: ( 2 , 140 ) LINE 111 REACTION 93: OPEN END  
 9 6071 Y = 10910.9375 , 3 REACTIONS: 54 93 57  
 2 6073 X = 404.6875 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 869 max.ph.: 3819  
 LEVEL: 4 SQUARE: ( 31 , 100 ) LINE 116 REACTION 26: OPEN END  
 3 6076 Y = 8785.9375 , 0 REACTIONS:  
 2 6078 X = 495.3125 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 869 max.ph.: 2135  
 LEVEL: 4 SQUARE: ( 25 , 121 ) LINE 118 REACTION 39: OPEN END  
 7 6085 Y = 9901.5625 , 1 REACTIONS: 39  
 6 6091 X = 476.5625 , 1 REACTIONS: 39  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 871 max.ph.: 2144  
 LEVEL: 4 SQUARE: ( 27 , 121 ) LINE 118 REACTION 39: OPEN END  
 7 6098 Y = 9901.5625 , 1 REACTIONS: 39  
 2 6100 X = 482.8125 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 872 max.ph.: 2116  
 LEVEL: 4 SQUARE: ( 26 , 122 ) LINE 118 REACTION 39: BUMP  
 7 6107 Y = 9954.6875 , 1 REACTIONS: 39  
 6 6113 X = 479.6875 , 1 REACTIONS: 39  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 874 max.ph.: 3086  
 LEVEL: 4 SQUARE: ( 27 , 122 ) LINE 118 REACTION 39: BUMP  
 7 6120 Y = 9954.6875 , 1 REACTIONS: 39  
 2 6122 X = 482.8125 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 875 max.ph.: 2053  
 LEVEL: 4 SQUARE: ( 25 , 20 ) LINE 120 REACTION 75: OPEN END  
 7 6129 Y = 4535.9375 , 1 REACTIONS: 11  
 2 6131 X = 476.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 139 NUMBER OF POINTS: 876 max.ph.: 2138  
 LEVEL: 5 SQUARE: ( 42 , 15 ) LINE 1 REACTION 1: OPEN END

REACTION: 108 1 = 53  
 position: 4.64844E+02 3.88516E+03 4.64941E+02 3.88516E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI BIO ClAMg CHLR ab q H2O = FSP EPI BIO (2)ClAMg CHLR ab q H2O  
 7 6138 Y = 3885.1562 , 2 REACTIONS: 108 77  
 8 6146 X = 464.8438 , 3 REACTIONS: 77 97 1  
 NUMBER OF LINES: 140 NUMBER OF POINTS: 881 max.ph.: 3334  
 LEVEL: 5 SQUARE: ( 47 , 29 ) LINE 2 REACTION 1: OPEN END  
 REACTION: 109 13 = 9  
 position: 4.72852E+02 4.25703E+03 4.72949E+02 4.25703E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: EPI BIO (2)ClAMg CHLR ab q H2O = FSP EPI BIO ClAMg CHLR ab q H2O  
 REACTION: 110 9 = 54  
 position: 4.72949E+02 4.25703E+03 4.73047E+02 4.25703E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP EPI BIO ClAMg CHLR ab q H2O = FSP BIO (2)ClAMg CHLR ab q H2O  
 6 6152 Y = 4257.0312 , 2 REACTIONS: 109 110  
 2 6154 X = 472.6562 , 0 REACTIONS:  
 NUMBER OF LINES: 142 NUMBER OF POINTS: 883 max.ph.: 2564  
 LEVEL: 5 SQUARE: ( 50 , 38 ) LINE 2 REACTION 1: OPEN END  
 6 6160 Y = 4496.0938 , 1 REACTIONS: 75  
 5 6165 X = 477.3438 , 1 REACTIONS: 1  
 NUMBER OF LINES: 142 NUMBER OF POINTS: 885 max.ph.: 2112  
 LEVEL: 5 SQUARE: ( 42 , 14 ) LINE 3 REACTION 2: OPEN END  
 REACTION: 111 9 = 10  
 position: 4.64551E+02 3.85859E+03 4.64648E+02 3.85859E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP EPI BIO ClAMg CHLR ab q H2O = FSP EPI BIO (2)ClAMg CHLR q H2O  
 8 6173 Y = 3858.5938 , 2 REACTIONS: 1 111  
 2 6175 X = 464.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 143 NUMBER OF POINTS: 887 max.ph.: 3156  
 LEVEL: 5 SQUARE: ( 45 , 24 ) LINE 5 REACTION 4: OPEN END  
 7 6182 Y = 4124.2188 , 2 REACTIONS: 76 84  
 2 6184 X = 469.5312 , 0 REACTIONS:  
 NUMBER OF LINES: 143 NUMBER OF POINTS: 889 max.ph.: 2661  
 LEVEL: 5 SQUARE: ( 63 , 31 ) LINE 6 REACTION 5: OPEN END  
 6 6190 Y = 4310.1562 , 1 REACTIONS: 5  
 8 6198 X = 497.6562 , 2 REACTIONS: 5 13  
 NUMBER OF LINES: 143 NUMBER OF POINTS: 892 max.ph.: 3096  
 LEVEL: 5 SQUARE: ( 114 , 55 ) LINE 7 REACTION 5: OPEN END  
 6 6204 Y = 4947.6562 , 2 REACTIONS: 5 6  
 2 6206 X = 577.3438 , 0 REACTIONS:  
 NUMBER OF LINES: 143 NUMBER OF POINTS: 894 max.ph.: 2154  
 LEVEL: 5 SQUARE: ( 248 , 102 ) LINE 9 REACTION 7: OPEN END  
 6 6212 Y = 6196.0938 , 1 REACTIONS: 80  
 2 6214 X = 786.7188 , 0 REACTIONS:  
 NUMBER OF LINES: 143 NUMBER OF POINTS: 895 max.ph.: 2062  
 LEVEL: 5 SQUARE: ( 249 , 96 ) LINE 11 REACTION 9: OPEN END

7 6221 Y = 6036.7188 , 3 REACTIONS: 85 19 20  
 5 6226 X = 788.2812 , 1 REACTIONS: 85  
 NUMBER OF LINES: 145 NUMBER OF POINTS: 899 max.ph.: 2179  
 LEVEL: 5 SQUARE: ( 49 , 60 ) LINE 13 REACTION 11: OPEN END  
 3 6229 Y = 5080.4688 , 0 REACTIONS:  
 2 6231 X = 475.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 145 NUMBER OF POINTS: 899 max.ph.: 2100  
 LEVEL: 5 SQUARE: ( 51 , 60 ) LINE 14 REACTION 11: OPEN END  
 6 6237 Y = 5080.4688 , 1 REACTIONS: 11  
 2 6239 X = 478.9062 , 0 REACTIONS:  
 NUMBER OF LINES: 145 NUMBER OF POINTS: 900 max.ph.: 2659  
 LEVEL: 5 SQUARE: (107 , 103 ) LINE 16 REACTION 13: OPEN END  
 6 6245 Y = 6222.6562 , 1 REACTIONS: 13  
 5 6250 X = 566.4062 , 1 REACTIONS: 86  
 NUMBER OF LINES: 145 NUMBER OF POINTS: 902 max.ph.: 2077  
 LEVEL: 5 SQUARE: ( 55 , 53 ) LINE 17 REACTION 14: OPEN END  
 9 6259 Y = 4894.5312 , 2 REACTIONS: 14 15  
 5 6264 X = 485.1562 , 1 REACTIONS: 15  
 NUMBER OF LINES: 145 NUMBER OF POINTS: 905 max.ph.: 2215  
 LEVEL: 5 SQUARE: ( 65 , 132 ) LINE 17 REACTION 14: OPEN END  
 6 6270 Y = 6992.9688 , 1 REACTIONS: 27  
 2 6272 X = 500.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 145 NUMBER OF POINTS: 906 max.ph.: 2132  
 LEVEL: 5 SQUARE: (100 , 103 ) LINE 18 REACTION 15: OPEN END  
 7 6279 Y = 6222.6562 , 2 REACTIONS: 22 23  
 2 6281 X = 555.4688 , 0 REACTIONS:  
 NUMBER OF LINES: 145 NUMBER OF POINTS: 908 max.ph.: 2138  
 LEVEL: 5 SQUARE: (114 , 56 ) LINE 19 REACTION 16: OPEN END  
 6 6287 Y = 4974.2188 , 1 REACTIONS: 16  
 2 6289 X = 577.3438 , 0 REACTIONS:  
 NUMBER OF LINES: 145 NUMBER OF POINTS: 909 max.ph.: 3232  
 LEVEL: 5 SQUARE: (248 , 121 ) LINE 20 REACTION 17: OPEN END  
 REACTION: 112 11 = 16  
 position: 7.86328E+02 6.70078E+03 7.86426E+02 6.70078E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg q H2O = FSP BIO ClAMg OPX6 q H2O  
 6 6295 Y = 6700.7812 , 1 REACTIONS: 112  
 2 6297 X = 786.7188 , 0 REACTIONS:  
 NUMBER OF LINES: 146 NUMBER OF POINTS: 910 max.ph.: 2147  
 LEVEL: 5 SQUARE: (249 , 97 ) LINE 21 REACTION 18: OPEN END  
 9 6306 Y = 6063.2812 , 2 REACTIONS: 85 19  
 2 6308 X = 788.2812 , 0 REACTIONS:  
 NUMBER OF LINES: 146 NUMBER OF POINTS: 912 max.ph.: 2184  
 LEVEL: 5 SQUARE: (298 , 171 ) LINE 24 REACTION 20: OPEN END  
 REACTION: 113 16 = 22  
 position: 8.64648E+02 8.02891E+03 8.64746E+02 8.02891E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO ClAMg OPX6 q H2O = (2)FSP BIO ClAMg OPX6 H2O  
 6 6314 Y = 8028.9062 , 1 REACTIONS: 113  
 5 6319 X = 864.8438 , 1 REACTIONS: 29  
 NUMBER OF LINES: 147 NUMBER OF POINTS: 914 max.ph.: 2020  
 LEVEL: 5 SQUARE: ( 58 , 215 ) LINE 25 REACTION 21: OPEN END

3 6322 Y = 9197.6562 , 0 REACTIONS:  
 2 6324 X = 489.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 147 NUMBER OF POINTS: 914 max.ph.: 2681  
 LEVEL: 5 SQUARE: ( 82 ,179 ) LINE 26 REACTION 22: OPEN END  
 6 6330 Y = 8241.4062 , 2 REACTIONS: 28 22  
 8 6338 X = 527.3438 , 2 REACTIONS: 22 34  
 NUMBER OF LINES: 147 NUMBER OF POINTS: 918 max.ph.: 2198  
 LEVEL: 5 SQUARE: (124 ,226 ) LINE 27 REACTION 23: OPEN END  
 7 6345 Y = 9489.8438 , 2 REACTIONS: 34 23  
 REACTION: 114 20 = 26  
 position: 5.92969E+02 9.49814E+03 5.92969E+02 9.49980E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO CIAMg ab q H2O = PHNG BIO CIAMg ab q H2O  
 5 6350 X = 592.9688 , 1 REACTIONS: 114  
 NUMBER OF LINES: 148 NUMBER OF POINTS: 921 max.ph.: 2113  
 LEVEL: 5 SQUARE: (126 ,232 ) LINE 28 REACTION 24: OPEN END  
 10 6360 Y = 9649.2188 , 3 REACTIONS: 73 95 24  
 8 6368 X = 596.0938 , 2 REACTIONS: 95 73  
 NUMBER OF LINES: 148 NUMBER OF POINTS: 926 max.ph.: 2159  
 LEVEL: 5 SQUARE: (299 ,215 ) LINE 29 REACTION 25: OPEN END  
 11 6379 Y = 9197.6562 , 3 REACTIONS: 25 35 36  
 7 6386 X = 866.4062 , 2 REACTIONS: 25 45  
 NUMBER OF LINES: 148 NUMBER OF POINTS: 931 max.ph.: 2067  
 LEVEL: 5 SQUARE: ( 56 ,222 ) LINE 30 REACTION 26: OPEN END  
 6 6392 Y = 9383.5938 , 1 REACTIONS: 39  
 2 6394 X = 486.7188 , 0 REACTIONS:  
 NUMBER OF LINES: 148 NUMBER OF POINTS: 932 max.ph.: 2138  
 LEVEL: 5 SQUARE: ( 65 ,145 ) LINE 31 REACTION 27: OPEN END  
 6 6400 Y = 7338.2812 , 1 REACTIONS: 27  
 2 6402 X = 500.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 148 NUMBER OF POINTS: 933 max.ph.: 3044  
 LEVEL: 5 SQUARE: ( 65 ,165 ) LINE 31 REACTION 27: OPEN END  
 3 6405 Y = 7869.5312 , 0 REACTIONS:  
 2 6407 X = 500.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 148 NUMBER OF POINTS: 933 max.ph.: 2109  
 LEVEL: 5 SQUARE: ( 58 ,214 ) LINE 34 REACTION 11: OPEN END  
 7 6414 Y = 9171.0938 , 2 REACTIONS: 11 82  
 2 6416 X = 489.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 148 NUMBER OF POINTS: 935 max.ph.: 2689  
 LEVEL: 5 SQUARE: ( 58 ,181 ) LINE 34 REACTION 11: OPEN END  
 6 6422 Y = 8294.5312 , 1 REACTIONS: 11  
 2 6424 X = 489.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 148 NUMBER OF POINTS: 936 max.ph.: 2032  
 LEVEL: 5 SQUARE: ( 60 ,181 ) LINE 35 REACTION 11: OPEN END  
 6 6430 Y = 8294.5312 , 1 REACTIONS: 11  
 2 6432 X = 492.9688 , 0 REACTIONS:  
 NUMBER OF LINES: 148 NUMBER OF POINTS: 937 max.ph.: 2077  
 LEVEL: 5 SQUARE: ( 61 ,198 ) LINE 35 REACTION 11: OPEN END  
 7 6439 Y = 8746.0938 , 2 REACTIONS: 11 30  
 2 6441 X = 494.5312 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 939 max.ph.: 2195  
 LEVEL: 5 SQUARE: ( 62 ,186 ) LINE 36 REACTION 30: OPEN END

3 6444 Y = 8427.3438 , 0 REACTIONS:  
 2 6446 X = 496.0938 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 939 max.ph.: 2087  
 LEVEL: 5 SQUARE: ( 61 ,195 ) LINE 36 REACTION 30: OPEN END  
 9 6455 Y = 8666.4062 , 3 REACTIONS: 11 21 26  
 2 6457 X = 494.5312 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 942 max.ph.: 2851  
 LEVEL: 5 SQUARE: ( 63 ,185 ) LINE 37 REACTION 31: OPEN END  
 9 6466 Y = 8400.7812 , 3 REACTIONS: 30 31 32  
 5 6471 X = 497.6562 , 1 REACTIONS: 32  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 946 max.ph.: 2176  
 LEVEL: 5 SQUARE: ( 64 ,208 ) LINE 37 REACTION 31: OPEN END  
 9 6480 Y = 9011.7188 , 2 REACTIONS: 40 41  
 7 6487 X = 499.2188 , 2 REACTIONS: 71 41  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 950 max.ph.: 2146  
 LEVEL: 5 SQUARE: ( 63 ,184 ) LINE 38 REACTION 32: OPEN END  
 6 6493 Y = 8374.2188 , 1 REACTIONS: 27  
 2 6495 X = 497.6562 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 951 max.ph.: 2143  
 LEVEL: 5 SQUARE: ( 69 ,205 ) LINE 38 REACTION 32: OPEN END  
 6 6501 Y = 8932.0312 , 1 REACTIONS: 32  
 2 6503 X = 507.0312 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 952 max.ph.: 3311  
 LEVEL: 5 SQUARE: ( 79 ,201 ) LINE 39 REACTION 33: OPEN END  
 6 6509 Y = 8825.7812 , 1 REACTIONS: 33  
 5 6514 X = 522.6562 , 1 REACTIONS: 44  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 954 max.ph.: 2263  
 LEVEL: 5 SQUARE: (299 ,178 ) LINE 42 REACTION 36: OPEN END  
 9 6523 Y = 8214.8438 , 2 REACTIONS: 81 74  
 7 6530 X = 866.4062 , 3 REACTIONS: 74 37 36  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 959 max.ph.: 2045  
 LEVEL: 5 SQUARE: (299 ,216 ) LINE 42 REACTION 36: OPEN END  
 11 6541 Y = 9224.2188 , 3 REACTIONS: 45 105 36  
 2 6543 X = 866.4062 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 962 max.ph.: 3063  
 LEVEL: 5 SQUARE: ( 51 ,245 ) LINE 44 REACTION 38: OPEN END  
 6 6549 Y = 9994.5312 , 1 REACTIONS: 50  
 5 6554 X = 478.9062 , 1 REACTIONS: 38  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 964 max.ph.: 2119  
 LEVEL: 5 SQUARE: ( 57 ,241 ) LINE 45 REACTION 38: OPEN END  
 3 6557 Y = 9888.2812 , 0 REACTIONS:  
 2 6559 X = 488.2812 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 964 max.ph.: 2116  
 LEVEL: 5 SQUARE: ( 59 ,234 ) LINE 45 REACTION 38: OPEN END  
 8 6567 Y = 9702.3438 , 2 REACTIONS: 38 51  
 2 6569 X = 491.4062 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 966 max.ph.: 3254  
 LEVEL: 5 SQUARE: ( 49 ,240 ) LINE 46 REACTION 39: OPEN END  
 3 6572 Y = 9861.7188 , 0 REACTIONS:  
 2 6574 X = 475.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 966 max.ph.: 2072  
 LEVEL: 5 SQUARE: ( 53 ,240 ) LINE 47 REACTION 39: OPEN END

3 6577 Y = 9861.7188 , 0 REACTIONS:  
 2 6579 X = 482.0312 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 966 max.ph.: 2126  
 LEVEL: 5 SQUARE: ( 60 ,200 ) LINE 48 REACTION 39: OPEN END  
 7 6586 Y = 8799.2188 , 2 REACTIONS: 82 39  
 2 6588 X = 492.9688 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 968 max.ph.: 2590  
 LEVEL: 5 SQUARE: (103 ,297 ) LINE 51 REACTION 42: OPEN END  
 6 6594 Y = 11375.7812 , 2 REACTIONS: 42 43  
 2 6596 X = 560.1562 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 970 max.ph.: 2266  
 LEVEL: 5 SQUARE: (134 ,257 ) LINE 53 REACTION 44: OPEN END  
 3 6599 Y = 10313.2812 , 0 REACTIONS:  
 2 6601 X = 608.5938 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 970 max.ph.: 2216  
 LEVEL: 5 SQUARE: (299 ,217 ) LINE 55 REACTION 46: OPEN END  
 8 6609 Y = 9250.7812 , 2 REACTIONS: 46 47  
 5 6614 X = 866.4062 , 1 REACTIONS: 46  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 973 max.ph.: 2001  
 LEVEL: 5 SQUARE: ( 56 ,256 ) LINE 57 REACTION 48: OPEN END  
 8 6622 Y = 10286.7188 , 3 REACTIONS: 50 49 49  
 2 6624 X = 486.7188 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 976 max.ph.: 2575  
 LEVEL: 5 SQUARE: ( 56 ,257 ) LINE 57 REACTION 48: OPEN END  
 6 6630 Y = 10313.2812 , 1 REACTIONS: 50  
 8 6638 X = 486.7188 , 4 REACTIONS: 49 49 106 60  
 NUMBER OF LINES: 153 NUMBER OF POINTS: 981 max.ph.: 2130  
 LEVEL: 5 SQUARE: ( 59 ,264 ) LINE 59 REACTION 50: OPEN END  
 6 6644 Y = 10499.2188 , 1 REACTIONS: 50  
 2 6646 X = 491.4062 , 0 REACTIONS:  
 NUMBER OF LINES: 153 NUMBER OF POINTS: 982 max.ph.: 2097  
 LEVEL: 5 SQUARE: ( 57 ,264 ) LINE 60 REACTION 50: OPEN END  
 9 6655 Y = 10499.2188 , 2 REACTIONS: 50 60  
 5 6660 X = 488.2812 , 1 REACTIONS: 50  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 985 max.ph.: 3443  
 LEVEL: 5 SQUARE: ( 56 ,260 ) LINE 60 REACTION 50: OPEN END  
 6 6666 Y = 10392.9688 , 1 REACTIONS: 50  
 5 6671 X = 486.7188 , 1 REACTIONS: 50  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 987 max.ph.: 2087  
 LEVEL: 5 SQUARE: (133 ,252 ) LINE 62 REACTION 52: OPEN END  
 6 6677 Y = 10180.4688 , 1 REACTIONS: 52  
 2 6679 X = 607.0312 , 0 REACTIONS:  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 988 max.ph.: 2131  
 LEVEL: 5 SQUARE: (126 ,233 ) LINE 63 REACTION 53: OPEN END  
 7 6686 Y = 9675.7812 , 2 REACTIONS: 73 72  
 2 6688 X = 596.0938 , 0 REACTIONS:  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 990 max.ph.: 2110  
 LEVEL: 5 SQUARE: ( 2 ,279 ) LINE 64 REACTION 54: OPEN END  
 3 6691 Y = 10897.6562 , 0 REACTIONS:  
 2 6693 X = 402.3438 , 0 REACTIONS:  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 990 max.ph.: 2197  
 LEVEL: 5 SQUARE: ( 3 ,281 ) LINE 65 REACTION 55: OPEN END

8 6701 Y = 10950.7812 , 3 REACTIONS: 54 93 57  
 5 6706 X = 403.9062 , 1 REACTIONS: 54  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 994 max.ph.: 2176  
 LEVEL: 5 SQUARE: ( 3,278 ) LINE 67 REACTION 57: OPEN END  
 3 6709 Y = 10871.0938 , 0 REACTIONS:  
 2 6711 X = 403.9062 , 0 REACTIONS:  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 994 max.ph.: 2129  
 LEVEL: 5 SQUARE: ( 2,277 ) LINE 73 REACTION 63: OPEN END  
 10 6721 Y = 10844.5312 , 3 REACTIONS: 83 64 63  
 8 6729 X = 402.3438 , 2 REACTIONS: 64 83  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 999 max.ph.: 2127  
 LEVEL: 5 SQUARE: ( 1,272 ) LINE 75 REACTION 65: OPEN END

WARNING: loops reached maximum: 301 X,Y = 401.171875 10711.718750 G(-)  
 ) = 6.84184E-08 dist = 1.00000E-09

9 6738 Y = 10711.7188 , 3 REACTIONS: 101 64 63  
 2 6740 X = 400.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 1002 max.ph.: 2234  
 LEVEL: 5 SQUARE: ( 2,278 ) LINE 79 REACTION 69: OPEN END  
 10 6750 Y = 10871.0938 , 3 REACTIONS: 69 83 102  
 5 6755 X = 402.3438 , 1 REACTIONS: 69  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 1006 max.ph.: 2163  
 LEVEL: 5 SQUARE: ( 64,165 ) LINE 80 REACTION 21: OPEN END  
 6 6761 Y = 7869.5312 , 1 REACTIONS: 27  
 2 6763 X = 499.2188 , 0 REACTIONS:  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 1007 max.ph.: 2094  
 LEVEL: 5 SQUARE: ( 51,39 ) LINE 86 REACTION 75: OPEN END  
 6 6769 Y = 4522.6562 , 1 REACTIONS: 12  
 2 6771 X = 478.9062 , 0 REACTIONS:  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 1008 max.ph.: 2094  
 LEVEL: 5 SQUARE: ( 47,27 ) LINE 87 REACTION 76: OPEN END  
 3 6774 Y = 4203.9062 , 0 REACTIONS:  
 2 6776 X = 472.6562 , 0 REACTIONS:  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 1008 max.ph.: 2082  
 LEVEL: 5 SQUARE: ( 65,140 ) LINE 92 REACTION 21: OPEN END  
 6 6782 Y = 7205.4688 , 1 REACTIONS: 27  
 2 6784 X = 500.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 1009 max.ph.: 2141  
 LEVEL: 5 SQUARE: ( 65,141 ) LINE 92 REACTION 21: OPEN END  
 6 6790 Y = 7232.0312 , 1 REACTIONS: 27  
 2 6792 X = 500.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 1010 max.ph.: 2135  
 LEVEL: 5 SQUARE: ( 65,144 ) LINE 93 REACTION 21: OPEN END  
 6 6798 Y = 7311.7188 , 1 REACTIONS: 27  
 2 6800 X = 500.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 1011 max.ph.: 3231  
 LEVEL: 5 SQUARE: ( 3,279 ) LINE 111 REACTION 93: OPEN END  
 7 6807 Y = 10897.6562 , 4 REACTIONS: 54 103 101 57  
 2 6809 X = 403.9062 , 0 REACTIONS:  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 1015 max.ph.: 2140  
 LEVEL: 5 SQUARE: ( 47,28 ) LINE 112 REACTION 94: TWO POINTS  
 6 6815 Y = 4230.4688 , 1 REACTIONS: 94



5 6820 X = 472.6562 , 2 REACTIONS: 84 76  
 NUMBER OF LINES: 159 NUMBER OF POINTS: 1018 max.ph.: 2145  
 LEVEL: 5 SQUARE: ( 61 ,199 ) LINE 117 REACTION 26: OPEN END  
 3 6823 Y = 8772.6562 , 0 REACTIONS:  
 2 6825 X = 494.5312 , 0 REACTIONS:  
 NUMBER OF LINES: 159 NUMBER OF POINTS: 1018 max.ph.: 2134  
 LEVEL: 5 SQUARE: ( 60 ,199 ) LINE 117 REACTION 26: OPEN END  
 6 6831 Y = 8772.6562 , 1 REACTIONS: 99  
 2 6833 X = 492.9688 , 0 REACTIONS:  
 NUMBER OF LINES: 159 NUMBER OF POINTS: 1019 max.ph.: 2061  
 LEVEL: 5 SQUARE: ( 49 ,241 ) LINE 119 REACTION 39: OPEN END  
 6 6839 Y = 9888.2812 , 1 REACTIONS: 39  
 5 6844 X = 475.7812 , 1 REACTIONS: 39  
 NUMBER OF LINES: 159 NUMBER OF POINTS: 1021 max.ph.: 3006  
 LEVEL: 5 SQUARE: ( 53 ,241 ) LINE 119 REACTION 39: OPEN END  
 6 6850 Y = 9888.2812 , 1 REACTIONS: 39  
 2 6852 X = 482.0312 , 0 REACTIONS:  
 NUMBER OF LINES: 159 NUMBER OF POINTS: 1022 max.ph.: 2090  
 LEVEL: 5 SQUARE: ( 50 ,39 ) LINE 121 REACTION 75: OPEN END  
 6 6858 Y = 4522.6562 , 1 REACTIONS: 1  
 2 6860 X = 477.3438 , 0 REACTIONS:  
 NUMBER OF LINES: 159 NUMBER OF POINTS: 1023 max.ph.: 2113  
 LEVEL: 5 SQUARE: ( 63 ,186 ) LINE 126 REACTION 21: OPEN END  
 11 6871 Y = 8427.3438 , 3 REACTIONS: 30 31 32  
 2 6873 X = 497.6562 , 0 REACTIONS:  
 NUMBER OF LINES: 159 NUMBER OF POINTS: 1026 max.ph.: 2162  
 LEVEL: 5 SQUARE: ( 58 ,263 ) LINE 137 REACTION 106: OPEN END  
 3 6876 Y = 10472.6562 , 0 REACTIONS:  
 2 6878 X = 489.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 159 NUMBER OF POINTS: 1026 max.ph.: 2073  
 LEVEL: 5 SQUARE: ( 57 ,263 ) LINE 137 REACTION 106: TWO POINTS  
 8 6886 Y = 10472.6562 , 2 REACTIONS: 60 106  
 5 6891 X = 488.2812 , 1 REACTIONS: 50  
 NUMBER OF LINES: 162 NUMBER OF POINTS: 1029 max.ph.: 2073  
 LEVEL: 5 SQUARE: ( 58 ,264 ) LINE 139 REACTION 106: OPEN END  
 6 6897 Y = 10499.2188 , 2 REACTIONS: 107 49  
 2 6899 X = 489.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 162 NUMBER OF POINTS: 1031 max.ph.: 2563  
 LEVEL: 5 SQUARE: ( 56 ,259 ) LINE 142 REACTION 106: OPEN END  
 7 6906 Y = 10366.4062 , 2 REACTIONS: 60 106  
 5 6911 X = 486.7188 , 1 REACTIONS: 50  
 NUMBER OF LINES: 164 NUMBER OF POINTS: 1034 max.ph.: 3000  
 exit DOMINO  
 CPU time: 7h 34m 09.52s

## Cont. Appendix I: Sample MNN21

SI(46.61)AL(15.34)FE(7.33)MG(14.53)CA(7.13)NA(4.23)K(0.18)O(?)H(10)O(0.01)

Bulk composition: O 152.435000

|    |           |
|----|-----------|
| AL | 15.340000 |
| CA | 7.130000  |
| FE | 7.330000  |
| H  | 10.000000 |
| K  | 0.180000  |
| MG | 14.530000 |
| NA | 4.230000  |
| SI | 46.610000 |
| E  | 0.000000  |

X: Temperature [C]

Y: Pressure [Bar]

MAXIMUM LEVEL: 6 PREC = 0.0050 WPREC = 0.0400

ASSEMBLAGE: 1: x,y = 4.00000000E+02 3.50000000E+03 BIO (3)ClAMg OPX6 ab q

assemblage: BIO\_phl ClAMg\_tr ClAMg\_ts ClAMg\_bcam OPX6\_fm ab q

ASSEMBLAGE: 2: x,y = 4.50000000E+02 3.50000000E+03 FSP BIO (2)ClAMg ab q

assemblage: FSP\_abh BIO\_phl ClAMg\_parg ClAMg\_bcam ab q

ASSEMBLAGE: 3: x,y = 5.50000000E+02 3.50000000E+03 FSP BIO (2)ClAMg CHLR q

assemblage: FSP\_abh BIO\_phl ClAMg\_parg ClAMg\_bcam CHLR\_clin q

ASSEMBLAGE: 4: x,y = 6.00000000E+02 3.50000000E+03 FSP BIO (2)ClAMg q H2O

assemblage: FSP\_abh BIO\_phl ClAMg\_parg ClAMg\_bcam q H2O

ASSEMBLAGE: 5: x,y = 6.50000000E+02 3.50000000E+03 FSP BIO (2)ClAMg H2O

assemblage: FSP\_anc1 BIO\_phl ClAMg\_parg ClAMg\_bcam H2O

ASSEMBLAGE: 6: x,y = 8.00000000E+02 3.50000000E+03 FSP ClAMg OPX6 H2O

assemblage: FSP\_anc1 ClAMg\_tr OPX6\_en H2O

ASSEMBLAGE: 7: x,y = 8.50000000E+02 3.50000000E+03 FSP ClAMg CPXo OPX6 H2O

assemblage: FSP\_anc1 ClAMg\_tr CPXo\_di OPX6\_en H2O

ASSEMBLAGE: 8: x,y = 4.25000000E+02 3.50000000E+03 FSP BIO (3)ClAMg ab q

assemblage: FSP\_abh BIO\_phl ClAMg\_tr ClAMg\_parg ClAMg\_bcam ab q

ASSEMBLAGE: 9: x,y = 5.04687500E+02 3.50000000E+03 FSP BIO (2)ClAMg CHLR ab q

assemblage: FSP\_abh BIO\_phl ClAMg\_parg ClAMg\_bcam CHLR\_clin ab q

ASSEMBLAGE: 10: x,y = 5.68750000E+02 3.50000000E+03 FSP BIO (2)ClAMg CHLR q H2O

assemblage: FSP\_abh BIO\_phl ClAMg\_parg ClAMg\_bcam CHLR\_clin q H2O

ASSEMBLAGE: 11: x,y = 7.75000000E+02 3.50000000E+03 FSP BIO ClAMg OPX6 H2O

assemblage: FSP\_anc1 BIO\_phl ClAMg\_tr OPX6\_fm H2O

ASSEMBLAGE: 12: x,y = 7.62500000E+02 3.50000000E+03 FSP BIO (2)ClAMg OPX6 H2O

assemblage: FSP\_anc1 BIO\_phl ClAMg\_tr ClAMg\_bcam OPX6\_fm H2O

REACTION: 1 1 = 8

position: 4.18164E+02 3.50000E+03 4.18262E+02 3.50000E+03

LABELED WITH ASSEMBLAGES

REACTION: BIO (3)ClAMg OPX6 ab q = FSP BIO (3)ClAMg ab q

REACTION: 2 8 = 2  
 position: 4.28711E+02 3.50000E+03 4.28809E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (3)ClAMg ab q = FSP BIO (2)ClAMg ab q  
 REACTION: 3 2 = 9  
 position: 5.03125E+02 3.50000E+03 5.03223E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg ab q = FSP BIO (2)ClAMg CHLR ab q  
 REACTION: 4 9 = 3  
 position: 5.05859E+02 3.50000E+03 5.05957E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg CHLR ab q = FSP BIO (2)ClAMg CHLR q  
 REACTION: 5 3 = 10  
 position: 5.68555E+02 3.50000E+03 5.68652E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg CHLR q = FSP BIO (2)ClAMg CHLR q H2O  
 REACTION: 6 10 = 4  
 position: 5.72168E+02 3.50000E+03 5.72266E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg CHLR q H2O = FSP BIO (2)ClAMg q H2O  
 REACTION: 7 4 = 5  
 position: 6.16895E+02 3.50000E+03 6.16992E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg q H2O = FSP BIO (2)ClAMg H2O  
 REACTION: 8 5 = 12  
 position: 7.54688E+02 3.50000E+03 7.54785E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg H2O = FSP BIO (2)ClAMg OPX6 H2O  
 REACTION: 9 12 = 11  
 position: 7.68262E+02 3.50000E+03 7.68359E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg OPX6 H2O = FSP BIO ClAMg OPX6 H2O  
 REACTION: 10 11 = 6  
 position: 7.86328E+02 3.50000E+03 7.86426E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO ClAMg OPX6 H2O = FSP ClAMg OPX6 H2O  
 REACTION: 11 6 = 7  
 position: 8.38379E+02 3.50000E+03 8.38477E+02 3.50000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP ClAMg OPX6 H2O = FSP ClAMg CPXo OPX6 H2O  
 98 98 Y = 3500.0000 , 11 REACTIONS: 1 2 3 4 5 6 7 8 9 10 11  
 ASSEMBLAGE: 13: x,y = 4.50000000E+02 4.35000000E+03 BIO (2)ClAMg OPX6 ab q  
 assemblage: BIO\_phl ClAMg\_parg ClAMg\_bcam OPX6\_fm ab q  
 ASSEMBLAGE: 14: x,y = 4.56250000E+02 4.35000000E+03 FSP BIO (2)ClAMg OPX6 ab q  
 assemblage: FSP\_abh BIO\_phl ClAMg\_parg ClAMg\_bcam OPX6\_fm ab q  
 ASSEMBLAGE: 15: x,y = 7.81250000E+02 4.35000000E+03 FSP (2)ClAMg OPX6 H2O  
 assemblage: FSP\_anc1 ClAMg\_tr ClAMg\_bcam OPX6\_fm H2O  
 REACTION: 12 1 = 13

position: 4.23535E+02 4.35000E+03 4.23633E+02 4.35000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: BIO (3)ClAMg OPX6 ab q = BIO (2)ClAMg OPX6 ab q  
 REACTION: 13 13 = 14  
 position: 4.56055E+02 4.35000E+03 4.56152E+02 4.35000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: BIO (2)ClAMg OPX6 ab q = FSP BIO (2)ClAMg OPX6 ab q  
 REACTION: 14 14 = 2  
 position: 4.56738E+02 4.35000E+03 4.56836E+02 4.35000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg OPX6 ab q = FSP BIO (2)ClAMg ab q  
 REACTION: 15 12 = 15  
 position: 7.75000E+02 4.35000E+03 7.75098E+02 4.35000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg OPX6 H2O = FSP (2)ClAMg OPX6 H2O  
 REACTION: 16 15 = 6  
 position: 7.83105E+02 4.35000E+03 7.83203E+02 4.35000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP (2)ClAMg OPX6 H2O = FSP ClAMg OPX6 H2O  
 99 197 Y = 4350.0000 , 12 REACTIONS: 12 13 14 3 4 5 6 7 8  
 15 16 11  
 ASSEMBLAGE: 16: x,y = 4.00000000E+02 5.20000000E+03 GRT BIO (3)ClAMg  
 OPX6 ab q  
 assemblage: GRT\_alm BIO\_phl ClAMg\_tr ClAMg\_parg ClAMg\_bcam OPX6\_fm ab q  
 ASSEMBLAGE: 17: x,y = 5.50000000E+02 5.20000000E+03 FSP BIO (2)ClAMg q  
 assemblage: FSP\_abh BIO\_phl ClAMg\_parg ClAMg\_bcam q  
 ASSEMBLAGE: 18: x,y = 8.00000000E+02 5.20000000E+03 FSP ClAMg OPX6 q H2O  
 assemblage: FSP\_anc1 ClAMg\_tr OPX6\_fm q H2O  
 ASSEMBLAGE: 19: x,y = 7.75000000E+02 5.20000000E+03 FSP (2)ClAMg H2O  
 assemblage: FSP\_anc1 ClAMg\_parg ClAMg\_bcam H2O  
 ASSEMBLAGE: 20: x,y = 7.90625000E+02 5.20000000E+03 FSP (2)ClAMg OPX6 q  
 H2O  
 assemblage: FSP\_anc1 ClAMg\_tr ClAMg\_bcam OPX6\_fm q H2O  
 REACTION: 17 16 = 1  
 position: 4.05273E+02 5.20000E+03 4.05371E+02 5.20000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (3)ClAMg OPX6 ab q = BIO (3)ClAMg OPX6 ab q  
 REACTION: 18 2 = 17  
 position: 5.34961E+02 5.20000E+03 5.35059E+02 5.20000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg ab q = FSP BIO (2)ClAMg q  
 REACTION: 19 17 = 4  
 position: 5.90430E+02 5.20000E+03 5.90527E+02 5.20000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg q = FSP BIO (2)ClAMg q H2O  
 REACTION: 20 5 = 19  
 position: 7.50488E+02 5.20000E+03 7.50586E+02 5.20000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg H2O = FSP (2)ClAMg H2O  
 REACTION: 21 19 = 15  
 position: 7.81348E+02 5.20000E+03 7.81445E+02 5.20000E+03  
 LABELED WITH ASSEMBLAGES

REACTION: FSP (2)ClAMg H2O = FSP (2)ClAMg OPX6 H2O  
 REACTION: 22 15 = 20  
 position: 7.90234E+02 5.20000E+03 7.90332E+02 5.20000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP (2)ClAMg OPX6 H2O = FSP (2)ClAMg OPX6 q H2O  
 REACTION: 23 20 = 18  
 position: 7.91602E+02 5.20000E+03 7.91699E+02 5.20000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP (2)ClAMg OPX6 q H2O = FSP ClAMg OPX6 q H2O  
 REACTION: 24 18 = 6  
 position: 8.15723E+02 5.20000E+03 8.15820E+02 5.20000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP ClAMg OPX6 q H2O = FSP ClAMg OPX6 H2O  
 115 312 Y = 5200.0000 , 13 REACTIONS: 17 12 13 14 18 19 7 20  
 21 22 23 24 11  
 ASSEMBLAGE: 21: x,y = 4.00000000E+02 6.05000000E+03 GRT BIO (3)ClAMg ab  
 q  
 assemblage: GRT\_alm BIO\_phl ClAMg\_tr ClAMg\_parg ClAMg\_bcam ab q  
 ASSEMBLAGE: 22: x,y = 4.50000000E+02 6.05000000E+03 GRT BIO (2)ClAMg  
 OPX6 ab q  
 assemblage: GRT\_alm BIO\_phl ClAMg\_parg ClAMg\_bcam OPX6\_fm ab q  
 ASSEMBLAGE: 23: x,y = 7.50000000E+02 6.05000000E+03 FSP (2)ClAMg q H2O  
 assemblage: FSP\_abh ClAMg\_parg ClAMg\_bcam q H2O  
 REACTION: 25 21 = 16  
 position: 4.31836E+02 6.05000E+03 4.31934E+02 6.05000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (3)ClAMg ab q = GRT BIO (3)ClAMg OPX6 ab q  
 REACTION: 26 16 = 22  
 position: 4.34277E+02 6.05000E+03 4.34375E+02 6.05000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (3)ClAMg OPX6 ab q = GRT BIO (2)ClAMg OPX6 ab q  
 REACTION: 27 22 = 13  
 position: 4.51465E+02 6.05000E+03 4.51562E+02 6.05000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (2)ClAMg OPX6 ab q = BIO (2)ClAMg OPX6 ab q  
 REACTION: 28 4 = 23  
 position: 7.14746E+02 6.05000E+03 7.14844E+02 6.05000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg q H2O = FSP (2)ClAMg q H2O  
 REACTION: 29 23 = 20  
 position: 7.88965E+02 6.05000E+03 7.89062E+02 6.05000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP (2)ClAMg q H2O = FSP (2)ClAMg OPX6 q H2O  
 99 411 Y = 6050.0000 , 12 REACTIONS: 25 26 27 13 14 18 19 28  
 29 23 24 11  
 ASSEMBLAGE: 24: x,y = 4.50000000E+02 6.90000000E+03 GRT BIO (2)ClAMg ab  
 q  
 assemblage: GRT\_alm BIO\_phl ClAMg\_parg ClAMg\_bcam ab q  
 ASSEMBLAGE: 25: x,y = 5.50000000E+02 6.90000000E+03 FSP BIO (2)ClAMg  
 OPX6 q  
 assemblage: FSP\_abh BIO\_phl ClAMg\_parg ClAMg\_bcam OPX6\_fm q

ASSEMBLAGE: 26: x,y = 8.81250000E+02 6.90000000E+03 FSP ClAMg CPXo OPX6  
q H2O  
assemblage: FSP\_anc1 ClAMg\_tr CPXo\_di OPX6\_en q H2O  
REACTION: 30 21 = 24  
position: 4.48340E+02 6.90000E+03 4.48438E+02 6.90000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: GRT BIO (3)ClAMg ab q = GRT BIO (2)ClAMg ab q  
REACTION: 31 24 = 22  
position: 4.73242E+02 6.90000E+03 4.73340E+02 6.90000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: GRT BIO (2)ClAMg ab q = GRT BIO (2)ClAMg OPX6 ab q  
REACTION: 32 14 = 25  
position: 5.49512E+02 6.90000E+03 5.49609E+02 6.90000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP BIO (2)ClAMg OPX6 ab q = FSP BIO (2)ClAMg OPX6 q  
REACTION: 33 25 = 17  
position: 5.67773E+02 6.90000E+03 5.67871E+02 6.90000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP BIO (2)ClAMg OPX6 q = FSP BIO (2)ClAMg q  
REACTION: 34 18 = 26  
position: 8.79395E+02 6.90000E+03 8.79492E+02 6.90000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP ClAMg OPX6 q H2O = FSP ClAMg CPXo OPX6 q H2O  
REACTION: 35 26 = 7  
position: 8.85352E+02 6.90000E+03 8.85449E+02 6.90000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP ClAMg CPXo OPX6 q H2O = FSP ClAMg CPXo OPX6 H2O  
105 516 Y = 6900.0000 , 12 REACTIONS: 30 31 27 13 32 33 19 28  
29 23 34 35  
ASSEMBLAGE: 27: x,y = 7.21875000E+02 7.75000000E+03 FSP (2)ClAMg q  
assemblage: FSP\_abh ClAMg\_parg ClAMg\_beam q  
ASSEMBLAGE: 28: x,y = 7.75000000E+02 7.75000000E+03 FSP ClAMg q H2O  
assemblage: FSP\_abh ClAMg\_parg q H2O  
REACTION: 36 17 = 27  
position: 7.19336E+02 7.75000E+03 7.19434E+02 7.75000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP BIO (2)ClAMg q = FSP (2)ClAMg q  
REACTION: 37 27 = 23  
position: 7.22363E+02 7.75000E+03 7.22461E+02 7.75000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP (2)ClAMg q = FSP (2)ClAMg q H2O  
REACTION: 38 23 = 28  
position: 7.73633E+02 7.75000E+03 7.73730E+02 7.75000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP (2)ClAMg q H2O = FSP ClAMg q H2O  
REACTION: 39 28 = 18  
position: 7.94238E+02 7.75000E+03 7.94336E+02 7.75000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP ClAMg q H2O = FSP ClAMg OPX6 q H2O  
95 611 Y = 7750.0000 , 11 REACTIONS: 30 31 27 13 32 33 36 37  
38 39 34  
ASSEMBLAGE: 29: x,y = 4.00000000E+02 8.60000000E+03 GRT BIO (4)ClAMg q

assemblage: GRT\_alm BIO\_phl ClAMg\_tr ClAMg\_parg ClAMg\_gl ClAMg\_bcam q  
 ASSEMBLAGE: 30: x,y = 6.00000000E+02 8.60000000E+03 GRT FSP BIO (2)ClAMg  
 OPX6 q  
 assemblage: GRT\_alm FSP\_abh BIO\_phl ClAMg\_parg ClAMg\_bcam OPX6\_fm q  
 ASSEMBLAGE: 31: x,y = 7.00000000E+02 8.60000000E+03 FSP (2)ClAMg OPX6 q  
 assemblage: FSP\_abh ClAMg\_parg ClAMg\_bcam OPX6\_fm q  
 ASSEMBLAGE: 32: x,y = 7.50000000E+02 8.60000000E+03 FSP ClAMg OPX6 q  
 assemblage: FSP\_abh ClAMg\_parg OPX6\_fm q  
 ASSEMBLAGE: 33: x,y = 4.25000000E+02 8.60000000E+03 GRT BIO (3)ClAMg q  
 assemblage: GRT\_alm BIO\_phl ClAMg\_tr ClAMg\_parg ClAMg\_bcam q  
 ASSEMBLAGE: 34: x,y = 7.62500000E+02 8.60000000E+03 FSP ClAMg q  
 assemblage: FSP\_abh ClAMg\_parg q  
 REACTION: 40 29 = 33  
 position: 4.14941E+02 8.60000E+03 4.15039E+02 8.60000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (4)ClAMg q = GRT BIO (3)ClAMg q  
 REACTION: 41 33 = 21  
 position: 4.38770E+02 8.60000E+03 4.38867E+02 8.60000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (3)ClAMg q = GRT BIO (3)ClAMg ab q  
 REACTION: 42 22 = 30  
 position: 5.98242E+02 8.60000E+03 5.98340E+02 8.60000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (2)ClAMg OPX6 ab q = GRT FSP BIO (2)ClAMg OPX6 q  
 REACTION: 43 30 = 25  
 position: 6.14258E+02 8.60000E+03 6.14355E+02 8.60000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP BIO (2)ClAMg OPX6 q = FSP BIO (2)ClAMg OPX6 q  
 REACTION: 44 25 = 31  
 position: 6.73242E+02 8.60000E+03 6.73340E+02 8.60000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg OPX6 q = FSP (2)ClAMg OPX6 q  
 REACTION: 45 31 = 32  
 position: 7.37598E+02 8.60000E+03 7.37695E+02 8.60000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP (2)ClAMg OPX6 q = FSP ClAMg OPX6 q  
 REACTION: 46 32 = 34  
 position: 7.54492E+02 8.60000E+03 7.54590E+02 8.60000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP ClAMg OPX6 q = FSP ClAMg q  
 REACTION: 47 34 = 28  
 position: 7.70508E+02 8.60000E+03 7.70605E+02 8.60000E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP ClAMg q = FSP ClAMg q H2O  
 106 717 Y = 8600.0000 , 11 REACTIONS: 40 41 30 31 42 43 44 45  
 46 47 39  
 ASSEMBLAGE: 35: x,y = 5.00000000E+02 9.45000000E+03 GRT BIO (2)ClAMg q  
 assemblage: GRT\_alm BIO\_phl ClAMg\_parg ClAMg\_bcam q  
 ASSEMBLAGE: 36: x,y = 6.50000000E+02 9.45000000E+03 GRT FSP BIO ClAMg  
 OPX6 q  
 assemblage: GRT\_alm FSP\_abh BIO\_phl ClAMg\_parg OPX6\_fm q

ASSEMBLAGE: 37: x,y = 6.81250000E+02 9.45000000E+03 FSP BIO ClAMg OPX6  
q  
assemblage: FSP\_abh BIO\_phl ClAMg\_parg OPX6\_fm q  
REACTION: 48 33 = 35  
position: 4.86523E+02 9.45000E+03 4.86621E+02 9.45000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: GRT BIO (3)ClAMg q = GRT BIO (2)ClAMg q  
REACTION: 49 35 = 24  
position: 5.36133E+02 9.45000E+03 5.36230E+02 9.45000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: GRT BIO (2)ClAMg q = GRT BIO (2)ClAMg ab q  
REACTION: 50 30 = 36  
position: 6.49609E+02 9.45000E+03 6.49707E+02 9.45000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: GRT FSP BIO (2)ClAMg OPX6 q = GRT FSP BIO ClAMg OPX6 q  
REACTION: 51 36 = 37  
position: 6.77246E+02 9.45000E+03 6.77344E+02 9.45000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: GRT FSP BIO ClAMg OPX6 q = FSP BIO ClAMg OPX6 q  
REACTION: 52 37 = 32  
position: 6.84570E+02 9.45000E+03 6.84668E+02 9.45000E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP BIO ClAMg OPX6 q = FSP ClAMg OPX6 q  
105 822 Y = 9450.0000, 11 REACTIONS: 40 48 49 31 42 50 51 52  
46 47 39  
ASSEMBLAGE: 38: x,y = 4.00000000E+02 1.03000000E+04 GRT BIO (3)ClAMg  
CHLR ky q  
assemblage: GRT\_alm BIO\_phl ClAMg\_tr ClAMg\_parg ClAMg\_gl CHLR\_clin ky q  
ASSEMBLAGE: 39: x,y = 7.50000000E+02 1.03000000E+04 GRT FSP ClAMg OPX6  
q  
assemblage: GRT\_alm FSP\_abh ClAMg\_parg OPX6\_fm q  
ASSEMBLAGE: 40: x,y = 4.25000000E+02 1.03000000E+04 GRT BIO (4)ClAMg  
CHLR q  
assemblage: GRT\_alm BIO\_phl ClAMg\_tr ClAMg\_parg ClAMg\_gl ClAMg\_bcam  
CHLR\_clin q  
ASSEMBLAGE: 41: x,y = 4.12500000E+02 1.03000000E+04 GRT BIO (3)ClAMg  
CHLR q  
assemblage: GRT\_alm BIO\_phl ClAMg\_tr ClAMg\_parg ClAMg\_gl CHLR\_clin q  
ASSEMBLAGE: 42: x,y = 6.62500000E+02 1.03000000E+04 GRT BIO ClAMg OPX6  
q  
assemblage: GRT\_alm BIO\_phl ClAMg\_parg OPX6\_fm q  
ASSEMBLAGE: 43: x,y = 6.51562500E+02 1.03000000E+04 GRT BIO (2)ClAMg  
OPX6 q  
assemblage: GRT\_alm BIO\_phl ClAMg\_parg ClAMg\_bcam OPX6\_fm q  
REACTION: 53 38 = 41  
position: 4.08105E+02 1.03000E+04 4.08203E+02 1.03000E+04  
LABELED WITH ASSEMBLAGES  
REACTION: GRT BIO (3)ClAMg CHLR ky q = GRT BIO (3)ClAMg CHLR q  
REACTION: 54 41 = 40  
position: 4.21094E+02 1.03000E+04 4.21191E+02 1.03000E+04  
LABELED WITH ASSEMBLAGES  
REACTION: GRT BIO (3)ClAMg CHLR q = GRT BIO (4)ClAMg CHLR q



REACTION: 55 40 = 29  
 position: 4.25293E+02 1.03000E+04 4.25391E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (4)ClAMg CHLR q = GRT BIO (4)ClAMg q  
 REACTION: 56 35 = 43  
 position: 6.50391E+02 1.03000E+04 6.50488E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (2)ClAMg q = GRT BIO (2)ClAMg OPX6 q  
 REACTION: 57 43 = 42  
 position: 6.52832E+02 1.03000E+04 6.52930E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (2)ClAMg OPX6 q = GRT BIO ClAMg OPX6 q  
 REACTION: 58 42 = 36  
 position: 6.66992E+02 1.03000E+04 6.67090E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO ClAMg OPX6 q = GRT FSP BIO ClAMg OPX6 q  
 REACTION: 59 36 = 39  
 position: 7.00293E+02 1.03000E+04 7.00391E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP BIO ClAMg OPX6 q = GRT FSP ClAMg OPX6 q  
 REACTION: 60 39 = 32  
 position: 8.23828E+02 1.03000E+04 8.23926E+02 1.03000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP ClAMg OPX6 q = FSP ClAMg OPX6 q  
 109 931 Y = 10300.0000 , 13 REACTIONS: 53 54 55 40 48 56 57 58  
 59 60 46 47 39  
 ASSEMBLAGE: 44: x,y = 4.00000000E+02 1.11500000E+04 GRT EPI PHNG  
 (2)ClAMg CHLR ky q  
 assemblage: GRT\_alm EPI\_cz PHNG\_mu ClAMg\_tr ClAMg\_gl CHLR\_clin ky q  
 ASSEMBLAGE: 45: x,y = 4.50000000E+02 1.11500000E+04 GRT BIO (2)ClAMg  
 CHLR q  
 assemblage: GRT\_alm BIO\_phl ClAMg\_tr ClAMg\_parg CHLR\_clin q  
 ASSEMBLAGE: 46: x,y = 6.50000000E+02 1.11500000E+04 GRT BIO ClAMg q  
 assemblage: GRT\_alm BIO\_phl ClAMg\_parg q  
 ASSEMBLAGE: 47: x,y = 7.50000000E+02 1.11500000E+04 GRT FSP ClAMg q  
 assemblage: GRT\_alm FSP\_abh ClAMg\_parg q  
 ASSEMBLAGE: 48: x,y = 9.00000000E+02 1.11500000E+04 GRT FSP ClAMg OPX6  
 q H2O  
 assemblage: GRT\_alm FSP\_abh ClAMg\_parg OPX6\_fm q H2O  
 ASSEMBLAGE: 49: x,y = 4.18750000E+02 1.11500000E+04 GRT PHNG (3)ClAMg  
 CHLR ky q  
 assemblage: GRT\_alm PHNG\_mu ClAMg\_tr ClAMg\_parg ClAMg\_gl CHLR\_clin ky q  
 ASSEMBLAGE: 50: x,y = 7.12500000E+02 1.11500000E+04 GRT ClAMg q  
 assemblage: GRT\_alm ClAMg\_parg q  
 ASSEMBLAGE: 51: x,y = 8.75000000E+02 1.11500000E+04 GRT FSP ClAMg q H2O  
 assemblage: GRT\_alm FSP\_abh ClAMg\_parg q H2O  
 REACTION: 61 44 = 49  
 position: 4.15039E+02 1.11500E+04 4.15137E+02 1.11500E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT EPI PHNG (2)ClAMg CHLR ky q = GRT PHNG (3)ClAMg CHLR ky  
 q  
 REACTION: 62 49 = 38

position: 4.20508E+02 1.11500E+04 4.20605E+02 1.11500E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT PHNG (3)CIAMg CHLR ky q = GRT BIO (3)CIAMg CHLR ky q  
 REACTION: 63 41 = 45  
 position: 4.46973E+02 1.11500E+04 4.47070E+02 1.11500E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (3)CIAMg CHLR q = GRT BIO (2)CIAMg CHLR q  
 REACTION: 64 41 = 33  
 position: 4.72656E+02 1.11500E+04 4.72754E+02 1.11500E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (3)CIAMg CHLR q = GRT BIO (3)CIAMg q  
 REACTION: 65 35 = 46  
 position: 6.46191E+02 1.11500E+04 6.46289E+02 1.11500E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (2)CIAMg q = GRT BIO CIAMg q  
 REACTION: 66 46 = 50  
 position: 7.09863E+02 1.11500E+04 7.09961E+02 1.11500E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO CIAMg q = GRT CIAMg q  
 REACTION: 67 50 = 47  
 position: 7.22852E+02 1.11500E+04 7.22949E+02 1.11500E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT CIAMg q = GRT FSP CIAMg q  
 REACTION: 68 47 = 51  
 position: 8.67383E+02 1.11500E+04 8.67480E+02 1.11500E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP CIAMg q = GRT FSP CIAMg q H2O  
 REACTION: 69 51 = 48  
 position: 8.99023E+02 1.11500E+04 8.99121E+02 1.11500E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP CIAMg q H2O = GRT FSP CIAMg OPX6 q H2O  
 105 1036 Y = 11150.0000, 12 REACTIONS: 61 62 53 63 63 64 48 65  
 66 67 68 69  
 ASSEMBLAGE: 52: x,y = 4.43750000E+02 1.20000000E+04 GRT PHNG (3)CIAMg  
 CHLR q  
 assemblage: GRT\_alm PHNG\_mu CIAMg\_tr CIAMg\_parg CIAMg\_gl CHLR\_clin q  
 ASSEMBLAGE: 53: x,y = 4.49218750E+02 1.20000000E+04 GRT PHNG BIO  
 (3)CIAMg CHLR q  
 assemblage: GRT\_alm PHNG\_mu BIO\_phl CIAMg\_tr CIAMg\_parg CIAMg\_gl  
 CHLR\_clin q  
 REACTION: 70 49 = 52  
 position: 4.38574E+02 1.20000E+04 4.38672E+02 1.20000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT PHNG (3)CIAMg CHLR ky q = GRT PHNG (3)CIAMg CHLR q  
 REACTION: 71 52 = 53  
 position: 4.48438E+02 1.20000E+04 4.48535E+02 1.20000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT PHNG (3)CIAMg CHLR q = GRT PHNG BIO (3)CIAMg CHLR q  
 REACTION: 72 53 = 41  
 position: 4.49414E+02 1.20000E+04 4.49512E+02 1.20000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT PHNG BIO (3)CIAMg CHLR q = GRT BIO (3)CIAMg CHLR q

REACTION: 73 45 = 35  
 position: 5.38281E+02 1.20000E+04 5.38379E+02 1.20000E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (2)CIAMg CHLR q = GRT BIO (2)CIAMg q  
 90 1126 Y = 12000.0000 , 10 REACTIONS: 61 70 71 72 63 73 65 66  
 67 68  
 ASSEMBLAGE: 54: x,y = 4.00000000E+02 8.00898438E+03 GRT BIO (4)CIAMg ab  
 q  
 assemblage: GRT\_alm BIO\_phl CIAMg\_tr CIAMg\_parg CIAMg\_gl CIAMg\_bcam ab q  
 ASSEMBLAGE: 55: x,y = 4.00000000E+02 1.04361328E+04 GRT PHNG BIO  
 (3)CIAMg CHLR ky q  
 assemblage: GRT\_alm PHNG\_mu BIO\_phl CIAMg\_tr CIAMg\_parg CIAMg\_gl  
 CHLR\_clin ky q  
 REACTION: 74 21 = 54  
 position: 4.00000E+02 8.00732E+03 4.00000E+02 8.00898E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (3)CIAMg ab q = GRT BIO (4)CIAMg ab q  
 REACTION: 75 54 = 29  
 position: 4.00000E+02 8.01396E+03 4.00000E+02 8.01562E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (4)CIAMg ab q = GRT BIO (4)CIAMg q  
 REACTION: 76 38 = 55  
 position: 4.00000E+02 1.04345E+04 4.00000E+02 1.04361E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (3)CIAMg CHLR ky q = GRT PHNG BIO (3)CIAMg CHLR ky q  
 REACTION: 77 55 = 49  
 position: 4.00000E+02 1.04361E+04 4.00000E+02 1.04378E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT PHNG BIO (3)CIAMg CHLR ky q = GRT PHNG (3)CIAMg CHLR ky  
 q  
 66 1192 X = 400.0000 , 10 REACTIONS: 17 25 74 75 55 54 53 76  
 77 61  
 75 1267 X = 450.0000 , 9 REACTIONS: 14 13 27 31 30 41 64 63  
 63  
 62 1329 X = 500.0000 , 8 REACTIONS: 14 13 27 31 49 73 63 63  
 REACTION: 78 3 = 17  
 position: 5.50000E+02 4.65713E+03 5.50000E+02 4.65879E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)CIAMg CHLR q = FSP BIO (2)CIAMg q  
 57 1386 X = 550.0000 , 7 REACTIONS: 78 33 32 13 27 31 49  
 ASSEMBLAGE: 56: x,y = 6.00000000E+02 8.66308594E+03 GRT FSP BIO (2)CIAMg  
 OPX6 ab q  
 assemblage: GRT\_alm FSP\_abh BIO\_phl CIAMg\_parg CIAMg\_bcam OPX6\_fm ab q  
 REACTION: 79 30 = 56  
 position: 6.00000E+02 8.66143E+03 6.00000E+02 8.66309E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP BIO (2)CIAMg OPX6 q = GRT FSP BIO (2)CIAMg OPX6 ab q  
 REACTION: 80 56 = 22  
 position: 6.00000E+02 8.66309E+03 6.00000E+02 8.66475E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP BIO (2)CIAMg OPX6 ab q = GRT BIO (2)CIAMg OPX6 ab q  
 REACTION: 81 22 = 43

position: 6.00000E+02 9.78701E+03 6.00000E+02 9.78867E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (2)ClAMg OPX6 ab q = GRT BIO (2)ClAMg OPX6 q  
 50 1436 X = 600.0000, 7 REACTIONS: 19 33 43 79 80 81 56  
 74 1510 X = 650.0000, 9 REACTIONS: 7 19 33 43 50 58 57 56  
 65  
 ASSEMBLAGE: 57: x,y = 7.00000000E+02 1.07250000E+04 GRT FSP BIO ClAMg q  
 assemblage: GRT\_alm FSP\_abh BIO\_phl ClAMg\_parg q  
 REACTION: 82 27 = 31  
 position: 7.00000E+02 8.21318E+03 7.00000E+02 8.21484E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP (2)ClAMg q = FSP (2)ClAMg OPX6 q  
 REACTION: 83 36 = 57  
 position: 7.00000E+02 1.04411E+04 7.00000E+02 1.04428E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP BIO ClAMg OPX6 q = GRT FSP BIO ClAMg q  
 REACTION: 84 57 = 46  
 position: 7.00000E+02 1.08213E+04 7.00000E+02 1.08229E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP BIO ClAMg q = GRT BIO ClAMg q  
 78 1588 X = 700.0000, 9 REACTIONS: 7 19 36 82 45 60 59 83  
 84  
 REACTION: 85 19 = 23  
 position: 7.50000E+02 5.34443E+03 7.50000E+02 5.34609E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP (2)ClAMg H2O = FSP (2)ClAMg q H2O  
 REACTION: 86 39 = 47  
 position: 7.50000E+02 1.03631E+04 7.50000E+02 1.03647E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP ClAMg OPX6 q = GRT FSP ClAMg q  
 65 1653 X = 750.0000, 8 REACTIONS: 20 85 38 47 46 60 86 67  
 53 1706 X = 800.0000, 6 REACTIONS: 24 39 47 46 60 86  
 REACTION: 87 34 = 47  
 position: 8.50000E+02 1.05391E+04 8.50000E+02 1.05407E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP ClAMg q = GRT FSP ClAMg q  
 43 1749 X = 850.0000, 5 REACTIONS: 11 24 39 47 87  
 REACTION: 88 18 = 48  
 position: 9.00000E+02 1.06204E+04 9.00000E+02 1.06221E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP ClAMg OPX6 q H2O = GRT FSP ClAMg OPX6 q H2O  
 36 1785 X = 900.0000, 4 REACTIONS: 35 34 88 69  
 NUMBER OF LINES: 89 NUMBER OF POINTS: 210 max.ph.: 2098  
 LEVEL: 0 SQUARE: ( 1, 1 ) LINE 1 REACTION 1: OPEN END  
 22 1807 Y = 3925.0000, 3 REACTIONS: 12 13 14  
 REACTION: 89 8 = 14  
 position: 4.25000E+02 3.63115E+03 4.25000E+02 3.63281E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (3)ClAMg ab q = FSP BIO (2)ClAMg OPX6 ab q  
 14 1821 X = 425.0000, 2 REACTIONS: 89 13  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 215 max.ph.: 2099  
 LEVEL: 0 SQUARE: ( 3, 2 ) LINE 3 REACTION 3: OPEN END

11 1832 Y = 4775.0000, 1 REACTIONS: 18  
 2 1834 X = 525.0000, 0 REACTIONS:  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 216 max.ph.: 2060  
 LEVEL: 0 SQUARE: ( 3, 1 ) LINE 3 REACTION 3: TWO POINTS  
 17 1851 Y = 3925.0000, 2 REACTIONS: 3 4  
 17 1868 X = 525.0000, 2 REACTIONS: 4 3  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 220 max.ph.: 2114  
 LEVEL: 0 SQUARE: ( 4, 2 ) LINE 5 REACTION 5: OPEN END  
 23 1891 Y = 4775.0000, 3 REACTIONS: 78 5 6  
 10 1901 X = 575.0000, 1 REACTIONS: 78  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 224 max.ph.: 2178  
 LEVEL: 0 SQUARE: ( 7, 3 ) LINE 7 REACTION 7: OPEN END  
 11 1912 Y = 5625.0000, 1 REACTIONS: 28  
 10 1922 X = 725.0000, 1 REACTIONS: 28  
 NUMBER OF LINES: 90 NUMBER OF POINTS: 226 max.ph.: 1953  
 LEVEL: 0 SQUARE: ( 8, 2 ) LINE 8 REACTION 8: OPEN END  
 REACTION: 90 15 = 18  
 position: 7.89551E+02 4.77500E+03 7.89648E+02 4.77500E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP (2)CIAMg OPX6 H2O = FSP CIAMg OPX6 q H2O  
 29 1951 Y = 4775.0000, 4 REACTIONS: 20 21 90 24  
 17 1968 X = 775.0000, 2 REACTIONS: 15 21  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 232 max.ph.: 2172  
 LEVEL: 0 SQUARE: ( 8, 1 ) LINE 8 REACTION 8: TWO POINTS  
 24 1992 Y = 3925.0000, 3 REACTIONS: 8 9 10  
 10 2002 X = 775.0000, 1 REACTIONS: 9  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 236 max.ph.: 1995  
 LEVEL: 0 SQUARE: ( 10, 4 ) LINE 11 REACTION 11: OPEN END  
 19 2021 Y = 6475.0000, 2 REACTIONS: 34 35  
 18 2039 X = 875.0000, 2 REACTIONS: 35 34  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 240 max.ph.: 2070  
 LEVEL: 0 SQUARE: ( 1, 3 ) LINE 12 REACTION 12: OPEN END  
 20 2059 Y = 5625.0000, 3 REACTIONS: 25 17 12  
 22 2081 X = 425.0000, 3 REACTIONS: 27 26 25  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 246 max.ph.: 2155  
 LEVEL: 0 SQUARE: ( 4, 6 ) LINE 13 REACTION 13: OPEN END  
 13 2094 Y = 8175.0000, 3 REACTIONS: 27 13 32  
 20 2114 X = 575.0000, 3 REACTIONS: 32 13 27  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 252 max.ph.: 2078  
 LEVEL: 0 SQUARE: ( 3, 4 ) LINE 14 REACTION 14: OPEN END  
 18 2132 Y = 6475.0000, 3 REACTIONS: 13 14 18  
 16 2148 X = 525.0000, 2 REACTIONS: 14 13  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 257 max.ph.: 2152  
 LEVEL: 0 SQUARE: ( 7, 5 ) LINE 19 REACTION 19: OPEN END  
 11 2159 Y = 7325.0000, 1 REACTIONS: 28  
 2 2161 X = 725.0000, 0 REACTIONS:  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 258 max.ph.: 3184  
 LEVEL: 0 SQUARE: ( 8, 3 ) LINE 21 REACTION 21: OPEN END  
 29 2190 Y = 5625.0000, 4 REACTIONS: 85 21 22 23  
 10 2200 X = 775.0000, 1 REACTIONS: 85  
 NUMBER OF LINES: 91 NUMBER OF POINTS: 263 max.ph.: 2049  
 LEVEL: 0 SQUARE: ( 8, 5 ) LINE 23 REACTION 23: OPEN END

REACTION: 91 23 = 18  
position: 7.87402E+02 7.32500E+03 7.87500E+02 7.32500E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP (2)ClAMg q H2O = FSP ClAMg OPX6 q H2O  
11 2211 Y = 7325.0000, 1 REACTIONS: 91  
10 2221 X = 775.0000, 1 REACTIONS: 38  
NUMBER OF LINES: 92 NUMBER OF POINTS: 265 max.ph.: 2076  
LEVEL: 0 SQUARE: ( 1, 4 ) LINE 25 REACTION 25: OPEN END  
17 2238 Y = 6475.0000, 2 REACTIONS: 30 31  
2 2240 X = 425.0000, 0 REACTIONS:  
NUMBER OF LINES: 92 NUMBER OF POINTS: 267 max.ph.: 2041  
LEVEL: 0 SQUARE: ( 7, 4 ) LINE 28 REACTION 28: BUMP  
11 2251 Y = 6475.0000, 1 REACTIONS: 28  
2 2253 X = 725.0000, 0 REACTIONS:  
NUMBER OF LINES: 92 NUMBER OF POINTS: 268 max.ph.: 2003  
LEVEL: 0 SQUARE: ( 8, 4 ) LINE 29 REACTION 29: TWO POINTS  
16 2269 Y = 6475.0000, 2 REACTIONS: 29 23  
2 2271 X = 775.0000, 0 REACTIONS:  
NUMBER OF LINES: 92 NUMBER OF POINTS: 270 max.ph.: 2068  
LEVEL: 0 SQUARE: ( 2, 7 ) LINE 30 REACTION 30: OPEN END  
17 2288 Y = 9025.0000, 2 REACTIONS: 41 30  
17 2305 X = 475.0000, 2 REACTIONS: 30 41  
NUMBER OF LINES: 92 NUMBER OF POINTS: 274 max.ph.: 2012  
LEVEL: 0 SQUARE: ( 4, 8 ) LINE 31 REACTION 31: OPEN END  
3 2308 Y = 9875.0000, 0 REACTIONS:  
10 2318 X = 575.0000, 1 REACTIONS: 49  
NUMBER OF LINES: 92 NUMBER OF POINTS: 275 max.ph.: 2161  
LEVEL: 0 SQUARE: ( 6, 6 ) LINE 33 REACTION 33: OPEN END  
19 2337 Y = 8175.0000, 2 REACTIONS: 44 82  
17 2354 X = 675.0000, 2 REACTIONS: 36 82  
NUMBER OF LINES: 92 NUMBER OF POINTS: 279 max.ph.: 2303  
LEVEL: 0 SQUARE: ( 7, 6 ) LINE 37 REACTION 37: OPEN END  
REACTION: 92 27 = 34  
position: 7.48242E+02 8.17500E+03 7.48340E+02 8.17500E+03  
LABELED WITH ASSEMBLAGES  
REACTION: FSP (2)ClAMg q = FSP ClAMg q  
11 2365 Y = 8175.0000, 1 REACTIONS: 92  
18 2383 X = 725.0000, 2 REACTIONS: 37 82  
NUMBER OF LINES: 93 NUMBER OF POINTS: 282 max.ph.: 3283  
LEVEL: 0 SQUARE: ( 10, 9 ) LINE 39 REACTION 39: OPEN END  
REACTION: 93 28 = 51  
position: 8.82227E+02 1.07250E+04 8.82324E+02 1.07250E+04  
LABELED WITH ASSEMBLAGES  
REACTION: FSP ClAMg q H2O = GRT FSP ClAMg q H2O  
31 2414 Y = 10725.0000, 4 REACTIONS: 87 47 93 69  
18 2432 X = 875.0000, 2 REACTIONS: 39 93  
NUMBER OF LINES: 94 NUMBER OF POINTS: 288 max.ph.: 2107  
LEVEL: 0 SQUARE: ( 1, 6 ) LINE 40 REACTION 40: OPEN END  
REACTION: 94 29 = 21  
position: 4.04590E+02 8.17500E+03 4.04688E+02 8.17500E+03  
LABELED WITH ASSEMBLAGES  
REACTION: GRT BIO (4)ClAMg q = GRT BIO (3)ClAMg ab q

11 2443 Y = 8175.0000, 1 REACTIONS: 94  
 10 2453 X = 425.0000, 1 REACTIONS: 41  
 NUMBER OF LINES: 95 NUMBER OF POINTS: 290 max.ph.: 2065  
 LEVEL: 0 SQUARE: ( 1, 9 ) LINE 40 REACTION 40: OPEN END  
 32 2485 Y = 10725.0000, 4 REACTIONS: 61 62 53 64  
 10 2495 X = 425.0000, 1 REACTIONS: 54  
 NUMBER OF LINES: 95 NUMBER OF POINTS: 295 max.ph.: 2568  
 LEVEL: 0 SQUARE: ( 4, 7 ) LINE 42 REACTION 42: OPEN END  
 11 2506 Y = 9025.0000, 1 REACTIONS: 31  
 10 2516 X = 575.0000, 1 REACTIONS: 31  
 NUMBER OF LINES: 95 NUMBER OF POINTS: 297 max.ph.: 2111  
 LEVEL: 0 SQUARE: ( 6, 7 ) LINE 43 REACTION 43: OPEN END  
 11 2527 Y = 9025.0000, 1 REACTIONS: 44  
 REACTION: 95 25 = 37  
 position: 6.75000E+02 9.23584E+03 6.75000E+02 9.23750E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg OPX6 q = FSP BIO ClAMg OPX6 q  
 25 2552 X = 675.0000, 3 REACTIONS: 44 95 51  
 NUMBER OF LINES: 96 NUMBER OF POINTS: 301 max.ph.: 2158  
 LEVEL: 0 SQUARE: ( 5, 7 ) LINE 43 REACTION 43: BUMP  
 19 2571 Y = 9025.0000, 2 REACTIONS: 42 43  
 10 2581 X = 625.0000, 1 REACTIONS: 43  
 NUMBER OF LINES: 96 NUMBER OF POINTS: 304 max.ph.: 2192  
 LEVEL: 0 SQUARE: ( 7, 7 ) LINE 45 REACTION 45: TWO POINTS  
 11 2592 Y = 9025.0000, 1 REACTIONS: 45  
 10 2602 X = 725.0000, 1 REACTIONS: 45  
 NUMBER OF LINES: 96 NUMBER OF POINTS: 306 max.ph.: 2169  
 LEVEL: 0 SQUARE: ( 9, 9 ) LINE 46 REACTION 46: OPEN END  
 3 2605 Y = 10725.0000, 0 REACTIONS:  
 15 2620 X = 825.0000, 2 REACTIONS: 60 86  
 NUMBER OF LINES: 96 NUMBER OF POINTS: 308 max.ph.: 2190  
 LEVEL: 0 SQUARE: ( 2, 10 ) LINE 48 REACTION 48: OPEN END  
 31 2651 Y = 11575.0000, 4 REACTIONS: 63 63 63 73  
 17 2668 X = 475.0000, 2 REACTIONS: 64 63  
 NUMBER OF LINES: 96 NUMBER OF POINTS: 314 max.ph.: 2203  
 LEVEL: 0 SQUARE: ( 5, 8 ) LINE 50 REACTION 42: OPEN END  
 25 2693 Y = 9875.0000, 3 REACTIONS: 56 57 58  
 REACTION: 96 30 = 43  
 position: 6.25000E+02 9.57949E+03 6.25000E+02 9.58115E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP BIO (2)ClAMg OPX6 q = GRT BIO (2)ClAMg OPX6 q  
 18 2711 X = 625.0000, 2 REACTIONS: 96 56  
 NUMBER OF LINES: 97 NUMBER OF POINTS: 319 max.ph.: 4075  
 LEVEL: 0 SQUARE: ( 6, 8 ) LINE 52 REACTION 51: OPEN END  
 11 2722 Y = 9875.0000, 1 REACTIONS: 59  
 2 2724 X = 675.0000, 0 REACTIONS:  
 NUMBER OF LINES: 97 NUMBER OF POINTS: 320 max.ph.: 2282  
 LEVEL: 0 SQUARE: ( 1, 10 ) LINE 54 REACTION 53: OPEN END  
 26 2750 Y = 11575.0000, 4 REACTIONS: 61 70 71 72  
 REACTION: 97 53 = 49  
 position: 4.25000E+02 1.13061E+04 4.25000E+02 1.13077E+04  
 LABELED WITH ASSEMBLAGES

REACTION: GRT PHNG BIO (3)CIAMg CHLR q = GRT PHNG (3)CIAMg CHLR ky q  
 18 2768 X = 425.0000 , 3 REACTIONS: 72 97 61  
 NUMBER OF LINES: 98 NUMBER OF POINTS: 327 max.ph.: 2194  
 LEVEL: 0 SQUARE: ( 1 , 8 ) LINE 56 REACTION 55: TWO POINTS  
 29 2797 Y = 9875.0000 , 4 REACTIONS: 53 54 55 40  
 REACTION: 98 33 = 40  
 position: 4.25000E+02 1.02934E+04 4.25000E+02 1.02950E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (3)CIAMg q = GRT BIO (4)CIAMg CHLR q  
 19 2816 X = 425.0000 , 3 REACTIONS: 40 40 98  
 NUMBER OF LINES: 101 NUMBER OF POINTS: 334 max.ph.: 2125  
 LEVEL: 0 SQUARE: ( 1 , 7 ) LINE 40 REACTION 40: BUMP  
 11 2827 Y = 9025.0000 , 1 REACTIONS: 40  
 2 2829 X = 425.0000 , 0 REACTIONS:  
 NUMBER OF LINES: 101 NUMBER OF POINTS: 335 max.ph.: 2158  
 LEVEL: 0 SQUARE: ( 6 , 9 ) LINE 58 REACTION 56: OPEN END  
 19 2848 Y = 10725.0000 , 2 REACTIONS: 65 84  
 13 2861 X = 675.0000 , 2 REACTIONS: 83 84  
 NUMBER OF LINES: 101 NUMBER OF POINTS: 339 max.ph.: 2225  
 LEVEL: 0 SQUARE: ( 7 , 9 ) LINE 61 REACTION 59: OPEN END  
 REACTION: 99 57 = 47  
 position: 7.06152E+02 1.07250E+04 7.06250E+02 1.07250E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP BIO CIAMg q = GRT FSP CIAMg q  
 11 2872 Y = 10725.0000 , 1 REACTIONS: 99  
 10 2882 X = 725.0000 , 1 REACTIONS: 86  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 341 max.ph.: 3295  
 LEVEL: 0 SQUARE: ( 2 , 9 ) LINE 65 REACTION 63: BUMP  
 11 2893 Y = 10725.0000 , 1 REACTIONS: 48  
 2 2895 X = 475.0000 , 0 REACTIONS:  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 342 max.ph.: 2193  
 LEVEL: 0 SQUARE: ( 3 , 10 ) LINE 65 REACTION 63: BUMP  
 3 2898 Y = 11575.0000 , 0 REACTIONS:  
 10 2908 X = 525.0000 , 1 REACTIONS: 73  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 343 max.ph.: 2173  
 LEVEL: 0 SQUARE: ( 7 , 10 ) LINE 68 REACTION 66: TWO POINTS  
 11 2919 Y = 11575.0000 , 1 REACTIONS: 66  
 10 2929 X = 725.0000 , 1 REACTIONS: 67  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 345 max.ph.: 2161  
 LEVEL: 0 SQUARE: ( 10 , 10 ) LINE 70 REACTION 68: TWO POINTS  
 11 2940 Y = 11575.0000 , 1 REACTIONS: 68  
 2 2942 X = 875.0000 , 0 REACTIONS:  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 346 max.ph.: 2122  
 LEVEL: 0 SQUARE: ( 8 , 9 ) LINE 88 REACTION 86: BUMP  
 3 2945 Y = 10725.0000 , 0 REACTIONS:  
 10 2955 X = 775.0000 , 1 REACTIONS: 86  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 347 max.ph.: 3304  
 LEVEL: 1 SQUARE: ( 1 , 1 ) LINE 1 REACTION 1: OPEN END  
 10 2965 Y = 3712.5000 , 1 REACTIONS: 12  
 2 2967 X = 412.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 348 max.ph.: 2154  
 LEVEL: 1 SQUARE: ( 2 , 1 ) LINE 2 REACTION 2: OPEN END



13 2980 Y = 3712.5000 , 2 REACTIONS: 13 14  
 12 2992 X = 437.5000 , 2 REACTIONS: 14 13  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 352 max.ph.: 2081  
 LEVEL: 1 SQUARE: ( 6 , 3 ) LINE 3 REACTION 3: OPEN END  
 17 3009 Y = 4562.5000 , 2 REACTIONS: 18 78  
 9 3018 X = 537.5000 , 1 REACTIONS: 78  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 355 max.ph.: 2235  
 LEVEL: 1 SQUARE: ( 8 , 4 ) LINE 5 REACTION 5: OPEN END  
 17 3035 Y = 4987.5000 , 3 REACTIONS: 78 5 6  
 9 3044 X = 587.5000 , 1 REACTIONS: 19  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 359 max.ph.: 2173  
 LEVEL: 1 SQUARE: ( 14 , 5 ) LINE 7 REACTION 7: OPEN END  
 10 3054 Y = 5412.5000 , 1 REACTIONS: 28  
 9 3063 X = 737.5000 , 1 REACTIONS: 28  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 361 max.ph.: 1842  
 LEVEL: 1 SQUARE: ( 15 , 3 ) LINE 8 REACTION 8: OPEN END  
 16 3079 Y = 4562.5000 , 2 REACTIONS: 20 21  
 9 3088 X = 762.5000 , 1 REACTIONS: 20  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 364 max.ph.: 2029  
 LEVEL: 1 SQUARE: ( 16 , 2 ) LINE 9 REACTION 9: OPEN END  
 15 3103 Y = 4137.5000 , 2 REACTIONS: 15 16  
 2 3105 X = 787.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 366 max.ph.: 2065  
 LEVEL: 1 SQUARE: ( 16 , 1 ) LINE 10 REACTION 10: TWO POINTS  
 10 3115 Y = 3712.5000 , 1 REACTIONS: 10  
 2 3117 X = 787.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 367 max.ph.: 2068  
 LEVEL: 1 SQUARE: ( 19 , 7 ) LINE 11 REACTION 11: OPEN END  
 15 3132 Y = 6262.5000 , 2 REACTIONS: 34 35  
 2 3134 X = 862.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 369 max.ph.: 2065  
 LEVEL: 1 SQUARE: ( 1 , 6 ) LINE 12 REACTION 12: OPEN END  
 10 3144 Y = 5837.5000 , 1 REACTIONS: 25  
 2 3146 X = 412.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 102 NUMBER OF POINTS: 370 max.ph.: 2060  
 LEVEL: 1 SQUARE: ( 8 , 12 ) LINE 13 REACTION 13: OPEN END  
 17 3163 Y = 8387.5000 , 3 REACTIONS: 80 79 43  
 REACTION: 100 14 = 22  
 position: 5.87500E+02 8.21484E+03 5.87500E+02 8.21650E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg OPX6 ab q = GRT BIO (2)ClAMg OPX6 ab q  
 12 3175 X = 587.5000 , 2 REACTIONS: 32 100  
 NUMBER OF LINES: 105 NUMBER OF POINTS: 375 max.ph.: 2184  
 LEVEL: 1 SQUARE: ( 6 , 8 ) LINE 14 REACTION 14: OPEN END  
 14 3189 Y = 6687.5000 , 2 REACTIONS: 13 32  
 REACTION: 101 17 = 14  
 position: 5.37500E+02 6.51318E+03 5.37500E+02 6.51484E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg q = FSP BIO (2)ClAMg OPX6 ab q  
 14 3203 X = 537.5000 , 2 REACTIONS: 101 13  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 379 max.ph.: 2074  
 LEVEL: 1 SQUARE: ( 16 , 3 ) LINE 16 REACTION 16: OPEN END

10 3213 Y = 4562.5000 , 1 REACTIONS: 16  
 9 3222 X = 787.5000 , 1 REACTIONS: 16  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 381 max.ph.: 2023  
 LEVEL: 1 SQUARE: ( 13 , 10 ) LINE 19 REACTION 19: OPEN END  
 17 3239 Y = 7537.5000 , 2 REACTIONS: 19 28  
 9 3248 X = 712.5000 , 1 REACTIONS: 19  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 384 max.ph.: 2080  
 LEVEL: 1 SQUARE: ( 16 , 6 ) LINE 21 REACTION 21: OPEN END  
 15 3263 Y = 5837.5000 , 2 REACTIONS: 29 23  
 15 3278 X = 787.5000 , 2 REACTIONS: 21 85  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 388 max.ph.: 2030  
 LEVEL: 1 SQUARE: ( 16 , 4 ) LINE 22 REACTION 22: OPEN END  
 22 3300 Y = 4987.5000 , 3 REACTIONS: 21 22 23  
 2 3302 X = 787.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 391 max.ph.: 2094  
 LEVEL: 1 SQUARE: ( 16 , 9 ) LINE 23 REACTION 23: OPEN END  
 15 3317 Y = 7112.5000 , 2 REACTIONS: 29 23  
 9 3326 X = 787.5000 , 1 REACTIONS: 91  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 394 max.ph.: 2049  
 LEVEL: 1 SQUARE: ( 2 , 7 ) LINE 25 REACTION 25: OPEN END  
 13 3339 Y = 6262.5000 , 2 REACTIONS: 25 26  
 14 3353 X = 437.5000 , 2 REACTIONS: 26 25  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 398 max.ph.: 2120  
 LEVEL: 1 SQUARE: ( 13 , 6 ) LINE 28 REACTION 28: BUMP  
 10 3363 Y = 5837.5000 , 1 REACTIONS: 28  
 2 3365 X = 712.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 399 max.ph.: 2048  
 LEVEL: 1 SQUARE: ( 13 , 7 ) LINE 28 REACTION 28: BUMP  
 10 3375 Y = 6262.5000 , 1 REACTIONS: 28  
 9 3384 X = 712.5000 , 1 REACTIONS: 28  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 401 max.ph.: 1976  
 LEVEL: 1 SQUARE: ( 4 , 14 ) LINE 30 REACTION 30: OPEN END  
 10 3394 Y = 9237.5000 , 1 REACTIONS: 48  
 9 3403 X = 487.5000 , 1 REACTIONS: 49  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 403 max.ph.: 2100  
 LEVEL: 1 SQUARE: ( 8 , 15 ) LINE 31 REACTION 31: OPEN END  
 10 3413 Y = 9662.5000 , 1 REACTIONS: 31  
 9 3422 X = 587.5000 , 1 REACTIONS: 49  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 405 max.ph.: 1986  
 LEVEL: 1 SQUARE: ( 11 , 11 ) LINE 33 REACTION 33: OPEN END  
 17 3439 Y = 7962.5000 , 2 REACTIONS: 44 82  
 14 3453 X = 662.5000 , 2 REACTIONS: 36 82  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 409 max.ph.: 3268  
 LEVEL: 1 SQUARE: ( 14 , 11 ) LINE 37 REACTION 37: OPEN END  
 10 3463 Y = 7962.5000 , 1 REACTIONS: 37  
 9 3472 X = 737.5000 , 1 REACTIONS: 37  
 NUMBER OF LINES: 106 NUMBER OF POINTS: 411 max.ph.: 2109  
 LEVEL: 1 SQUARE: ( 16 , 10 ) LINE 38 REACTION 38: OPEN END  
 11 3483 Y = 7537.5000 , 2 REACTIONS: 29 23  
 16 3499 X = 787.5000 , 2 REACTIONS: 91 38  
 NUMBER OF LINES: 108 NUMBER OF POINTS: 415 max.ph.: 2081  
 LEVEL: 1 SQUARE: ( 20 , 17 ) LINE 39 REACTION 39: OPEN END

10 3509 Y = 10512.5000 , 1 REACTIONS: 39  
 9 3518 X = 887.5000 , 1 REACTIONS: 88  
 NUMBER OF LINES: 108 NUMBER OF POINTS: 417 max.ph.: 2110  
 LEVEL: 1 SQUARE: ( 1 , 12 ) LINE 40 REACTION 40: OPEN END  
 16 3534 Y = 8387.5000 , 2 REACTIONS: 40 41  
 9 3543 X = 412.5000 , 1 REACTIONS: 94  
 NUMBER OF LINES: 108 NUMBER OF POINTS: 420 max.ph.: 2040  
 LEVEL: 1 SQUARE: ( 2 , 17 ) LINE 40 REACTION 40: OPEN END  
 10 3553 Y = 10512.5000 , 1 REACTIONS: 64  
 9 3562 X = 437.5000 , 1 REACTIONS: 64  
 NUMBER OF LINES: 108 NUMBER OF POINTS: 422 max.ph.: 2158  
 LEVEL: 1 SQUARE: ( 1 , 15 ) LINE 40 REACTION 40: BUMP  
 17 3579 Y = 9662.5000 , 2 REACTIONS: 55 40  
 2 3581 X = 412.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 108 NUMBER OF POINTS: 424 max.ph.: 2147  
 LEVEL: 1 SQUARE: ( 2 , 16 ) LINE 40 REACTION 40: BUMP  
 10 3591 Y = 10087.5000 , 1 REACTIONS: 40  
 2 3593 X = 437.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 108 NUMBER OF POINTS: 425 max.ph.: 4085  
 LEVEL: 1 SQUARE: ( 8 , 13 ) LINE 42 REACTION 42: OPEN END  
 3 3596 Y = 8812.5000 , 0 REACTIONS:  
 2 3598 X = 587.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 108 NUMBER OF POINTS: 425 max.ph.: 2257  
 LEVEL: 1 SQUARE: ( 11 , 14 ) LINE 43 REACTION 43: OPEN END  
 REACTION: 102 30 = 37  
 position: 6.51465E+02 9.23750E+03 6.51562E+02 9.23750E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP BIO (2)CIAMg OPX6 q = FSP BIO CIAMg OPX6 q  
 35 3633 Y = 9237.5000 , 6 REACTIONS: 102 102 43 95 95 95  
 14 3647 X = 662.5000 , 2 REACTIONS: 95 51  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 433 max.ph.: 2289  
 LEVEL: 1 SQUARE: ( 12 , 14 ) LINE 44 REACTION 44: OPEN END  
 10 3657 Y = 9237.5000 , 1 REACTIONS: 52  
 22 3679 X = 687.5000 , 3 REACTIONS: 44 95 52  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 437 max.ph.: 3419  
 LEVEL: 1 SQUARE: ( 14 , 12 ) LINE 45 REACTION 45: OPEN END  
 17 3696 Y = 8387.5000 , 2 REACTIONS: 82 92  
 9 3705 X = 737.5000 , 1 REACTIONS: 82  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 440 max.ph.: 2182  
 LEVEL: 1 SQUARE: ( 18 , 17 ) LINE 46 REACTION 46: OPEN END  
 10 3715 Y = 10512.5000 , 1 REACTIONS: 87  
 20 3735 X = 837.5000 , 3 REACTIONS: 46 60 86  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 444 max.ph.: 2168  
 LEVEL: 1 SQUARE: ( 19 , 18 ) LINE 47 REACTION 47: OPEN END  
 10 3745 Y = 10937.5000 , 1 REACTIONS: 68  
 9 3754 X = 862.5000 , 1 REACTIONS: 87  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 446 max.ph.: 2168  
 LEVEL: 1 SQUARE: ( 4 , 19 ) LINE 48 REACTION 48: OPEN END  
 17 3771 Y = 11362.5000 , 2 REACTIONS: 64 48  
 9 3780 X = 487.5000 , 1 REACTIONS: 64  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 449 max.ph.: 2175  
 LEVEL: 1 SQUARE: ( 9 , 13 ) LINE 50 REACTION 42: OPEN END

10 3790 Y = 8812.5000 , 1 REACTIONS: 42  
 2 3792 X = 612.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 450 max.ph.: 2150  
 LEVEL: 1 SQUARE: ( 9 , 15 ) LINE 50 REACTION 42: OPEN END  
 10 3802 Y = 9662.5000 , 1 REACTIONS: 81  
 9 3811 X = 612.5000 , 1 REACTIONS: 81  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 452 max.ph.: 2139  
 LEVEL: 1 SQUARE: ( 10 , 15 ) LINE 51 REACTION 50: OPEN END  
 10 3821 Y = 9662.5000 , 2 REACTIONS: 57 58  
 21 3842 X = 637.5000 , 3 REACTIONS: 50 58 57  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 457 max.ph.: 2353  
 LEVEL: 1 SQUARE: ( 12 , 15 ) LINE 52 REACTION 51: OPEN END  
 10 3852 Y = 9662.5000 , 1 REACTIONS: 59  
 16 3868 X = 687.5000 , 2 REACTIONS: 60 59  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 460 max.ph.: 2131  
 LEVEL: 1 SQUARE: ( 1 , 19 ) LINE 54 REACTION 53: OPEN END  
 10 3878 Y = 11362.5000 , 1 REACTIONS: 61  
 2 3880 X = 412.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 109 NUMBER OF POINTS: 461 max.ph.: 2200  
 LEVEL: 1 SQUARE: ( 1 , 16 ) LINE 56 REACTION 55: OPEN END  
 22 3902 Y = 10087.5000 , 3 REACTIONS: 53 54 55  
 15 3917 X = 412.5000 , 2 REACTIONS: 55 54  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 466 max.ph.: 2213  
 LEVEL: 1 SQUARE: ( 11 , 17 ) LINE 58 REACTION 56: OPEN END  
 10 3927 Y = 10512.5000 , 1 REACTIONS: 65  
 REACTION: 103 42 = 46  
 position: 6.62500E+02 1.03797E+04 6.62500E+02 1.03813E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO ClAMg OPX6 q = GRT BIO ClAMg q  
 9 3936 X = 662.5000 , 1 REACTIONS: 103  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 468 max.ph.: 3260  
 LEVEL: 1 SQUARE: ( 13 , 17 ) LINE 61 REACTION 59: OPEN END  
 10 3946 Y = 10512.5000 , 1 REACTIONS: 99  
 9 3955 X = 712.5000 , 1 REACTIONS: 86  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 470 max.ph.: 2189  
 LEVEL: 1 SQUARE: ( 1 , 17 ) LINE 64 REACTION 62: OPEN END  
 16 3971 Y = 10512.5000 , 2 REACTIONS: 62 53  
 9 3980 X = 412.5000 , 1 REACTIONS: 53  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 473 max.ph.: 2157  
 LEVEL: 1 SQUARE: ( 2 , 19 ) LINE 65 REACTION 63: BUMP  
 12 3992 Y = 11362.5000 , 2 REACTIONS: 97 72  
 2 3994 X = 437.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 475 max.ph.: 4161  
 LEVEL: 1 SQUARE: ( 3 , 18 ) LINE 65 REACTION 63: BUMP  
 10 4004 Y = 10937.5000 , 1 REACTIONS: 64  
 9 4013 X = 462.5000 , 1 REACTIONS: 64  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 477 max.ph.: 3245  
 LEVEL: 1 SQUARE: ( 4 , 20 ) LINE 65 REACTION 63: BUMP  
 10 4023 Y = 11787.5000 , 1 REACTIONS: 63  
 9 4032 X = 487.5000 , 1 REACTIONS: 63  
 NUMBER OF LINES: 112 NUMBER OF POINTS: 479 max.ph.: 2170  
 LEVEL: 1 SQUARE: ( 5 , 20 ) LINE 65 REACTION 63: OPEN END

17 4049 Y = 11787.5000 , 2 REACTIONS: 63 73  
 9 4058 X = 512.5000 , 1 REACTIONS: 73  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 482 max.ph.: 2191  
 LEVEL: 1 SQUARE: ( 13 , 18 ) LINE 68 REACTION 66: OPEN END  
 12 4070 Y = 10937.5000 , 2 REACTIONS: 84 99  
 9 4079 X = 712.5000 , 1 REACTIONS: 67  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 485 max.ph.: 3189  
 LEVEL: 1 SQUARE: ( 1 , 11 ) LINE 76 REACTION 74: OPEN END  
 3 4082 Y = 7962.5000 , 0 REACTIONS:  
 2 4084 X = 412.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 485 max.ph.: 2046  
 LEVEL: 1 SQUARE: ( 12 , 17 ) LINE 85 REACTION 83: TWO POINTS  
 10 4094 Y = 10512.5000 , 1 REACTIONS: 84  
 16 4110 X = 687.5000 , 2 REACTIONS: 83 84  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 488 max.ph.: 2199  
 LEVEL: 1 SQUARE: ( 15 , 5 ) LINE 87 REACTION 85: BUMP  
 10 4120 Y = 5412.5000 , 1 REACTIONS: 85  
 9 4129 X = 762.5000 , 1 REACTIONS: 85  
 NUMBER OF LINES: 110 NUMBER OF POINTS: 490 max.ph.: 1992  
 LEVEL: 1 SQUARE: ( 20 , 18 ) LINE 95 REACTION 93: TWO POINTS  
 10 4139 Y = 10937.5000 , 1 REACTIONS: 69  
 9 4148 X = 887.5000 , 1 REACTIONS: 69  
 NUMBER OF LINES: 111 NUMBER OF POINTS: 492 max.ph.: 2136  
 LEVEL: 2 SQUARE: ( 2 , 1 ) LINE 1 REACTION 1: OPEN END  
 9 4157 Y = 3606.2500 , 1 REACTIONS: 1  
 ASSEMBLAGE: 58: x,y = 4.18750000E+02 3.50996094E+03 FSP BIO (3)ClAMg  
 OPX6 ab q  
 assemblage: FSP\_abh BIO\_phl ClAMg\_tr ClAMg\_parg ClAMg\_bcam OPX6\_fm ab q  
 REACTION: 104 8 = 58  
 position: 4.18750E+02 3.50830E+03 4.18750E+02 3.50996E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (3)ClAMg ab q = FSP BIO (3)ClAMg OPX6 ab q  
 REACTION: 105 58 = 1  
 position: 4.18750E+02 3.50996E+03 4.18750E+02 3.51162E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (3)ClAMg OPX6 ab q = BIO (3)ClAMg OPX6 ab q  
 9 4166 X = 418.7500 , 2 REACTIONS: 104 105  
 NUMBER OF LINES: 113 NUMBER OF POINTS: 495 max.ph.: 2186  
 LEVEL: 2 SQUARE: ( 3 , 1 ) LINE 2 REACTION 2: OPEN END  
 9 4175 Y = 3606.2500 , 1 REACTIONS: 2  
 2 4177 X = 431.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 114 NUMBER OF POINTS: 496 max.ph.: 2084  
 LEVEL: 2 SQUARE: ( 11 , 5 ) LINE 3 REACTION 3: OPEN END  
 9 4186 Y = 4456.2500 , 2 REACTIONS: 3 4  
 2 4188 X = 531.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 113 NUMBER OF POINTS: 498 max.ph.: 2147  
 LEVEL: 2 SQUARE: ( 15 , 8 ) LINE 5 REACTION 5: OPEN END  
 REACTION: 106 3 = 4  
 position: 5.85352E+02 5.09375E+03 5.85449E+02 5.09375E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg CHLR q = FSP BIO (2)ClAMg q H2O  
 10 4198 Y = 5093.7500 , 2 REACTIONS: 78 106

8 4206 X = 581.2500 , 1 REACTIONS: 78  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 501 max.ph.: 2186  
 LEVEL: 2 SQUARE: ( 28 , 9 ) LINE 7 REACTION 7: OPEN END  
 14 4220 Y = 5306.2500 , 2 REACTIONS: 7 20  
 14 4234 X = 743.7500 , 2 REACTIONS: 7 28  
 NUMBER OF LINES: 114 NUMBER OF POINTS: 505 max.ph.: 1947  
 LEVEL: 2 SQUARE: ( 30 , 5 ) LINE 8 REACTION 8: OPEN END  
 11 4245 Y = 4456.2500 , 2 REACTIONS: 20 21  
 8 4253 X = 768.7500 , 1 REACTIONS: 20  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 508 max.ph.: 2082  
 LEVEL: 2 SQUARE: ( 31 , 3 ) LINE 9 REACTION 9: OPEN END  
 11 4264 Y = 4031.2500 , 2 REACTIONS: 15 16  
 2 4266 X = 781.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 114 NUMBER OF POINTS: 510 max.ph.: 2027  
 LEVEL: 2 SQUARE: ( 38 , 13 ) LINE 11 REACTION 11: OPEN END  
 10 4276 Y = 6156.2500 , 2 REACTIONS: 34 35  
 13 4289 X = 868.7500 , 2 REACTIONS: 11 24  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 514 max.ph.: 2085  
 LEVEL: 2 SQUARE: ( 2 , 11 ) LINE 12 REACTION 12: OPEN END  
 9 4298 Y = 5731.2500 , 1 REACTIONS: 25  
 8 4306 X = 418.7500 , 1 REACTIONS: 25  
 NUMBER OF LINES: 114 NUMBER OF POINTS: 516 max.ph.: 2086  
 LEVEL: 2 SQUARE: ( 15 , 23 ) LINE 13 REACTION 13: OPEN END  
 3 4309 Y = 8281.2500 , 0 REACTIONS:  
 2 4311 X = 581.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 516 max.ph.: 2140  
 LEVEL: 2 SQUARE: ( 11 , 15 ) LINE 14 REACTION 14: OPEN END  
 3 4314 Y = 6581.2500 , 0 REACTIONS:  
 2 4316 X = 531.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 114 NUMBER OF POINTS: 516 max.ph.: 2179  
 LEVEL: 2 SQUARE: ( 32 , 6 ) LINE 16 REACTION 16: OPEN END  
 9 4325 Y = 4668.7500 , 1 REACTIONS: 16  
 2 4327 X = 793.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 517 max.ph.: 2013  
 LEVEL: 2 SQUARE: ( 26 , 20 ) LINE 19 REACTION 19: OPEN END  
 15 4342 Y = 7643.7500 , 2 REACTIONS: 19 28  
 8 4350 X = 718.7500 , 1 REACTIONS: 19  
 NUMBER OF LINES: 114 NUMBER OF POINTS: 520 max.ph.: 3023  
 LEVEL: 2 SQUARE: ( 32 , 11 ) LINE 21 REACTION 21: OPEN END  
 17 4367 Y = 5731.2500 , 3 REACTIONS: 21 22 23  
 2 4369 X = 793.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 523 max.ph.: 1959  
 LEVEL: 2 SQUARE: ( 32 , 7 ) LINE 22 REACTION 22: OPEN END  
 16 4385 Y = 4881.2500 , 3 REACTIONS: 22 23 24  
 8 4393 X = 793.7500 , 1 REACTIONS: 24  
 NUMBER OF LINES: 114 NUMBER OF POINTS: 527 max.ph.: 2008  
 LEVEL: 2 SQUARE: ( 32 , 18 ) LINE 23 REACTION 23: OPEN END  
 14 4407 Y = 7218.7500 , 2 REACTIONS: 29 23  
 2 4409 X = 793.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 529 max.ph.: 2063  
 LEVEL: 2 SQUARE: ( 4 , 14 ) LINE 25 REACTION 25: OPEN END  
 12 4421 Y = 6368.7500 , 2 REACTIONS: 30 31

8 4429 X = 443.7500 , 1 REACTIONS: 31  
 NUMBER OF LINES: 114 NUMBER OF POINTS: 532 max.ph.: 2112  
 LEVEL: 2 SQUARE: ( 26 , 12 ) LINE 28 REACTION 28: BUMP  
 9 4438 Y = 5943.7500 , 1 REACTIONS: 28  
 8 4446 X = 718.7500 , 1 REACTIONS: 28  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 534 max.ph.: 1986  
 LEVEL: 2 SQUARE: ( 7 , 27 ) LINE 30 REACTION 30: OPEN END  
 9 4455 Y = 9131.2500 , 1 REACTIONS: 48  
 8 4463 X = 481.2500 , 1 REACTIONS: 41  
 NUMBER OF LINES: 114 NUMBER OF POINTS: 536 max.ph.: 2922  
 LEVEL: 2 SQUARE: ( 16 , 30 ) LINE 31 REACTION 31: OPEN END  
 15 4478 Y = 9768.7500 , 2 REACTIONS: 49 31  
 8 4486 X = 593.7500 , 1 REACTIONS: 49  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 539 max.ph.: 2180  
 LEVEL: 2 SQUARE: ( 12 , 15 ) LINE 32 REACTION 32: OPEN END  
 18 4504 Y = 6581.2500 , 3 REACTIONS: 13 32 33  
 8 4512 X = 543.7500 , 1 REACTIONS: 33  
 NUMBER OF LINES: 114 NUMBER OF POINTS: 543 max.ph.: 2122  
 LEVEL: 2 SQUARE: ( 16 , 23 ) LINE 32 REACTION 32: OPEN END  
 11 4523 Y = 8281.2500 , 2 REACTIONS: 42 43  
 8 4531 X = 593.7500 , 1 REACTIONS: 43  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 546 max.ph.: 2077  
 LEVEL: 2 SQUARE: ( 21 , 21 ) LINE 33 REACTION 33: OPEN END  
 9 4540 Y = 7856.2500 , 1 REACTIONS: 33  
 15 4555 X = 656.2500 , 3 REACTIONS: 36 82 44  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 550 max.ph.: 3304  
 LEVEL: 2 SQUARE: ( 28 , 22 ) LINE 37 REACTION 37: OPEN END  
 14 4569 Y = 8068.7500 , 2 REACTIONS: 37 38  
 8 4577 X = 743.7500 , 1 REACTIONS: 37  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 553 max.ph.: 3223  
 LEVEL: 2 SQUARE: ( 32 , 20 ) LINE 38 REACTION 38: OPEN END  
 9 4586 Y = 7643.7500 , 1 REACTIONS: 39  
 8 4594 X = 793.7500 , 1 REACTIONS: 39  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 555 max.ph.: 2116  
 LEVEL: 2 SQUARE: ( 39 , 34 ) LINE 39 REACTION 39: OPEN END  
 9 4603 Y = 10618.7500 , 1 REACTIONS: 39  
 8 4611 X = 881.2500 , 1 REACTIONS: 39  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 557 max.ph.: 2107  
 LEVEL: 2 SQUARE: ( 2 , 23 ) LINE 40 REACTION 40: OPEN END  
 3 4614 Y = 8281.2500 , 0 REACTIONS:  
 8 4622 X = 418.7500 , 1 REACTIONS: 41  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 558 max.ph.: 2075  
 LEVEL: 2 SQUARE: ( 3 , 33 ) LINE 40 REACTION 40: OPEN END  
 19 4641 Y = 10406.2500 , 5 REACTIONS: 54 54 54 54 64  
 8 4649 X = 431.2500 , 1 REACTIONS: 64  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 564 max.ph.: 3095  
 LEVEL: 2 SQUARE: ( 2 , 30 ) LINE 40 REACTION 40: BUMP  
 9 4658 Y = 9768.7500 , 1 REACTIONS: 40  
 2 4660 X = 418.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 565 max.ph.: 2124  
 LEVEL: 2 SQUARE: ( 16 , 24 ) LINE 42 REACTION 42: OPEN END  
 9 4669 Y = 8493.7500 , 1 REACTIONS: 42

8 4677 X = 593.7500 , 1 REACTIONS: 42  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 567 max.ph.: 2221  
 LEVEL: 2 SQUARE: ( 16 , 25 ) LINE 42 REACTION 42: OPEN END  
 3 4680 Y = 8706.2500 , 0 REACTIONS:  
 2 4682 X = 593.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 567 max.ph.: 2228  
 LEVEL: 2 SQUARE: ( 21 , 28 ) LINE 43 REACTION 43: OPEN END  
 9 4691 Y = 9343.7500 , 1 REACTIONS: 50  
 14 4705 X = 656.2500 , 3 REACTIONS: 95 95 51  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 571 max.ph.: 2167  
 LEVEL: 2 SQUARE: ( 24 , 27 ) LINE 44 REACTION 44: OPEN END  
 14 4719 Y = 9131.2500 , 2 REACTIONS: 44 45  
 8 4727 X = 693.7500 , 1 REACTIONS: 45  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 574 max.ph.: 3261  
 LEVEL: 2 SQUARE: ( 28 , 24 ) LINE 45 REACTION 45: OPEN END  
 14 4741 Y = 8493.7500 , 2 REACTIONS: 45 46  
 14 4755 X = 743.7500 , 2 REACTIONS: 82 45  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 578 max.ph.: 2179  
 LEVEL: 2 SQUARE: ( 36 , 33 ) LINE 46 REACTION 46: OPEN END  
 14 4769 Y = 10406.2500 , 2 REACTIONS: 60 46  
 8 4777 X = 843.7500 , 1 REACTIONS: 87  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 581 max.ph.: 2180  
 LEVEL: 2 SQUARE: ( 38 , 35 ) LINE 47 REACTION 47: OPEN END  
 15 4792 Y = 10831.2500 , 2 REACTIONS: 87 47  
 14 4806 X = 868.7500 , 2 REACTIONS: 47 87  
 NUMBER OF LINES: 115 NUMBER OF POINTS: 585 max.ph.: 3246  
 LEVEL: 2 SQUARE: ( 8 , 38 ) LINE 48 REACTION 48: OPEN END  
 15 4821 Y = 11468.7500 , 2 REACTIONS: 64 48  
 REACTION: 107 41 = 35  
 position: 4.93750E+02 1.15202E+04 4.93750E+02 1.15219E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (3)CIAMg CHLR q = GRT BIO (2)CIAMg q  
 15 4836 X = 493.7500 , 3 REACTIONS: 64 107 107  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 590 max.ph.: 2196  
 LEVEL: 2 SQUARE: ( 17 , 25 ) LINE 50 REACTION 42: OPEN END  
 9 4845 Y = 8706.2500 , 1 REACTIONS: 42  
 2 4847 X = 606.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 591 max.ph.: 2159  
 LEVEL: 2 SQUARE: ( 18 , 29 ) LINE 50 REACTION 42: OPEN END  
 9 4856 Y = 9556.2500 , 1 REACTIONS: 42  
 8 4864 X = 618.7500 , 1 REACTIONS: 81  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 593 max.ph.: 2235  
 LEVEL: 2 SQUARE: ( 19 , 29 ) LINE 51 REACTION 50: OPEN END  
 3 4867 Y = 9556.2500 , 0 REACTIONS:  
 8 4875 X = 631.2500 , 1 REACTIONS: 96  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 594 max.ph.: 2103  
 LEVEL: 2 SQUARE: ( 23 , 29 ) LINE 52 REACTION 51: OPEN END  
 9 4884 Y = 9556.2500 , 1 REACTIONS: 59  
 8 4892 X = 681.2500 , 1 REACTIONS: 51  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 596 max.ph.: 2178  
 LEVEL: 2 SQUARE: ( 2 , 37 ) LINE 54 REACTION 53: OPEN END  
 17 4909 Y = 11256.2500 , 3 REACTIONS: 61 62 53



8 4917 X = 418.7500 , 1 REACTIONS: 61  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 600 max.ph.: 2145  
 LEVEL: 2 SQUARE: ( 2 , 33 ) LINE 55 REACTION 54: BUMP  
 3 4920 Y = 10406.2500 , 0 REACTIONS:  
 2 4922 X = 418.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 600 max.ph.: 3089  
 LEVEL: 2 SQUARE: ( 2 , 32 ) LINE 56 REACTION 55: OPEN END  
 15 4937 Y = 10193.7500 , 2 REACTIONS: 54 55  
 14 4951 X = 418.7500 , 2 REACTIONS: 55 54  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 604 max.ph.: 2184  
 LEVEL: 2 SQUARE: ( 3 , 32 ) LINE 57 REACTION 55: OPEN END  
 9 4960 Y = 10193.7500 , 1 REACTIONS: 40  
 2 4962 X = 431.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 605 max.ph.: 3207  
 LEVEL: 2 SQUARE: ( 21 , 33 ) LINE 58 REACTION 56: OPEN END  
 9 4971 Y = 10406.2500 , 1 REACTIONS: 65  
 8 4979 X = 656.2500 , 1 REACTIONS: 103  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 607 max.ph.: 2215  
 LEVEL: 2 SQUARE: ( 22 , 33 ) LINE 60 REACTION 58: OPEN END  
 15 4994 Y = 10406.2500 , 2 REACTIONS: 103 58  
 14 5008 X = 668.7500 , 2 REACTIONS: 58 103  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 611 max.ph.: 2309  
 LEVEL: 2 SQUARE: ( 25 , 33 ) LINE 61 REACTION 59: OPEN END  
 9 5017 Y = 10406.2500 , 1 REACTIONS: 59  
 8 5025 X = 706.2500 , 1 REACTIONS: 86  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 613 max.ph.: 3179  
 LEVEL: 2 SQUARE: ( 1 , 33 ) LINE 64 REACTION 62: OPEN END  
 9 5034 Y = 10406.2500 , 1 REACTIONS: 53  
 2 5036 X = 406.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 614 max.ph.: 2160  
 LEVEL: 2 SQUARE: ( 4 , 37 ) LINE 65 REACTION 63: BUMP  
 9 5045 Y = 11256.2500 , 1 REACTIONS: 63  
 2 5047 X = 443.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 615 max.ph.: 2194  
 LEVEL: 1 SQUARE: ( 2 , 18 ) LINE 65 REACTION 63: BUMP  
 3 5050 Y = 10937.5000 , 0 REACTIONS:  
 2 5052 X = 437.5000 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 615 max.ph.: 2131  
 LEVEL: 2 SQUARE: ( 4 , 36 ) LINE 65 REACTION 63: BUMP  
 9 5061 Y = 11043.7500 , 1 REACTIONS: 63  
 2 5063 X = 443.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 616 max.ph.: 2218  
 LEVEL: 2 SQUARE: ( 5 , 36 ) LINE 65 REACTION 63: BUMP  
 9 5072 Y = 11043.7500 , 1 REACTIONS: 63  
 8 5080 X = 456.2500 , 1 REACTIONS: 63  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 618 max.ph.: 2147  
 LEVEL: 2 SQUARE: ( 8 , 39 ) LINE 65 REACTION 63: BUMP  
 9 5089 Y = 11681.2500 , 1 REACTIONS: 63  
 8 5097 X = 493.7500 , 1 REACTIONS: 63  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 620 max.ph.: 2173  
 LEVEL: 2 SQUARE: ( 8 , 40 ) LINE 65 REACTION 63: BUMP  
 3 5100 Y = 11893.7500 , 0 REACTIONS:

2 5102 X = 493.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 620 max.ph.: 2201  
 LEVEL: 2 SQUARE: ( 9 , 39 ) LINE 65 REACTION 63: BUMP  
 15 5117 Y = 11681.2500 , 2 REACTIONS: 63 73  
 8 5125 X = 506.2500 , 1 REACTIONS: 73  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 623 max.ph.: 2087  
 LEVEL: 2 SQUARE: ( 25 , 36 ) LINE 68 REACTION 66: OPEN END  
 9 5134 Y = 11043.7500 , 1 REACTIONS: 66  
 2 5136 X = 706.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 624 max.ph.: 2101  
 LEVEL: 2 SQUARE: ( 3 , 38 ) LINE 72 REACTION 70: OPEN END  
 16 5152 Y = 11468.7500 , 3 REACTIONS: 70 71 72  
 17 5169 X = 431.2500 , 3 REACTIONS: 72 71 70  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 630 max.ph.: 2146  
 LEVEL: 1 SQUARE: ( 2 , 20 ) LINE 72 REACTION 70: BUMP  
 26 5195 Y = 11787.5000 , 4 REACTIONS: 61 70 71 72  
 22 5217 X = 437.5000 , 3 REACTIONS: 72 71 70  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 637 max.ph.: 2165  
 LEVEL: 2 SQUARE: ( 3 , 39 ) LINE 72 REACTION 70: BUMP  
 20 5237 Y = 11681.2500 , 3 REACTIONS: 61 70 71  
 2 5239 X = 431.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 640 max.ph.: 2197  
 LEVEL: 2 SQUARE: ( 1 , 22 ) LINE 76 REACTION 74: OPEN END  
 10 5249 Y = 8068.7500 , 2 REACTIONS: 75 74  
 2 5251 X = 406.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 642 max.ph.: 2044  
 LEVEL: 2 SQUARE: ( 32 , 19 ) LINE 93 REACTION 91: OPEN END  
 11 5262 Y = 7431.2500 , 2 REACTIONS: 29 23  
 2 5264 X = 793.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 644 max.ph.: 3141  
 LEVEL: 2 SQUARE: ( 28 , 23 ) LINE 94 REACTION 92: TWO POINTS  
 9 5273 Y = 8281.2500 , 1 REACTIONS: 92  
 2 5275 X = 743.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 645 max.ph.: 3097  
 LEVEL: 2 SQUARE: ( 39 , 35 ) LINE 95 REACTION 93: TWO POINTS  
 9 5284 Y = 10831.2500 , 1 REACTIONS: 93  
 8 5292 X = 881.2500 , 1 REACTIONS: 93  
 NUMBER OF LINES: 116 NUMBER OF POINTS: 647 max.ph.: 3047  
 LEVEL: 2 SQUARE: ( 1 , 23 ) LINE 96 REACTION 94: TWO POINTS  
 18 5310 Y = 8281.2500 , 5 REACTIONS: 40 40 40 40 94  
 8 5318 X = 406.2500 , 1 REACTIONS: 94  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 653 max.ph.: 2098  
 LEVEL: 2 SQUARE: ( 22 , 28 ) LINE 97 REACTION 95: BUMP  
 9 5327 Y = 9343.7500 , 1 REACTIONS: 51  
 14 5341 X = 668.7500 , 2 REACTIONS: 95 51  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 656 max.ph.: 2160  
 LEVEL: 2 SQUARE: ( 3 , 37 ) LINE 99 REACTION 97: TWO POINTS  
 3 5344 Y = 11256.2500 , 0 REACTIONS:  
 2 5346 X = 431.2500 , 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 656 max.ph.: 2164  
 LEVEL: 3 SQUARE: ( 3 , 1 ) LINE 1 REACTION 1: OPEN END  
 3 5349 Y = 3553.1250 , 0 REACTIONS:

2 5351 X = 415.6250, 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 656 max.ph.: 2175  
 LEVEL: 3 SQUARE: ( 5, 2 ) LINE 2 REACTION 2: OPEN END  
 14 5365 Y = 3659.3750, 3 REACTIONS: 13 89 2  
 15 5380 X = 428.1250, 3 REACTIONS: 2 14 13  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 662 max.ph.: 2137  
 LEVEL: 3 SQUARE: ( 22, 10 ) LINE 3 REACTION 3: OPEN END  
 8 5388 Y = 4509.3750, 1 REACTIONS: 18  
 2 5390 X = 534.3750, 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 663 max.ph.: 2073  
 LEVEL: 3 SQUARE: ( 30, 15 ) LINE 5 REACTION 5: OPEN END  
 8 5398 Y = 5040.6250, 2 REACTIONS: 5 6  
 7 5405 X = 584.3750, 1 REACTIONS: 78  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 666 max.ph.: 2080  
 LEVEL: 3 SQUARE: ( 56, 18 ) LINE 7 REACTION 7: OPEN END  
 8 5413 Y = 5359.3750, 1 REACTIONS: 28  
 10 5423 X = 746.8750, 2 REACTIONS: 7 28  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 669 max.ph.: 3006  
 LEVEL: 3 SQUARE: ( 60, 9 ) LINE 8 REACTION 8: OPEN END  
 13 5436 Y = 4403.1250, 2 REACTIONS: 8 15  
 7 5443 X = 771.8750, 1 REACTIONS: 15  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 672 max.ph.: 2082  
 LEVEL: 3 SQUARE: ( 61, 5 ) LINE 9 REACTION 9: OPEN END  
 13 5456 Y = 3978.1250, 2 REACTIONS: 9 10  
 7 5463 X = 778.1250, 1 REACTIONS: 10  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 675 max.ph.: 2066  
 LEVEL: 3 SQUARE: ( 76, 25 ) LINE 11 REACTION 11: OPEN END  
 8 5471 Y = 6103.1250, 1 REACTIONS: 11  
 2 5473 X = 871.8750, 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 676 max.ph.: 3112  
 LEVEL: 3 SQUARE: ( 4, 2 ) LINE 12 REACTION 12: OPEN END  
 8 5481 Y = 3659.3750, 1 REACTIONS: 12  
 2 5483 X = 421.8750, 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 677 max.ph.: 2162  
 LEVEL: 3 SQUARE: ( 4, 21 ) LINE 12 REACTION 12: OPEN END  
 8 5491 Y = 5678.1250, 1 REACTIONS: 26  
 2 5493 X = 421.8750, 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 678 max.ph.: 2087  
 LEVEL: 3 SQUARE: ( 30, 45 ) LINE 13 REACTION 13: OPEN END  
 3 5496 Y = 8228.1250, 0 REACTIONS:  
 2 5498 X = 584.3750, 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 678 max.ph.: 2234  
 LEVEL: 3 SQUARE: ( 22, 29 ) LINE 14 REACTION 14: OPEN END  
 8 5506 Y = 6528.1250, 1 REACTIONS: 13  
 2 5508 X = 534.3750, 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 679 max.ph.: 2239  
 LEVEL: 3 SQUARE: ( 63, 12 ) LINE 16 REACTION 16: OPEN END  
 8 5516 Y = 4721.8750, 1 REACTIONS: 16  
 2 5518 X = 790.6250, 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 680 max.ph.: 2029  
 LEVEL: 3 SQUARE: ( 30, 16 ) LINE 19 REACTION 19: OPEN END  
 3 5521 Y = 5146.8750, 0 REACTIONS:

2 5523 X = 584.3750 , 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 680 max.ph.: 2199  
 LEVEL: 3 SQUARE: ( 52 , 40 ) LINE 19 REACTION 19: OPEN END  
 12 5535 Y = 7696.8750 , 2 REACTIONS: 19 28  
 7 5542 X = 721.8750 , 1 REACTIONS: 37  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 683 max.ph.: 2143  
 LEVEL: 3 SQUARE: ( 63 , 22 ) LINE 21 REACTION 21: OPEN END  
 12 5554 Y = 5784.3750 , 2 REACTIONS: 29 23  
 12 5566 X = 790.6250 , 2 REACTIONS: 23 23  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 687 max.ph.: 2028  
 LEVEL: 3 SQUARE: ( 63 , 13 ) LINE 22 REACTION 22: OPEN END  
 16 5582 Y = 4828.1250 , 3 REACTIONS: 22 23 24  
 7 5589 X = 790.6250 , 1 REACTIONS: 24  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 691 max.ph.: 2892  
 LEVEL: 3 SQUARE: ( 63 , 36 ) LINE 23 REACTION 23: OPEN END  
 10 5599 Y = 7271.8750 , 2 REACTIONS: 29 23  
 7 5606 X = 790.6250 , 1 REACTIONS: 23  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 694 max.ph.: 3046  
 LEVEL: 3 SQUARE: ( 63 , 21 ) LINE 23 REACTION 23: BUMP  
 17 5623 Y = 5678.1250 , 3 REACTIONS: 21 22 23  
 2 5625 X = 790.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 697 max.ph.: 2083  
 LEVEL: 2 SQUARE: ( 32 , 12 ) LINE 23 REACTION 23: BUMP  
 14 5639 Y = 5943.7500 , 2 REACTIONS: 29 23  
 2 5641 X = 793.7500 , 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 699 max.ph.: 2026  
 LEVEL: 3 SQUARE: ( 63 , 23 ) LINE 23 REACTION 23: BUMP  
 13 5654 Y = 5890.6250 , 2 REACTIONS: 29 23  
 2 5656 X = 790.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 701 max.ph.: 3040  
 LEVEL: 3 SQUARE: ( 7 , 27 ) LINE 25 REACTION 25: OPEN END  
 11 5667 Y = 6315.6250 , 2 REACTIONS: 25 26  
 11 5678 X = 440.6250 , 2 REACTIONS: 26 25  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 705 max.ph.: 4061  
 LEVEL: 3 SQUARE: ( 14 , 53 ) LINE 30 REACTION 30: OPEN END  
 10 5688 Y = 9078.1250 , 2 REACTIONS: 48 49  
 10 5698 X = 484.3750 , 2 REACTIONS: 30 41  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 709 max.ph.: 2135  
 LEVEL: 3 SQUARE: ( 32 , 60 ) LINE 31 REACTION 31: OPEN END  
 3 5701 Y = 9821.8750 , 0 REACTIONS:  
 7 5708 X = 596.8750 , 1 REACTIONS: 49  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 710 max.ph.: 2195  
 LEVEL: 3 SQUARE: ( 23 , 29 ) LINE 32 REACTION 32: OPEN END  
 11 5719 Y = 6528.1250 , 2 REACTIONS: 32 33  
 7 5726 X = 540.6250 , 1 REACTIONS: 33  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 713 max.ph.: 2164  
 LEVEL: 3 SQUARE: ( 31 , 45 ) LINE 32 REACTION 32: OPEN END  
 10 5736 Y = 8228.1250 , 2 REACTIONS: 100 32  
 2 5738 X = 590.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 715 max.ph.: 2155  
 LEVEL: 3 SQUARE: ( 41 , 42 ) LINE 33 REACTION 33: OPEN END  
 8 5746 Y = 7909.3750 , 1 REACTIONS: 44

7 5753 X = 653.1250 , 1 REACTIONS: 33  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 717 max.ph.: 2218  
 LEVEL: 3 SQUARE: ( 56 , 44 ) LINE 37 REACTION 37: OPEN END  
 12 5765 Y = 8121.8750 , 2 REACTIONS: 92 47  
 7 5772 X = 746.8750 , 1 REACTIONS: 37  
 NUMBER OF LINES: 117 NUMBER OF POINTS: 720 max.ph.: 2128  
 LEVEL: 3 SQUARE: ( 63 , 39 ) LINE 38 REACTION 38: OPEN END  
 8 5780 Y = 7590.6250 , 1 REACTIONS: 91  
 7 5787 X = 790.6250 , 1 REACTIONS: 39  
 NUMBER OF LINES: 118 NUMBER OF POINTS: 722 max.ph.: 2093  
 LEVEL: 3 SQUARE: ( 78 , 68 ) LINE 39 REACTION 39: OPEN END  
 13 5800 Y = 10671.8750 , 2 REACTIONS: 39 88  
 11 5811 X = 884.3750 , 2 REACTIONS: 88 69  
 NUMBER OF LINES: 118 NUMBER OF POINTS: 726 max.ph.: 2122  
 LEVEL: 3 SQUARE: ( 3 , 46 ) LINE 40 REACTION 40: OPEN END  
 12 5823 Y = 8334.3750 , 2 REACTIONS: 40 41  
 7 5830 X = 415.6250 , 1 REACTIONS: 41  
 NUMBER OF LINES: 118 NUMBER OF POINTS: 729 max.ph.: 2005  
 LEVEL: 3 SQUARE: ( 5 , 65 ) LINE 40 REACTION 40: OPEN END  
 16 5846 Y = 10353.1250 , 3 REACTIONS: 98 40 40  
 15 5861 X = 428.1250 , 3 REACTIONS: 40 40 98  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 735 max.ph.: 2141  
 LEVEL: 3 SQUARE: ( 31 , 47 ) LINE 42 REACTION 42: OPEN END  
 3 5864 Y = 8440.6250 , 0 REACTIONS:  
 2 5866 X = 590.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 735 max.ph.: 2100  
 LEVEL: 3 SQUARE: ( 32 , 49 ) LINE 42 REACTION 42: OPEN END  
 8 5874 Y = 8653.1250 , 1 REACTIONS: 42  
 2 5876 X = 596.8750 , 0 REACTIONS:  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 736 max.ph.: 2105  
 LEVEL: 3 SQUARE: ( 41 , 55 ) LINE 43 REACTION 43: OPEN END  
 8 5884 Y = 9290.6250 , 1 REACTIONS: 50  
 7 5891 X = 653.1250 , 1 REACTIONS: 43  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 738 max.ph.: 3112  
 LEVEL: 3 SQUARE: ( 47 , 54 ) LINE 44 REACTION 44: OPEN END  
 8 5899 Y = 9184.3750 , 1 REACTIONS: 52  
 7 5906 X = 690.6250 , 1 REACTIONS: 45  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 740 max.ph.: 3284  
 LEVEL: 3 SQUARE: ( 56 , 47 ) LINE 45 REACTION 45: OPEN END  
 8 5914 Y = 8440.6250 , 1 REACTIONS: 92  
 11 5925 X = 746.8750 , 2 REACTIONS: 82 45  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 743 max.ph.: 3321  
 LEVEL: 3 SQUARE: ( 71 , 66 ) LINE 46 REACTION 46: OPEN END  
 3 5928 Y = 10459.3750 , 0 REACTIONS:  
 10 5938 X = 840.6250 , 2 REACTIONS: 60 86  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 745 max.ph.: 3310  
 LEVEL: 3 SQUARE: ( 76 , 70 ) LINE 47 REACTION 47: OPEN END  
 11 5949 Y = 10884.3750 , 3 REACTIONS: 87 47 93  
 13 5962 X = 871.8750 , 3 REACTIONS: 47 87 68  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 751 max.ph.: 3168  
 LEVEL: 3 SQUARE: ( 16 , 76 ) LINE 48 REACTION 48: OPEN END  
 3 5965 Y = 11521.8750 , 0 REACTIONS:

7 5972 X = 496.8750 , 1 REACTIONS: 73  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 752 max.ph.: 2191  
 LEVEL: 3 SQUARE: ( 33 , 49 ) LINE 50 REACTION 42: OPEN END  
 3 5975 Y = 8653.1250 , 0 REACTIONS:  
 2 5977 X = 603.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 752 max.ph.: 2104  
 LEVEL: 3 SQUARE: ( 36 , 58 ) LINE 50 REACTION 42: OPEN END  
 8 5985 Y = 9609.3750 , 1 REACTIONS: 81  
 7 5992 X = 621.8750 , 1 REACTIONS: 81  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 754 max.ph.: 2267  
 LEVEL: 3 SQUARE: ( 38 , 58 ) LINE 51 REACTION 50: OPEN END  
 3 5995 Y = 9609.3750 , 0 REACTIONS:  
 7 6002 X = 634.3750 , 1 REACTIONS: 96  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 755 max.ph.: 2148  
 LEVEL: 3 SQUARE: ( 46 , 57 ) LINE 52 REACTION 51: OPEN END  
 13 6015 Y = 9503.1250 , 2 REACTIONS: 59 60  
 16 6031 X = 684.3750 , 3 REACTIONS: 52 60 59  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 760 max.ph.: 2189  
 LEVEL: 3 SQUARE: ( 4 , 74 ) LINE 54 REACTION 53: OPEN END  
 8 6039 Y = 11309.3750 , 1 REACTIONS: 61  
 2 6041 X = 421.8750 , 0 REACTIONS:  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 761 max.ph.: 2183  
 LEVEL: 3 SQUARE: ( 4 , 65 ) LINE 55 REACTION 54: BUMP  
 8 6049 Y = 10353.1250 , 1 REACTIONS: 54  
 7 6056 X = 421.8750 , 1 REACTIONS: 54  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 763 max.ph.: 2170  
 LEVEL: 3 SQUARE: ( 5 , 66 ) LINE 55 REACTION 54: BUMP  
 13 6069 Y = 10459.3750 , 2 REACTIONS: 54 54  
 7 6076 X = 428.1250 , 1 REACTIONS: 54  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 766 max.ph.: 2172  
 LEVEL: 3 SQUARE: ( 4 , 64 ) LINE 56 REACTION 55: OPEN END  
 13 6089 Y = 10246.8750 , 2 REACTIONS: 54 55  
 7 6096 X = 421.8750 , 1 REACTIONS: 55  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 769 max.ph.: 2112  
 LEVEL: 3 SQUARE: ( 5 , 64 ) LINE 57 REACTION 55: OPEN END  
 8 6104 Y = 10246.8750 , 1 REACTIONS: 40  
 2 6106 X = 428.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 770 max.ph.: 2147  
 LEVEL: 3 SQUARE: ( 41 , 65 ) LINE 58 REACTION 56: OPEN END  
 8 6114 Y = 10353.1250 , 1 REACTIONS: 65  
 11 6125 X = 653.1250 , 2 REACTIONS: 57 56  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 773 max.ph.: 2217  
 LEVEL: 3 SQUARE: ( 44 , 66 ) LINE 60 REACTION 58: OPEN END  
 3 6128 Y = 10459.3750 , 0 REACTIONS:  
 7 6135 X = 671.8750 , 1 REACTIONS: 103  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 774 max.ph.: 2306  
 LEVEL: 3 SQUARE: ( 49 , 66 ) LINE 61 REACTION 59: OPEN END  
 8 6143 Y = 10459.3750 , 1 REACTIONS: 99  
 9 6152 X = 703.1250 , 2 REACTIONS: 59 83  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 777 max.ph.: 2153  
 LEVEL: 3 SQUARE: ( 1 , 66 ) LINE 64 REACTION 62: OPEN END  
 8 6160 Y = 10459.3750 , 1 REACTIONS: 62

2 6162 X = 403.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 778 max.ph.: 2203  
 LEVEL: 3 SQUARE: ( 8 , 72 ) LINE 65 REACTION 63: BUMP  
 8 6170 Y = 11096.8750 , 1 REACTIONS: 63  
 7 6177 X = 446.8750 , 1 REACTIONS: 63  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 780 max.ph.: 2099  
 LEVEL: 3 SQUARE: ( 8 , 71 ) LINE 65 REACTION 63: BUMP  
 13 6190 Y = 10990.6250 , 2 REACTIONS: 63 63  
 7 6197 X = 446.8750 , 1 REACTIONS: 63  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 783 max.ph.: 2160  
 LEVEL: 3 SQUARE: ( 16 , 79 ) LINE 65 REACTION 63: BUMP  
 8 6205 Y = 11840.6250 , 1 REACTIONS: 63  
 7 6212 X = 496.8750 , 1 REACTIONS: 63  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 785 max.ph.: 2171  
 LEVEL: 2 SQUARE: ( 9 , 40 ) LINE 65 REACTION 63: BUMP  
 15 6227 Y = 11893.7500 , 2 REACTIONS: 63 63  
 14 6241 X = 506.2500 , 2 REACTIONS: 63 63  
 NUMBER OF LINES: 120 NUMBER OF POINTS: 789 max.ph.: 2122  
 LEVEL: 3 SQUARE: ( 17 , 79 ) LINE 65 REACTION 63: BUMP  
 3 6244 Y = 11840.6250 , 0 REACTIONS:  
 2 6246 X = 503.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 789 max.ph.: 2152  
 LEVEL: 3 SQUARE: ( 17 , 80 ) LINE 65 REACTION 63: BUMP  
 8 6254 Y = 11946.8750 , 1 REACTIONS: 63  
 7 6261 X = 503.1250 , 1 REACTIONS: 63  
 NUMBER OF LINES: 119 NUMBER OF POINTS: 791 max.ph.: 2165  
 LEVEL: 3 SQUARE: ( 18 , 80 ) LINE 65 REACTION 63: BUMP  
 8 6269 Y = 11946.8750 , 1 REACTIONS: 63  
 7 6276 X = 509.3750 , 1 REACTIONS: 63  
 NUMBER OF LINES: 120 NUMBER OF POINTS: 793 max.ph.: 2136  
 LEVEL: 3 SQUARE: ( 50 , 71 ) LINE 69 REACTION 66: OPEN END  
 13 6289 Y = 10990.6250 , 2 REACTIONS: 66 67  
 7 6296 X = 709.3750 , 1 REACTIONS: 67  
 NUMBER OF LINES: 120 NUMBER OF POINTS: 796 max.ph.: 2161  
 LEVEL: 3 SQUARE: ( 5 , 75 ) LINE 73 REACTION 70: OPEN END  
 11 6307 Y = 11415.6250 , 2 REACTIONS: 97 72  
 10 6317 X = 428.1250 , 2 REACTIONS: 72 97  
 NUMBER OF LINES: 120 NUMBER OF POINTS: 800 max.ph.: 2205  
 LEVEL: 3 SQUARE: ( 1 , 44 ) LINE 77 REACTION 74: OPEN END  
 8 6325 Y = 8121.8750 , 2 REACTIONS: 75 74  
 8 6333 X = 403.1250 , 2 REACTIONS: 74 75  
 NUMBER OF LINES: 120 NUMBER OF POINTS: 804 max.ph.: 2030  
 LEVEL: 3 SQUARE: ( 63 , 37 ) LINE 94 REACTION 91: OPEN END  
 10 6343 Y = 7378.1250 , 2 REACTIONS: 29 23  
 2 6345 X = 790.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 120 NUMBER OF POINTS: 806 max.ph.: 2094  
 LEVEL: 3 SQUARE: ( 2 , 45 ) LINE 97 REACTION 94: BUMP  
 21 6366 Y = 8228.1250 , 6 REACTIONS: 94 94 94 94 75 74  
 24 6390 X = 409.3750 , 7 REACTIONS: 74 75 94 94 94 94 40  
 NUMBER OF LINES: 124 NUMBER OF POINTS: 819 max.ph.: 2004  
 LEVEL: 3 SQUARE: ( 42 , 55 ) LINE 99 REACTION 95: BUMP  
 8 6398 Y = 9290.6250 , 1 REACTIONS: 51

12 6410 X = 659.3750 , 2 REACTIONS: 95 51  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 822 max.ph.: 3305  
 LEVEL: 3 SQUARE: ( 2 , 46 ) LINE 98 REACTION 94: TWO POINTS  
 3 6413 Y = 8334.3750 , 0 REACTIONS:  
 7 6420 X = 409.3750 , 1 REACTIONS: 40  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 823 max.ph.: 2061  
 LEVEL: 3 SQUARE: ( 31 , 46 ) LINE 105 REACTION 80: OPEN END  
 8 6428 Y = 8334.3750 , 1 REACTIONS: 42  
 11 6439 X = 590.6250 , 2 REACTIONS: 43 42  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 826 max.ph.: 2099  
 LEVEL: 3 SQUARE: ( 4 , 1 ) LINE 113 REACTION 1: OPEN END  
 8 6447 Y = 3553.1250 , 1 REACTIONS: 1  
 7 6454 X = 421.8750 , 1 REACTIONS: 1  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 828 max.ph.: 2078  
 LEVEL: 3 SQUARE: ( 15 , 76 ) LINE 118 REACTION 107: TWO POINTS  
 8 6462 Y = 11521.8750 , 1 REACTIONS: 107  
 2 6464 X = 490.6250 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 829 max.ph.: 2164  
 LEVEL: 4 SQUARE: ( 6 , 1 ) LINE 1 REACTION 1: OPEN END  
 3 6467 Y = 3526.5625 , 0 REACTIONS:  
 2 6469 X = 417.1875 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 829 max.ph.: 2180  
 LEVEL: 4 SQUARE: ( 9 , 4 ) LINE 2 REACTION 2: OPEN END  
 10 6479 Y = 3685.9375 , 2 REACTIONS: 13 14  
 8 6487 X = 426.5625 , 2 REACTIONS: 89 13  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 833 max.ph.: 2161  
 LEVEL: 4 SQUARE: ( 44 , 19 ) LINE 3 REACTION 3: OPEN END  
 11 6498 Y = 4482.8125 , 2 REACTIONS: 18 78  
 6 6504 X = 535.9375 , 1 REACTIONS: 78  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 836 max.ph.: 2148  
 LEVEL: 4 SQUARE: ( 60 , 30 ) LINE 5 REACTION 5: OPEN END  
 7 6511 Y = 5067.1875 , 1 REACTIONS: 106  
 2 6513 X = 585.9375 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 837 max.ph.: 3188  
 LEVEL: 4 SQUARE: ( 112 , 35 ) LINE 7 REACTION 7: OPEN END  
 7 6520 Y = 5332.8125 , 1 REACTIONS: 85  
 6 6526 X = 748.4375 , 1 REACTIONS: 85  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 839 max.ph.: 1980  
 LEVEL: 4 SQUARE: ( 119 , 18 ) LINE 8 REACTION 8: OPEN END  
 7 6533 Y = 4429.6875 , 1 REACTIONS: 8  
 6 6539 X = 770.3125 , 1 REACTIONS: 8  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 841 max.ph.: 2058  
 LEVEL: 4 SQUARE: ( 121 , 10 ) LINE 9 REACTION 9: OPEN END  
 10 6549 Y = 4004.6875 , 2 REACTIONS: 9 10  
 2 6551 X = 776.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 843 max.ph.: 2025  
 LEVEL: 4 SQUARE: ( 151 , 50 ) LINE 11 REACTION 11: OPEN END  
 7 6558 Y = 6129.6875 , 2 REACTIONS: 34 35  
 2 6560 X = 870.3125 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 845 max.ph.: 3246  
 LEVEL: 4 SQUARE: ( 8 , 3 ) LINE 12 REACTION 12: OPEN END  
 10 6570 Y = 3632.8125 , 2 REACTIONS: 12 13



2 6572 X = 423.4375 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 847 max.ph.: 2099  
 LEVEL: 4 SQUARE: ( 8 , 41 ) LINE 12 REACTION 12: OPEN END  
 9 6581 Y = 5651.5625 , 2 REACTIONS: 26 27  
 6 6587 X = 423.4375 , 2 REACTIONS: 27 26  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 851 max.ph.: 2094  
 LEVEL: 4 SQUARE: ( 60 , 89 ) LINE 13 REACTION 13: OPEN END  
 9 6596 Y = 8201.5625 , 2 REACTIONS: 100 32  
 2 6598 X = 585.9375 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 853 max.ph.: 2069  
 LEVEL: 4 SQUARE: ( 44 , 57 ) LINE 14 REACTION 14: OPEN END  
 12 6610 Y = 6501.5625 , 3 REACTIONS: 13 14 18  
 6 6616 X = 535.9375 , 1 REACTIONS: 13  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 857 max.ph.: 2166  
 LEVEL: 4 SQUARE: ( 125 , 24 ) LINE 16 REACTION 16: OPEN END  
 7 6623 Y = 4748.4375 , 1 REACTIONS: 16  
 6 6629 X = 789.0625 , 1 REACTIONS: 16  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 859 max.ph.: 2003  
 LEVEL: 4 SQUARE: ( 60 , 31 ) LINE 19 REACTION 19: OPEN END  
 7 6636 Y = 5120.3125 , 1 REACTIONS: 19  
 6 6642 X = 585.9375 , 1 REACTIONS: 19  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 861 max.ph.: 2170  
 LEVEL: 4 SQUARE: ( 103 , 80 ) LINE 19 REACTION 19: OPEN END  
 10 6652 Y = 7723.4375 , 2 REACTIONS: 19 28  
 10 6662 X = 720.3125 , 2 REACTIONS: 19 36  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 865 max.ph.: 2165  
 LEVEL: 4 SQUARE: ( 125 , 43 ) LINE 21 REACTION 21: OPEN END  
 12 6674 Y = 5757.8125 , 3 REACTIONS: 85 21 22  
 2 6676 X = 789.0625 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 868 max.ph.: 2031  
 LEVEL: 4 SQUARE: ( 125 , 25 ) LINE 22 REACTION 22: OPEN END  
 7 6683 Y = 4801.5625 , 2 REACTIONS: 22 23  
 2 6685 X = 789.0625 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 870 max.ph.: 2063  
 LEVEL: 4 SQUARE: ( 125 , 72 ) LINE 23 REACTION 23: OPEN END  
 9 6694 Y = 7298.4375 , 2 REACTIONS: 29 23  
 2 6696 X = 789.0625 , 0 REACTIONS:  
 NUMBER OF LINES: 123 NUMBER OF POINTS: 872 max.ph.: 2038  
 LEVEL: 4 SQUARE: ( 14 , 54 ) LINE 25 REACTION 25: OPEN END  
 REACTION: 108 21 = 22  
 position: 4.42090E+02 6.34219E+03 4.42188E+02 6.34219E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (3)CIAMg ab q = GRT BIO (2)CIAMg OPX6 ab q  
 7 6703 Y = 6342.1875 , 1 REACTIONS: 108  
 7 6710 X = 442.1875 , 2 REACTIONS: 31 30  
 NUMBER OF LINES: 124 NUMBER OF POINTS: 875 max.ph.: 2120  
 LEVEL: 4 SQUARE: ( 28 , 105 ) LINE 30 REACTION 30: OPEN END  
 3 6713 Y = 9051.5625 , 0 REACTIONS:  
 2 6715 X = 485.9375 , 0 REACTIONS:  
 NUMBER OF LINES: 124 NUMBER OF POINTS: 875 max.ph.: 2054  
 LEVEL: 4 SQUARE: ( 64 , 119 ) LINE 31 REACTION 31: OPEN END  
 12 6727 Y = 9795.3125 , 3 REACTIONS: 49 31 81

REACTION: 109 22 = 35  
 position: 5.98438E+02 9.79531E+03 5.98438E+02 9.79697E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (2)ClAMg OPX6 ab q = GRT BIO (2)ClAMg q  
 6 6733 X = 598.4375, 1 REACTIONS: 109  
 NUMBER OF LINES: 125 NUMBER OF POINTS: 879 max.ph.: 2178  
 LEVEL: 4 SQUARE: (45, 57) LINE 32 REACTION 32: OPEN END  
 3 6736 Y = 6501.5625, 0 REACTIONS:  
 2 6738 X = 539.0625, 0 REACTIONS:  
 NUMBER OF LINES: 125 NUMBER OF POINTS: 879 max.ph.: 2133  
 LEVEL: 4 SQUARE: (61, 90) LINE 32 REACTION 32: OPEN END  
 9 6747 Y = 8254.6875, 2 REACTIONS: 100 32  
 REACTION: 110 25 = 56  
 position: 5.89062E+02 8.26797E+03 5.89062E+02 8.26963E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (2)ClAMg OPX6 q = GRT FSP BIO (2)ClAMg OPX6 ab q  
 6 6753 X = 589.0625, 2 REACTIONS: 110 80  
 NUMBER OF LINES: 127 NUMBER OF POINTS: 883 max.ph.: 2137  
 LEVEL: 4 SQUARE: (82, 83) LINE 33 REACTION 33: OPEN END  
 7 6760 Y = 7882.8125, 1 REACTIONS: 33  
 6 6766 X = 654.6875, 1 REACTIONS: 33  
 NUMBER OF LINES: 127 NUMBER OF POINTS: 885 max.ph.: 2172  
 LEVEL: 4 SQUARE: (112, 87) LINE 37 REACTION 37: OPEN END  
 11 6777 Y = 8095.3125, 2 REACTIONS: 92 47  
 6 6783 X = 748.4375, 2 REACTIONS: 38 47  
 NUMBER OF LINES: 127 NUMBER OF POINTS: 889 max.ph.: 2138  
 LEVEL: 4 SQUARE: (125, 78) LINE 38 REACTION 38: OPEN END  
 9 6792 Y = 7617.1875, 2 REACTIONS: 38 39  
 6 6798 X = 789.0625, 1 REACTIONS: 38  
 NUMBER OF LINES: 127 NUMBER OF POINTS: 892 max.ph.: 3124  
 LEVEL: 4 SQUARE: (155, 136) LINE 39 REACTION 39: OPEN END  
 10 6808 Y = 10698.4375, 2 REACTIONS: 39 88  
 10 6818 X = 882.8125, 2 REACTIONS: 39 93  
 NUMBER OF LINES: 127 NUMBER OF POINTS: 896 max.ph.: 2136  
 LEVEL: 4 SQUARE: (5, 91) LINE 40 REACTION 40: OPEN END  
 9 6827 Y = 8307.8125, 2 REACTIONS: 40 41  
 6 6833 X = 414.0625, 1 REACTIONS: 41  
 NUMBER OF LINES: 127 NUMBER OF POINTS: 899 max.ph.: 2077  
 LEVEL: 4 SQUARE: (9, 129) LINE 40 REACTION 40: OPEN END  
 3 6836 Y = 10326.5625, 0 REACTIONS:  
 6 6842 X = 426.5625, 1 REACTIONS: 98  
 NUMBER OF LINES: 128 NUMBER OF POINTS: 900 max.ph.: 2100  
 LEVEL: 4 SQUARE: (62, 93) LINE 43 REACTION 42: OPEN END  
 7 6849 Y = 8414.0625, 1 REACTIONS: 42  
 2 6851 X = 592.1875, 0 REACTIONS:  
 NUMBER OF LINES: 128 NUMBER OF POINTS: 901 max.ph.: 2088  
 LEVEL: 4 SQUARE: (64, 98) LINE 43 REACTION 42: OPEN END  
 3 6854 Y = 8679.6875, 0 REACTIONS:  
 2 6856 X = 598.4375, 0 REACTIONS:  
 NUMBER OF LINES: 128 NUMBER OF POINTS: 901 max.ph.: 2183  
 LEVEL: 4 SQUARE: (82, 109) LINE 44 REACTION 43: OPEN END  
 8 6864 Y = 9264.0625, 2 REACTIONS: 102 95

6 6870 X = 654.6875 , 1 REACTIONS: 43  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 904 max.ph.: 2188  
 LEVEL: 4 SQUARE: (93 ,107 ) LINE 45 REACTION 44: OPEN END  
 11 6881 Y = 9157.8125 , 2 REACTIONS: 44 45  
 6 6887 X = 689.0625 , 1 REACTIONS: 45  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 907 max.ph.: 3414  
 LEVEL: 4 SQUARE: (112 ,94 ) LINE 46 REACTION 45: OPEN END  
 10 6897 Y = 8467.1875 , 2 REACTIONS: 45 46  
 6 6903 X = 748.4375 , 1 REACTIONS: 46  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 910 max.ph.: 3278  
 LEVEL: 4 SQUARE: (142 ,131 ) LINE 47 REACTION 46: OPEN END  
 14 6917 Y = 10432.8125 , 3 REACTIONS: 86 60 46  
 13 6930 X = 842.1875 , 3 REACTIONS: 46 60 86  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 916 max.ph.: 3220  
 LEVEL: 4 SQUARE: (152 ,140 ) LINE 48 REACTION 47: OPEN END  
 7 6937 Y = 10910.9375 , 1 REACTIONS: 68  
 2 6939 X = 873.4375 , 0 REACTIONS:  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 917 max.ph.: 2110  
 LEVEL: 4 SQUARE: (31 ,151 ) LINE 49 REACTION 48: OPEN END  
 7 6946 Y = 11495.3125 , 1 REACTIONS: 48  
 2 6948 X = 495.3125 , 0 REACTIONS:  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 918 max.ph.: 3224  
 LEVEL: 4 SQUARE: (65 ,98 ) LINE 51 REACTION 42: OPEN END  
 7 6955 Y = 8679.6875 , 1 REACTIONS: 42  
 2 6957 X = 601.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 131 NUMBER OF POINTS: 919 max.ph.: 2128  
 LEVEL: 4 SQUARE: (72 ,115 ) LINE 51 REACTION 42: OPEN END  
 7 6964 Y = 9582.8125 , 1 REACTIONS: 81  
 REACTION: 111 30 = 42  
 position: 6.23438E+02 9.56123E+03 6.23438E+02 9.56289E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP BIO (2)CIAMg OPX6 q = GRT BIO CIAMg OPX6 q  
 13 6977 X = 623.4375 , 4 REACTIONS: 111 111 96 57  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 924 max.ph.: 3281  
 LEVEL: 4 SQUARE: (76 ,116 ) LINE 52 REACTION 50: OPEN END  
 3 6980 Y = 9635.9375 , 0 REACTIONS:  
 6 6986 X = 635.9375 , 1 REACTIONS: 50  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 925 max.ph.: 2249  
 LEVEL: 2 SQUARE: (20 ,29 ) LINE 52 REACTION 50: BUMP  
 9 6995 Y = 9556.2500 , 1 REACTIONS: 50  
 8 7003 X = 643.7500 , 1 REACTIONS: 50  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 927 max.ph.: 2156  
 LEVEL: 4 SQUARE: (91 ,113 ) LINE 53 REACTION 51: OPEN END  
 7 7010 Y = 9476.5625 , 1 REACTIONS: 52  
 6 7016 X = 682.8125 , 1 REACTIONS: 51  
 NUMBER OF LINES: 133 NUMBER OF POINTS: 929 max.ph.: 2217  
 LEVEL: 4 SQUARE: (8 ,147 ) LINE 55 REACTION 53: OPEN END  
 REACTION: 112 49 = 41  
 position: 4.24316E+02 1.12828E+04 4.24414E+02 1.12828E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT PHNG (3)CIAMg CHLR ky q = GRT BIO (3)CIAMg CHLR q  
 7 7023 Y = 11282.8125 , 1 REACTIONS: 112

2 7025 X = 423.4375 , 0 REACTIONS:  
 NUMBER OF LINES: 134 NUMBER OF POINTS: 930 max.ph.: 2170  
 LEVEL: 4 SQUARE: ( 10 ,130 ) LINE 56 REACTION 54: OPEN END  
 10 7035 Y = 10379.6875 , 3 REACTIONS: 98 40 40  
 2 7037 X = 429.6875 , 0 REACTIONS:  
 NUMBER OF LINES: 135 NUMBER OF POINTS: 933 max.ph.: 2139  
 LEVEL: 4 SQUARE: ( 9 ,131 ) LINE 56 REACTION 54: BUMP  
 7 7044 Y = 10432.8125 , 1 REACTIONS: 54  
 10 7054 X = 426.5625 , 2 REACTIONS: 54 54  
 NUMBER OF LINES: 135 NUMBER OF POINTS: 936 max.ph.: 3342  
 LEVEL: 4 SQUARE: ( 9 ,130 ) LINE 56 REACTION 54: BUMP  
 11 7065 Y = 10379.6875 , 2 REACTIONS: 54 54  
 6 7071 X = 426.5625 , 1 REACTIONS: 54  
 NUMBER OF LINES: 135 NUMBER OF POINTS: 939 max.ph.: 2178  
 LEVEL: 4 SQUARE: ( 8 ,130 ) LINE 56 REACTION 54: BUMP  
 7 7078 Y = 10379.6875 , 1 REACTIONS: 54  
 6 7084 X = 423.4375 , 1 REACTIONS: 54  
 NUMBER OF LINES: 135 NUMBER OF POINTS: 941 max.ph.: 2208  
 LEVEL: 4 SQUARE: ( 10 ,132 ) LINE 56 REACTION 54: BUMP  
 7 7091 Y = 10485.9375 , 1 REACTIONS: 54  
 2 7093 X = 429.6875 , 0 REACTIONS:  
 NUMBER OF LINES: 136 NUMBER OF POINTS: 942 max.ph.: 2085  
 LEVEL: 4 SQUARE: ( 10 ,131 ) LINE 57 REACTION 54: BUMP  
 10 7103 Y = 10432.8125 , 2 REACTIONS: 54 64  
 9 7112 X = 429.6875 , 2 REACTIONS: 64 54  
 NUMBER OF LINES: 136 NUMBER OF POINTS: 946 max.ph.: 2390  
 LEVEL: 4 SQUARE: ( 8 ,128 ) LINE 58 REACTION 55: OPEN END  
 7 7119 Y = 10273.4375 , 2 REACTIONS: 98 40  
 6 7125 X = 423.4375 , 1 REACTIONS: 55  
 NUMBER OF LINES: 136 NUMBER OF POINTS: 949 max.ph.: 2190  
 LEVEL: 4 SQUARE: ( 9 ,128 ) LINE 59 REACTION 55: OPEN END  
 11 7136 Y = 10273.4375 , 2 REACTIONS: 40 40  
 2 7138 X = 426.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 137 NUMBER OF POINTS: 951 max.ph.: 2167  
 LEVEL: 4 SQUARE: ( 82 ,129 ) LINE 60 REACTION 56: OPEN END  
 7 7145 Y = 10326.5625 , 1 REACTIONS: 57  
 6 7151 X = 654.6875 , 1 REACTIONS: 103  
 NUMBER OF LINES: 137 NUMBER OF POINTS: 953 max.ph.: 3339  
 LEVEL: 4 SQUARE: ( 88 ,131 ) LINE 62 REACTION 58: OPEN END  
 11 7162 Y = 10432.8125 , 2 REACTIONS: 103 58  
 10 7172 X = 673.4375 , 2 REACTIONS: 58 103  
 NUMBER OF LINES: 137 NUMBER OF POINTS: 957 max.ph.: 2276  
 LEVEL: 4 SQUARE: ( 98 ,131 ) LINE 63 REACTION 59: OPEN END  
 3 7175 Y = 10432.8125 , 0 REACTIONS:  
 6 7181 X = 704.6875 , 1 REACTIONS: 86  
 NUMBER OF LINES: 137 NUMBER OF POINTS: 958 max.ph.: 3301  
 LEVEL: 4 SQUARE: ( 1 ,131 ) LINE 66 REACTION 62: OPEN END  
 3 7184 Y = 10432.8125 , 0 REACTIONS:  
 2 7186 X = 401.5625 , 0 REACTIONS:  
 NUMBER OF LINES: 137 NUMBER OF POINTS: 958 max.ph.: 2181  
 LEVEL: 4 SQUARE: ( 35 ,160 ) LINE 67 REACTION 63: OPEN END  
 7 7193 Y = 11973.4375 , 1 REACTIONS: 63

6 7199 X = 507.8125 , 1 REACTIONS: 63  
 NUMBER OF LINES: 137 NUMBER OF POINTS: 960 max.ph.: 2127  
 LEVEL: 4 SQUARE: ( 15 ,141 ) LINE 67 REACTION 63: BUMP  
 3 7202 Y = 10964.0625 , 0 REACTIONS:  
 2 7204 X = 445.3125 , 0 REACTIONS:  
 NUMBER OF LINES: 138 NUMBER OF POINTS: 960 max.ph.: 2200  
 LEVEL: 4 SQUARE: ( 36 ,160 ) LINE 69 REACTION 63: OPEN END  
 7 7211 Y = 11973.4375 , 1 REACTIONS: 63  
 6 7217 X = 510.9375 , 1 REACTIONS: 63  
 NUMBER OF LINES: 138 NUMBER OF POINTS: 962 max.ph.: 2103  
 LEVEL: 4 SQUARE: ( 31 ,152 ) LINE 69 REACTION 63: OPEN END  
 9 7226 Y = 11548.4375 , 2 REACTIONS: 63 73  
 8 7234 X = 495.3125 , 2 REACTIONS: 73 63  
 NUMBER OF LINES: 138 NUMBER OF POINTS: 966 max.ph.: 2189  
 LEVEL: 4 SQUARE: ( 99 ,141 ) LINE 72 REACTION 66: OPEN END  
 7 7241 Y = 10964.0625 , 1 REACTIONS: 66  
 2 7243 X = 707.8125 , 0 REACTIONS:  
 NUMBER OF LINES: 138 NUMBER OF POINTS: 967 max.ph.: 2083  
 LEVEL: 4 SQUARE: ( 10 ,150 ) LINE 76 REACTION 70: OPEN END  
 11 7254 Y = 11442.1875 , 2 REACTIONS: 97 72  
 10 7264 X = 429.6875 , 2 REACTIONS: 72 71  
 NUMBER OF LINES: 138 NUMBER OF POINTS: 971 max.ph.: 2231  
 LEVEL: 4 SQUARE: ( 2 , 88 ) LINE 80 REACTION 74: OPEN END  
 7 7271 Y = 8148.4375 , 2 REACTIONS: 75 74  
 6 7277 X = 404.6875 , 1 REACTIONS: 94  
 NUMBER OF LINES: 138 NUMBER OF POINTS: 974 max.ph.: 2133  
 LEVEL: 4 SQUARE: ( 125 , 73 ) LINE 97 REACTION 91: OPEN END  
 9 7286 Y = 7351.5625 , 2 REACTIONS: 29 23  
 2 7288 X = 789.0625 , 0 REACTIONS:  
 NUMBER OF LINES: 138 NUMBER OF POINTS: 976 max.ph.: 2036  
 LEVEL: 4 SQUARE: ( 3 , 89 ) LINE 100 REACTION 94: OPEN END  
 7 7295 Y = 8201.5625 , 1 REACTIONS: 94  
 11 7306 X = 407.8125 , 3 REACTIONS: 74 75 94  
 NUMBER OF LINES: 142 NUMBER OF POINTS: 980 max.ph.: 2913  
 LEVEL: 3 SQUARE: ( 1 , 45 ) LINE 100 REACTION 94: BUMP  
 3 7309 Y = 8228.1250 , 0 REACTIONS:  
 2 7311 X = 403.1250 , 0 REACTIONS:  
 NUMBER OF LINES: 141 NUMBER OF POINTS: 980 max.ph.: 1996  
 LEVEL: 4 SQUARE: ( 2 , 89 ) LINE 100 REACTION 94: BUMP  
 3 7314 Y = 8201.5625 , 0 REACTIONS:  
 6 7320 X = 404.6875 , 1 REACTIONS: 94  
 NUMBER OF LINES: 142 NUMBER OF POINTS: 981 max.ph.: 2065  
 LEVEL: 4 SQUARE: ( 4 , 90 ) LINE 102 REACTION 94: BUMP  
 7 7327 Y = 8254.6875 , 1 REACTIONS: 94  
 2 7329 X = 410.9375 , 0 REACTIONS:  
 NUMBER OF LINES: 141 NUMBER OF POINTS: 982 max.ph.: 2093  
 LEVEL: 4 SQUARE: ( 3 , 90 ) LINE 102 REACTION 94: BUMP  
 3 7332 Y = 8254.6875 , 0 REACTIONS:  
 6 7338 X = 407.8125 , 1 REACTIONS: 94  
 NUMBER OF LINES: 140 NUMBER OF POINTS: 983 max.ph.: 2126  
 LEVEL: 4 SQUARE: ( 83 , 109 ) LINE 102 REACTION 95: BUMP  
 3 7341 Y = 9264.0625 , 0 REACTIONS:

6 7347 X = 657.8125 , 1 REACTIONS: 95  
 NUMBER OF LINES: 143 NUMBER OF POINTS: 984 max.ph.: 3276  
 LEVEL: 4 SQUARE: ( 4 , 91 ) LINE 103 REACTION 94: OPEN END  
 11 7358 Y = 8307.8125 , 2 REACTIONS: 40 40  
 13 7371 X = 410.9375 , 4 REACTIONS: 41 40 40 40  
 NUMBER OF LINES: 145 NUMBER OF POINTS: 990 max.ph.: 2070  
 LEVEL: 4 SQUARE: ( 62 , 92 ) LINE 112 REACTION 80: OPEN END  
 7 7378 Y = 8360.9375 , 1 REACTIONS: 42  
 6 7384 X = 592.1875 , 1 REACTIONS: 42  
 NUMBER OF LINES: 147 NUMBER OF POINTS: 992 max.ph.: 2210  
 LEVEL: 4 SQUARE: ( 125 , 77 ) LINE 116 REACTION 29: OPEN END  
 8 7392 Y = 7564.0625 , 2 REACTIONS: 29 23  
 2 7394 X = 789.0625 , 0 REACTIONS:  
 NUMBER OF LINES: 146 NUMBER OF POINTS: 994 max.ph.: 3114  
 LEVEL: 4 SQUARE: ( 7 , 1 ) LINE 120 REACTION 1: OPEN END  
 7 7401 Y = 3526.5625 , 1 REACTIONS: 1  
 6 7407 X = 420.3125 , 1 REACTIONS: 1  
 NUMBER OF LINES: 146 NUMBER OF POINTS: 996 max.ph.: 2123  
 LEVEL: 4 SQUARE: ( 4 , 89 ) LINE 131 REACTION 74: TWO POINTS  
 3 7410 Y = 8201.5625 , 0 REACTIONS:  
 2 7412 X = 410.9375 , 0 REACTIONS:  
 NUMBER OF LINES: 147 NUMBER OF POINTS: 996 max.ph.: 2014  
 LEVEL: 5 SQUARE: ( 12 , 1 ) LINE 1 REACTION 1: OPEN END  
 3 7415 Y = 3513.2812 , 0 REACTIONS:  
 2 7417 X = 417.9688 , 0 REACTIONS:  
 NUMBER OF LINES: 146 NUMBER OF POINTS: 996 max.ph.: 2234  
 LEVEL: 5 SQUARE: ( 18 , 7 ) LINE 2 REACTION 2: OPEN END  
 11 7428 Y = 3672.6562 , 3 REACTIONS: 13 89 2  
 5 7433 X = 427.3438 , 1 REACTIONS: 89  
 NUMBER OF LINES: 146 NUMBER OF POINTS: 1000 max.ph.: 2108  
 LEVEL: 5 SQUARE: ( 87 , 37 ) LINE 3 REACTION 3: OPEN END  
 9 7442 Y = 4469.5312 , 2 REACTIONS: 18 78  
 5 7447 X = 535.1562 , 1 REACTIONS: 78  
 NUMBER OF LINES: 147 NUMBER OF POINTS: 1003 max.ph.: 2137  
 LEVEL: 5 SQUARE: ( 119 , 59 ) LINE 5 REACTION 5: OPEN END  
 9 7456 Y = 5053.9062 , 2 REACTIONS: 5 6  
 8 7464 X = 585.1562 , 2 REACTIONS: 6 5  
 NUMBER OF LINES: 146 NUMBER OF POINTS: 1007 max.ph.: 2148  
 LEVEL: 5 SQUARE: ( 223 , 69 ) LINE 7 REACTION 7: OPEN END  
 9 7473 Y = 5319.5312 , 2 REACTIONS: 28 85  
 5 7478 X = 747.6562 , 1 REACTIONS: 85  
 NUMBER OF LINES: 146 NUMBER OF POINTS: 1010 max.ph.: 2004  
 LEVEL: 5 SQUARE: ( 238 , 36 ) LINE 8 REACTION 8: OPEN END  
 8 7486 Y = 4442.9688 , 2 REACTIONS: 8 15  
 5 7491 X = 771.0938 , 1 REACTIONS: 15  
 NUMBER OF LINES: 147 NUMBER OF POINTS: 1013 max.ph.: 2982  
 LEVEL: 5 SQUARE: ( 242 , 20 ) LINE 9 REACTION 9: OPEN END  
 6 7497 Y = 4017.9688 , 2 REACTIONS: 9 10  
 5 7502 X = 777.3438 , 1 REACTIONS: 9  
 NUMBER OF LINES: 146 NUMBER OF POINTS: 1016 max.ph.: 2057  
 LEVEL: 5 SQUARE: ( 301 , 99 ) LINE 11 REACTION 11: OPEN END  
 6 7508 Y = 6116.4062 , 1 REACTIONS: 11

2 7510 X = 869.5312 , 0 REACTIONS:  
 NUMBER OF LINES: 146 NUMBER OF POINTS: 1017 max.ph.: 2074  
 LEVEL: 5 SQUARE: ( 16 , 5 ) LINE 12 REACTION 12: OPEN END  
 REACTION: 113 13 = 8  
 position: 4.24316E+02 3.61953E+03 4.24414E+02 3.61953E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: BIO (2)ClAMg OPX6 ab q = FSP BIO (3)ClAMg ab q  
 9 7519 Y = 3619.5312 , 2 REACTIONS: 12 113  
 REACTION: 114 58 = 13  
 position: 4.24219E+02 3.61621E+03 4.24219E+02 3.61787E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: FSP BIO (3)ClAMg OPX6 ab q = BIO (2)ClAMg OPX6 ab q  
 6 7525 X = 424.2188 , 2 REACTIONS: 104 114  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1021 max.ph.: 2162  
 LEVEL: 5 SQUARE: ( 15 , 81 ) LINE 12 REACTION 12: OPEN END  
 7 7532 Y = 5638.2812 , 2 REACTIONS: 17 12  
 5 7537 X = 422.6562 , 1 REACTIONS: 17  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 1024 max.ph.: 2143  
 LEVEL: 5 SQUARE: (120 , 177 ) LINE 13 REACTION 13: OPEN END  
 6 7543 Y = 8188.2812 , 2 REACTIONS: 100 32  
 6 7549 X = 586.7188 , 2 REACTIONS: 32 100  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 1028 max.ph.: 3070  
 LEVEL: 5 SQUARE: ( 88 , 114 ) LINE 14 REACTION 14: OPEN END  
 6 7555 Y = 6514.8438 , 1 REACTIONS: 13  
 5 7560 X = 536.7188 , 1 REACTIONS: 13  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1030 max.ph.: 2121  
 LEVEL: 5 SQUARE: (250 , 48 ) LINE 16 REACTION 16: OPEN END  
 7 7567 Y = 4761.7188 , 2 REACTIONS: 90 24  
 5 7572 X = 789.8438 , 1 REACTIONS: 24  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 1033 max.ph.: 2001  
 LEVEL: 1 SQUARE: ( 1 , 5 ) LINE 17 REACTION 17: BUMP  
 23 7595 Y = 5412.5000 , 3 REACTIONS: 25 17 12  
 16 7611 X = 412.5000 , 2 REACTIONS: 17 25  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 1038 max.ph.: 2124  
 LEVEL: 5 SQUARE: (119 , 61 ) LINE 19 REACTION 19: OPEN END  
 3 7614 Y = 5107.0312 , 0 REACTIONS:  
 2 7616 X = 585.1562 , 0 REACTIONS:  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1038 max.ph.: 2201  
 LEVEL: 5 SQUARE: (206 , 160 ) LINE 19 REACTION 19: OPEN END  
 6 7622 Y = 7736.7188 , 2 REACTIONS: 19 28  
 8 7630 X = 721.0938 , 2 REACTIONS: 19 36  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 1042 max.ph.: 2127  
 LEVEL: 5 SQUARE: (249 , 86 ) LINE 21 REACTION 21: OPEN END  
 6 7636 Y = 5771.0938 , 1 REACTIONS: 29  
 5 7641 X = 788.2812 , 1 REACTIONS: 85  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 1044 max.ph.: 2059  
 LEVEL: 5 SQUARE: (250 , 49 ) LINE 22 REACTION 22: OPEN END  
 7 7648 Y = 4788.2812 , 2 REACTIONS: 22 23  
 2 7650 X = 789.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1046 max.ph.: 2012  
 LEVEL: 5 SQUARE: (250 , 144 ) LINE 23 REACTION 23: OPEN END  
 8 7658 Y = 7311.7188 , 2 REACTIONS: 29 23

2 7660 X = 789.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 1048 max.ph.: 3074  
 LEVEL: 5 SQUARE: ( 27 ,107 ) LINE 25 REACTION 25: OPEN END  
 6 7666 Y = 6328.9062 , 2 REACTIONS: 25 26  
 5 7671 X = 441.4062 , 1 REACTIONS: 25  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 1051 max.ph.: 2094  
 LEVEL: 5 SQUARE: ( 27 ,108 ) LINE 30 REACTION 30: OPEN END  
 3 7674 Y = 6355.4688 , 0 REACTIONS:  
 2 7676 X = 441.4062 , 0 REACTIONS:  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1051 max.ph.: 2071  
 LEVEL: 5 SQUARE: ( 55 ,210 ) LINE 30 REACTION 30: OPEN END  
 6 7682 Y = 9064.8438 , 1 REACTIONS: 30  
 2 7684 X = 485.1562 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 1052 max.ph.: 2133  
 LEVEL: 5 SQUARE: (127 ,238 ) LINE 31 REACTION 31: OPEN END  
 3 7687 Y = 9808.5938 , 0 REACTIONS:  
 2 7689 X = 597.6562 , 0 REACTIONS:  
 NUMBER OF LINES: 149 NUMBER OF POINTS: 1052 max.ph.: 2233  
 LEVEL: 5 SQUARE: ( 89 ,114 ) LINE 32 REACTION 32: OPEN END  
 6 7695 Y = 6514.8438 , 2 REACTIONS: 32 33  
 5 7700 X = 538.2812 , 1 REACTIONS: 33  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1055 max.ph.: 2142  
 LEVEL: 5 SQUARE: (121 ,180 ) LINE 32 REACTION 32: OPEN END  
 REACTION: 115 22 = 25  
 position: 5.88965E+02 8.26797E+03 5.89062E+02 8.26797E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (2)CIAMg OPX6 ab q = FSP BIO (2)CIAMg OPX6 q  
 6 7706 Y = 8267.9688 , 1 REACTIONS: 115  
 2 7708 X = 588.2812 , 0 REACTIONS:  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1056 max.ph.: 2240  
 LEVEL: 5 SQUARE: (164 ,166 ) LINE 33 REACTION 33: OPEN END  
 6 7714 Y = 7896.0938 , 1 REACTIONS: 44  
 5 7719 X = 655.4688 , 1 REACTIONS: 33  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1058 max.ph.: 2234  
 LEVEL: 5 SQUARE: (223 ,173 ) LINE 37 REACTION 37: OPEN END  
 6 7725 Y = 8082.0312 , 1 REACTIONS: 37  
 5 7730 X = 747.6562 , 1 REACTIONS: 37  
 NUMBER OF LINES: 151 NUMBER OF POINTS: 1060 max.ph.: 4162  
 LEVEL: 5 SQUARE: (250 ,155 ) LINE 38 REACTION 38: OPEN END  
 6 7736 Y = 7603.9062 , 1 REACTIONS: 91  
 2 7738 X = 789.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1061 max.ph.: 2120  
 LEVEL: 5 SQUARE: (310 ,272 ) LINE 39 REACTION 39: OPEN END  
 9 7747 Y = 10711.7188 , 2 REACTIONS: 93 69  
 5 7752 X = 883.5938 , 2 REACTIONS: 39 93  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1065 max.ph.: 2096  
 LEVEL: 5 SQUARE: ( 9 ,181 ) LINE 40 REACTION 40: OPEN END  
 3 7755 Y = 8294.5312 , 0 REACTIONS:  
 2 7757 X = 413.2812 , 0 REACTIONS:  
 NUMBER OF LINES: 151 NUMBER OF POINTS: 1065 max.ph.: 2068  
 LEVEL: 5 SQUARE: ( 17 ,257 ) LINE 40 REACTION 40: OPEN END  
 7 7764 Y = 10313.2812 , 3 REACTIONS: 55 40 40



5 7769 X = 425.7812 , 1 REACTIONS: 55  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1069 max.ph.: 3105  
 LEVEL: 5 SQUARE: (124 ,185 ) LINE 43 REACTION 42: OPEN END  
 6 7775 Y = 8400.7812 , 1 REACTIONS: 42  
 5 7780 X = 592.9688 , 1 REACTIONS: 42  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1071 max.ph.: 2191  
 LEVEL: 5 SQUARE: (128 ,195 ) LINE 43 REACTION 42: OPEN END  
 3 7783 Y = 8666.4062 , 0 REACTIONS:  
 2 7785 X = 599.2188 , 0 REACTIONS:  
 NUMBER OF LINES: 151 NUMBER OF POINTS: 1071 max.ph.: 2233  
 LEVEL: 5 SQUARE: (122 ,180 ) LINE 44 REACTION 43: OPEN END  
 3 7788 Y = 8267.9688 , 0 REACTIONS:  
 2 7790 X = 589.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1071 max.ph.: 2149  
 LEVEL: 5 SQUARE: (163 ,217 ) LINE 44 REACTION 43: OPEN END  
 6 7796 Y = 9250.7812 , 1 REACTIONS: 43  
 8 7804 X = 653.9062 , 3 REACTIONS: 43 102 102  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1075 max.ph.: 2247  
 LEVEL: 5 SQUARE: (185 ,214 ) LINE 45 REACTION 44: OPEN END  
 8 7812 Y = 9171.0938 , 2 REACTIONS: 95 52  
 5 7817 X = 688.2812 , 1 REACTIONS: 95  
 NUMBER OF LINES: 151 NUMBER OF POINTS: 1078 max.ph.: 2186  
 LEVEL: 5 SQUARE: (223 ,187 ) LINE 46 REACTION 45: OPEN END  
 6 7823 Y = 8453.9062 , 1 REACTIONS: 92  
 7 7830 X = 747.6562 , 2 REACTIONS: 82 45  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1081 max.ph.: 3392  
 LEVEL: 5 SQUARE: (284 ,262 ) LINE 47 REACTION 46: OPEN END  
 3 7833 Y = 10446.0938 , 0 REACTIONS:  
 6 7839 X = 842.9688 , 2 REACTIONS: 60 86  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1083 max.ph.: 2166  
 LEVEL: 5 SQUARE: (303 ,279 ) LINE 48 REACTION 47: OPEN END  
 6 7845 Y = 10897.6562 , 1 REACTIONS: 68  
 5 7850 X = 872.6562 , 1 REACTIONS: 93  
 NUMBER OF LINES: 151 NUMBER OF POINTS: 1085 max.ph.: 2161  
 LEVEL: 5 SQUARE: ( 61 ,302 ) LINE 49 REACTION 48: OPEN END  
 6 7856 Y = 11508.5938 , 1 REACTIONS: 48  
 2 7858 X = 494.5312 , 0 REACTIONS:  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1086 max.ph.: 2182  
 LEVEL: 5 SQUARE: (129 ,195 ) LINE 51 REACTION 42: OPEN END  
 6 7864 Y = 8666.4062 , 1 REACTIONS: 42  
 2 7866 X = 600.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 150 NUMBER OF POINTS: 1087 max.ph.: 2152  
 LEVEL: 5 SQUARE: (143 ,229 ) LINE 51 REACTION 42: OPEN END  
 REACTION: 116 22 = 42  
 position: 6.22559E+02 9.56953E+03 6.22656E+02 9.56953E+03  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT BIO (2)CIAMg OPX6 ab q = GRT BIO CIAMg OPX6 q  
 10 7876 Y = 9569.5312 , 3 REACTIONS: 116 116 81  
 9 7885 X = 622.6562 , 3 REACTIONS: 116 116 81  
 NUMBER OF LINES: 152 NUMBER OF POINTS: 1093 max.ph.: 3085  
 LEVEL: 5 SQUARE: (164 ,218 ) LINE 52 REACTION 50: OPEN END  
 6 7891 Y = 9277.3438 , 1 REACTIONS: 43

7 7898 X = 655.4688 , 2 REACTIONS: 43 50  
 NUMBER OF LINES: 151 NUMBER OF POINTS: 1096 max.ph.: 2218  
 LEVEL: 5 SQUARE: (151,232) LINE 52 REACTION 50: OPEN END  
 6 7904 Y = 9649.2188 , 1 REACTIONS: 50  
 5 7909 X = 635.1562 , 1 REACTIONS: 50  
 NUMBER OF LINES: 151 NUMBER OF POINTS: 1098 max.ph.: 2112  
 LEVEL: 5 SQUARE: (182,226) LINE 53 REACTION 51: OPEN END  
 6 7915 Y = 9489.8438 , 1 REACTIONS: 52  
 5 7920 X = 683.5938 , 1 REACTIONS: 51  
 NUMBER OF LINES: 152 NUMBER OF POINTS: 1100 max.ph.: 3314  
 LEVEL: 5 SQUARE: (16,293) LINE 55 REACTION 53: OPEN END  
 7 7927 Y = 11269.5312 , 2 REACTIONS: 62 53  
 7 7934 X = 424.2188 , 2 REACTIONS: 53 62  
 NUMBER OF LINES: 151 NUMBER OF POINTS: 1104 max.ph.: 2187  
 LEVEL: 5 SQUARE: (19,264) LINE 56 REACTION 54: OPEN END  
 6 7940 Y = 10499.2188 , 1 REACTIONS: 54  
 5 7945 X = 428.9062 , 1 REACTIONS: 54  
 NUMBER OF LINES: 151 NUMBER OF POINTS: 1106 max.ph.: 2134  
 LEVEL: 5 SQUARE: (20,263) LINE 57 REACTION 54: OPEN END  
 3 7948 Y = 10472.6562 , 0 REACTIONS:  
 5 7953 X = 430.4688 , 1 REACTIONS: 54  
 NUMBER OF LINES: 152 NUMBER OF POINTS: 1107 max.ph.: 2160  
 LEVEL: 5 SQUARE: (19,260) LINE 57 REACTION 54: OPEN END  
 11 7964 Y = 10392.9688 , 3 REACTIONS: 54 55 40  
 8 7972 X = 428.9062 , 4 REACTIONS: 40 64 54 54  
 NUMBER OF LINES: 153 NUMBER OF POINTS: 1114 max.ph.: 2834  
 LEVEL: 5 SQUARE: (16,255) LINE 59 REACTION 55: OPEN END  
 6 7978 Y = 10260.1562 , 1 REACTIONS: 55  
 5 7983 X = 424.2188 , 1 REACTIONS: 55  
 NUMBER OF LINES: 153 NUMBER OF POINTS: 1116 max.ph.: 2130  
 LEVEL: 5 SQUARE: (17,256) LINE 60 REACTION 55: OPEN END  
 3 7986 Y = 10286.7188 , 0 REACTIONS:  
 2 7988 X = 425.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 1116 max.ph.: 2118  
 LEVEL: 5 SQUARE: (128,238) LINE 62 REACTION 56: OPEN END  
 6 7994 Y = 9808.5938 , 1 REACTIONS: 56  
 5 7999 X = 599.2188 , 1 REACTIONS: 56  
 NUMBER OF LINES: 154 NUMBER OF POINTS: 1118 max.ph.: 2181  
 LEVEL: 5 SQUARE: (163,258) LINE 62 REACTION 56: OPEN END  
 6 8005 Y = 10339.8438 , 1 REACTIONS: 65  
 5 8010 X = 653.9062 , 1 REACTIONS: 103  
 NUMBER OF LINES: 154 NUMBER OF POINTS: 1120 max.ph.: 3187  
 LEVEL: 5 SQUARE: (176,262) LINE 64 REACTION 58: OPEN END  
 6 8016 Y = 10446.0938 , 1 REACTIONS: 84  
 REACTION: 117 36 = 46  
 position: 6.74219E+02 1.04411E+04 6.74219E+02 1.04428E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT FSP BIO ClAMg OPX6 q = GRT BIO ClAMg q  
 5 8021 X = 674.2188 , 1 REACTIONS: 117  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 1122 max.ph.: 2192  
 LEVEL: 5 SQUARE: (195,262) LINE 65 REACTION 59: OPEN END  
 6 8027 Y = 10446.0938 , 1 REACTIONS: 99

5 8032 X = 703.9062 , 1 REACTIONS: 86  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 1124 max.ph.: 3290  
 LEVEL: 5 SQUARE: ( 1,262 ) LINE 68 REACTION 62: OPEN END  
 6 8038 Y = 10446.0938 , 2 REACTIONS: 77 76  
 2 8040 X = 400.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 1126 max.ph.: 2155  
 LEVEL: 5 SQUARE: ( 29,282 ) LINE 69 REACTION 63: OPEN END  
 9 8049 Y = 10977.3438 , 2 REACTIONS: 63 63  
 8 8057 X = 444.5312 , 2 REACTIONS: 63 63  
 NUMBER OF LINES: 156 NUMBER OF POINTS: 1130 max.ph.: 2084  
 LEVEL: 5 SQUARE: ( 30,281 ) LINE 70 REACTION 63: OPEN END  
 6 8063 Y = 10950.7812 , 1 REACTIONS: 63  
 5 8068 X = 446.0938 , 1 REACTIONS: 63  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 1132 max.ph.: 2099  
 LEVEL: 5 SQUARE: ( 70,320 ) LINE 70 REACTION 63: OPEN END  
 3 8071 Y = 11986.7188 , 0 REACTIONS:  
 2 8073 X = 508.5938 , 0 REACTIONS:  
 NUMBER OF LINES: 155 NUMBER OF POINTS: 1132 max.ph.: 2191  
 LEVEL: 5 SQUARE: ( 72,320 ) LINE 71 REACTION 63: OPEN END  
 3 8076 Y = 11986.7188 , 0 REACTIONS:  
 5 8081 X = 511.7188 , 1 REACTIONS: 63  
 NUMBER OF LINES: 157 NUMBER OF POINTS: 1133 max.ph.: 2152  
 LEVEL: 5 SQUARE: ( 61,303 ) LINE 71 REACTION 63: OPEN END  
 7 8088 Y = 11535.1562 , 2 REACTIONS: 64 48  
 5 8093 X = 494.5312 , 1 REACTIONS: 64  
 NUMBER OF LINES: 158 NUMBER OF POINTS: 1136 max.ph.: 2121  
 LEVEL: 5 SQUARE: ( 198,281 ) LINE 74 REACTION 66: OPEN END  
 9 8102 Y = 10950.7812 , 2 REACTIONS: 66 67  
 5 8107 X = 708.5938 , 1 REACTIONS: 67  
 NUMBER OF LINES: 158 NUMBER OF POINTS: 1139 max.ph.: 2232  
 LEVEL: 5 SQUARE: ( 19,300 ) LINE 78 REACTION 70: OPEN END  
 8 8115 Y = 11455.4688 , 2 REACTIONS: 70 71  
 5 8120 X = 428.9062 , 1 REACTIONS: 97  
 NUMBER OF LINES: 159 NUMBER OF POINTS: 1142 max.ph.: 2230  
 LEVEL: 5 SQUARE: ( 16,294 ) LINE 80 REACTION 72: OPEN END  
 REACTION: 118 55 = 41  
 position: 4.24707E+02 1.12961E+04 4.24805E+02 1.12961E+04  
 LABELED WITH ASSEMBLAGES  
 REACTION: GRT PHNG BIO (3)CIAMg CHLR ky q = GRT BIO (3)CIAMg CHLR q  
 6 8126 Y = 11296.0938 , 2 REACTIONS: 77 118  
 2 8128 X = 424.2188 , 0 REACTIONS:  
 NUMBER OF LINES: 160 NUMBER OF POINTS: 1144 max.ph.: 2187  
 LEVEL: 5 SQUARE: ( 4,176 ) LINE 82 REACTION 74: OPEN END  
 3 8131 Y = 8161.7188 , 0 REACTIONS:  
 2 8133 X = 405.4688 , 0 REACTIONS:  
 NUMBER OF LINES: 160 NUMBER OF POINTS: 1144 max.ph.: 2082  
 LEVEL: 5 SQUARE: ( 249,144 ) LINE 99 REACTION 91: OPEN END  
 3 8136 Y = 7311.7188 , 0 REACTIONS:  
 2 8138 X = 788.2812 , 0 REACTIONS:  
 NUMBER OF LINES: 161 NUMBER OF POINTS: 1144 max.ph.: 2066  
 LEVEL: 5 SQUARE: ( 249,145 ) LINE 99 REACTION 91: OPEN END  
 3 8141 Y = 7338.2812 , 0 REACTIONS:

2 8143 X = 788.2812 , 0 REACTIONS:  
 NUMBER OF LINES: 160 NUMBER OF POINTS: 1144 max.ph.: 2132  
 LEVEL: 5 SQUARE: ( 5,177 ) LINE 102 REACTION 94: OPEN END  
 6 8149 Y = 8188.2812 , 2 REACTIONS: 75 74  
 5 8154 X = 407.0312 , 1 REACTIONS: 94  
 NUMBER OF LINES: 161 NUMBER OF POINTS: 1147 max.ph.: 2137  
 LEVEL: 5 SQUARE: ( 6,177 ) LINE 103 REACTION 94: OPEN END  
 3 8157 Y = 8188.2812 , 0 REACTIONS:  
 2 8159 X = 408.5938 , 0 REACTIONS:  
 NUMBER OF LINES: 162 NUMBER OF POINTS: 1147 max.ph.: 2056  
 LEVEL: 5 SQUARE: ( 7,181 ) LINE 103 REACTION 94: OPEN END  
 3 8162 Y = 8294.5312 , 0 REACTIONS:  
 2 8164 X = 410.1562 , 0 REACTIONS:  
 NUMBER OF LINES: 161 NUMBER OF POINTS: 1147 max.ph.: 2125  
 LEVEL: 5 SQUARE: ( 7,179 ) LINE 104 REACTION 94: OPEN END  
 3 8167 Y = 8241.4062 , 0 REACTIONS:  
 5 8172 X = 410.1562 , 1 REACTIONS: 94  
 NUMBER OF LINES: 160 NUMBER OF POINTS: 1148 max.ph.: 2026  
 LEVEL: 5 SQUARE: ( 6,178 ) LINE 104 REACTION 94: OPEN END  
 10 8182 Y = 8214.8438 , 3 REACTIONS: 94 75 74  
 5 8187 X = 408.5938 , 2 REACTIONS: 74 75  
 NUMBER OF LINES: 162 NUMBER OF POINTS: 1153 max.ph.: 2027  
 LEVEL: 5 SQUARE: ( 6,179 ) LINE 105 REACTION 94: OPEN END  
 6 8193 Y = 8241.4062 , 1 REACTIONS: 94  
 8 8201 X = 408.5938 , 2 REACTIONS: 94 94  
 NUMBER OF LINES: 161 NUMBER OF POINTS: 1156 max.ph.: 2058  
 LEVEL: 5 SQUARE: ( 6,180 ) LINE 106 REACTION 94: TWO POINTS  
 3 8204 Y = 8267.9688 , 0 REACTIONS:  
 8 8212 X = 408.5938 , 2 REACTIONS: 40 40  
 NUMBER OF LINES: 162 NUMBER OF POINTS: 1158 max.ph.: 2910  
 LEVEL: 5 SQUARE: ( 8,181 ) LINE 107 REACTION 94: OPEN END  
 6 8218 Y = 8294.5312 , 1 REACTIONS: 94  
 5 8223 X = 411.7188 , 1 REACTIONS: 94  
 NUMBER OF LINES: 164 NUMBER OF POINTS: 1160 max.ph.: 2034  
 LEVEL: 5 SQUARE: ( 16,256 ) LINE 112 REACTION 40: TWO POINTS  
 6 8229 Y = 10286.7188 , 1 REACTIONS: 55  
 2 8231 X = 424.2188 , 0 REACTIONS:  
 NUMBER OF LINES: 166 NUMBER OF POINTS: 1161 max.ph.: 2174  
 LEVEL: 5 SQUARE: ( 124,184 ) LINE 117 REACTION 80: OPEN END  
 3 8234 Y = 8374.2188 , 0 REACTIONS:  
 2 8236 X = 592.9688 , 0 REACTIONS:  
 NUMBER OF LINES: 167 NUMBER OF POINTS: 1161 max.ph.: 2150  
 LEVEL: 5 SQUARE: ( 250,145 ) LINE 121 REACTION 29: OPEN END  
 8 8244 Y = 7338.2812 , 2 REACTIONS: 29 23  
 2 8246 X = 789.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 166 NUMBER OF POINTS: 1163 max.ph.: 2030  
 LEVEL: 5 SQUARE: ( 250,154 ) LINE 121 REACTION 29: OPEN END  
 6 8252 Y = 7577.3438 , 1 REACTIONS: 91  
 2 8254 X = 789.8438 , 0 REACTIONS:  
 NUMBER OF LINES: 167 NUMBER OF POINTS: 1164 max.ph.: 2089  
 LEVEL: 5 SQUARE: ( 13, 1 ) LINE 125 REACTION 1: OPEN END  
 6 8260 Y = 3513.2812 , 1 REACTIONS: 1

5 8265 X = 419.5312 , 1 REACTIONS: 1  
 NUMBER OF LINES: 166 NUMBER OF POINTS: 1166 max.ph.: 2186  
 LEVEL: 5 SQUARE: (119,60) LINE 128 REACTION 106: TWO POINTS  
 6 8271 Y = 5080.4688 , 1 REACTIONS: 106  
 5 8276 X = 585.1562 , 1 REACTIONS: 78  
 NUMBER OF LINES: 167 NUMBER OF POINTS: 1168 max.ph.: 2152  
 LEVEL: 5 SQUARE: (7,180) LINE 132 REACTION 40: OPEN END  
 9 8285 Y = 8267.9688 , 2 REACTIONS: 40 94  
 2 8287 X = 410.1562 , 0 REACTIONS:  
 NUMBER OF LINES: 166 NUMBER OF POINTS: 1170 max.ph.: 2053  
 LEVEL: 5 SQUARE: (17,258) LINE 135 REACTION 98: OPEN END  
 6 8293 Y = 10339.8438 , 1 REACTIONS: 98  
 2 8295 X = 425.7812 , 0 REACTIONS:  
 NUMBER OF LINES: 166 NUMBER OF POINTS: 1171 max.ph.: 2177  
 LEVEL: 5 SQUARE: (163,218) LINE 142 REACTION 102: OPEN END  
 3 8298 Y = 9277.3438 , 0 REACTIONS:  
 2 8300 X = 653.9062 , 0 REACTIONS:  
 NUMBER OF LINES: 166 NUMBER OF POINTS: 1171 max.ph.: 2118  
 LEVEL: 5 SQUARE: (144,229) LINE 145 REACTION 111: TWO POINTS  
 6 8306 Y = 9569.5312 , 1 REACTIONS: 96  
 5 8311 X = 624.2188 , 1 REACTIONS: 96  
 NUMBER OF LINES: 166 NUMBER OF POINTS: 1173 max.ph.: 2205  
 LEVEL: 5 SQUARE: (143,230) LINE 146 REACTION 57: OPEN END  
 3 8314 Y = 9596.0938 , 0 REACTIONS:  
 5 8319 X = 622.6562 , 1 REACTIONS: 57  
 NUMBER OF LINES: 166 NUMBER OF POINTS: 1174 max.ph.: 2104  
 LEVEL: 5 SQUARE: (144,230) LINE 146 REACTION 57: OPEN END  
 3 8322 Y = 9596.0938 , 0 REACTIONS:  
 2 8324 X = 624.2188 , 0 REACTIONS:  
 NUMBER OF LINES: 166 NUMBER OF POINTS: 1174 max.ph.: 2230  
 LEVEL: 5 SQUARE: (18,255) LINE 149 REACTION 40: OPEN END  
 9 8333 Y = 10260.1562 , 2 REACTIONS: 40 40  
 2 8335 X = 427.3438 , 0 REACTIONS:  
 NUMBER OF LINES: 167 NUMBER OF POINTS: 1176 max.ph.: 2127  
 LEVEL: 5 SQUARE: (18,256) LINE 149 REACTION 40: OPEN END  
 6 8341 Y = 10286.7188 , 1 REACTIONS: 40  
 2 8343 X = 427.3438 , 0 REACTIONS:  
 NUMBER OF LINES: 168 NUMBER OF POINTS: 1177 max.ph.: 2146  
 exit DOMINO  
 CPU time: 6h 11m 10.12s