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STRUCTURES IN JURASSIC ROCKS OF THE WESSEX BASIN, SOUTHERN ENGLAND - II: DIAPIRISM IN EVAPORITE LAYERS

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ABSTRACT The Jurassic Purbeck Beds of the Fossil Forest cliff, Lulworth Cove (southern England) encloses a ~ 10 m-thick wedge in which four juxtaposed levels (L2-L5) of differential strain have been characterized, between two levels of non deformed rocks (LI and L6). Within the zone of strain, level L2 comprises basal calcareous marls displaying 1 cm-thick zones of bed-parallel foliation developed in an anastomosed pathway to form pillow-like features, and upper layers of evaporite where tens of mushrooms or diapirs are observed. They commonly display a~ 1 m-sized circular geometry on bed-parallel sections, a ~0.5 m high central zone forming a generally bed-perpendicular tail, and are surrounded by rim synclines where the evaporite layers are entrapped together with chert and shale; level 3 consists of evaporite and shales displaying cm- to dm-scale extension and contraction structures; level L4 comprises remnants of evaporite layers embedded in a shale matrix - a tectonic melange; and level L5 comprises blocks of evaporite and limestone involved in a shale / argillite matrix, a limestone breccia (the so-called Broken Beds) inside which some layers are still preserved and exhibit 1-10 m-scale contraction and extension structures. Level L5 results from the westwards displacement of a wedge above an extensional detachment (the interface L3 / L4) and below another detachment established on a layer of shale at the contact with level L6. The mushrooms clearly deform the L3 / L4 detachment and are interpreted as thermal convection structures formed by a progressive down-sucking of the layers back in the direction of an imaginary point at the center of the diapirs - a centripetal suction leading to contraction and coeval extension, soon after initial displacement of the wedge. The pillow-like features result from percolation of fluids across the marls simultaneously with the evolution of the mushrooms.

Keywords : Diapirism, structural analysis, Purbeck Formation, thermal convection, salt tectonics

RESUMO No afloramento Fóssil Forest da localidade de Lulworth Cove, no sul da Inglaterra, a Formação Purbeck (Jurássico) engloba uma cunha (espessura ~ lOm) de rochas divididas em quatro andares verticalmente justapostos, os quais diferem quanto a estilos / intensidade de deformação (L2-L5) e ocorrem encaixados entre dois andares de rochas não deformadas (LI e L6). O andar L2 consiste, na base, de margas carbonáticas que exibem zonas de 1-2 cm de espessura nas quais a rocha é foliada e que se dispõem de modo a formar um padrão anastomosado ou em almofadas e, no topo, de camadas de evaporitos exibindo dezenas de estruturas na forma de cogumelos (ou diápiros) que têm geometria normalmente circular (~lm de diâmetro) em seções paralelas ao acamamento, e que normalmente exibem uma zona tubular central com cerca de 0.5 m de altura, formando uma chaminé ou cauda perpendicular às camadas; tais estruturas são comumente circundadas por dobras sinclinais asimétricas e apertadas, na zona interna das quais o evaporito, folhelho e *chert* são trapeados e deformados. O andar L3 consiste de evaporitos e folhelhos afetados por estruturas compressionais e extensionais de escala sub-métrica; o andar L4 consiste de fragmentos de camadas de evaporito misturados caoticamente em matriz de folhelhos, ou seja, típica melange tectônica; e o andar L5 apresenta camadas brechadas de evaporito e calcáreo, com intercalações de folhehos e argilitos, todas afetadas por estruturas compressionais e extensionais de escala = l 0 metros. O andar L5 resulta do deslocamento, para oeste, das camadas superiores da cunha ao longo e acima de um descolamento extensional estabelecido na interface dos andares L3 e L4, e abaixo de um outro descolamento estabelecido ao longo de camada de folhelho no contato com o andar L6. Os cogumelos do andar L2 claramente deformam o descolamento L3 / L4 e são, portanto, estruturas tectônicas, aqui interpretadas como devidas a processo de convecção termal que teve lugar logo após o deslocamento inicial das rochas acima da interface L3/L4. Em consequência do processo convectivo, as camadas foram sugadas para baixo e para trás, em direção a um ponto imaginário no centro dos diápiros - uma espécie de sucção centrípeta responsável pela formação simultânea de estruturas contracionais e extensionais. Simultaneamente, formaram-se as almofadas da base do andar L2 por percolação de fluidos através das margas.

Palavras-chave : Diapirismo, análise estrutural, Purbeck Formation, convecção termal, tectônica de sal

INTRODUCTION The area surrounding the locality of West Lulworth, southern England (see geological map and cross section in the Introduction to the companion paper) has specially charmed geologists, as the rocks that form its substratum - limestones of the Upper Jurassic Portland-Purbeck Beds, and the Cretaceous argillites, arenites (Wealden Group), gault, greensands and chalk, as well as Tertiary (Paleogene) sands, gravel and clays - contains well-exposed important geological features around Lulworth Cove, such as: two megasequence boundary unconformities, hm-scale folds that affect Wealden Group rocks and constitute the Lulworth crumple (to the west of the cove), and the Broken Beds plus a series of mushroom structures recorded within the Purbeck Formation that crop out along the Fossil Forest cliff, to the east of the cove (West 1975, Underhill & Paterson 1998).

The Upper Jurassic Purbeck Formation, or Purbeck Beds, consists of carbonate and clay sediments (West 1975). The detailed structural analysis presented in the companion paper has allowed to show that, at the Fossil Forest cliff, the Purbeck Formation encloses a ~ 10 m-thick wedge of highly deformed rocks divided in four juxtaposed structural levels (L2-L5) situated above non deformed limestones (level LI) and below non deformed limestones with intercalated shales / argillites (level L6). Structural level L2 comprises basal calcareous marls displaying 1 cm-thick zones of bed-parallel foliation developed in an anastomosed pathway to form pillow-like features, and upper layers of evaporite plus chert / shale deformed around the mushrooms. Level 3 consists of evaporite and shales displaying cm- to dm-scale extension and contraction structures such as boudinage, domino- and listric-style normal faults; a bedding sub-parallel foliation affected by recumbent folds; and thrust faults as well as asymmetric folds verging either to the west or to the east. Level L4 comprises remnants of evaporite layers and fragments of these layers embedded in a shale matrix, a typical tectonic melange. Level L5 (the so-called Broken Beds) comprises = Im-sized blocks of evaporite and limestone involved in a shale / argillite matrix (a typical limestone breccia) and also some still preserved layers exhibit 1-10 m-scale contraction and extension structures such as asymmetric folds, thrust, and planar- and listric-style normal faults.

The detailed description of the structures led to the conclusions that: **(1)** - Structural level L5 results from the westward displacement of a wedge above a top-down to the west extensional detachment established on levels L3 and L4 and below a detachment established along a layer of shale at the contact with level L6. The Broken Beds formed by intense fracturing associated to inter-layer slip and also to the folding that resulted from this slip; **(2)** - The westward displacement may be part of a more regional tectonic event, if one considers that the close spatial relationship of the Broken Beds and the evaporite layers, at the Fossil Forest cliff, is remarkably noticed across several localities of the Dorset coast, according to a detailed description in West (1975); **(3)** - The displacement of the wedge took place earlier in the Alpine inversion of the Wessex basin, that ended the tilting of Purbeck Beds to the north. The chaotic structure of the breccia was finally attained by further slip associated to this latter tilting; **(4)** - The record of varied style and intensity of strain, even for adjacent parts of a single layer or in juxtaposed structural levels makes the Fossil Forest outcrop a key field locality for understanding crustal deformation processes that have been described in recent literature (summary in Axen et al. 1998); and **(5)** -The east-west flow along the basal evaporite detachment was followed in time by the north-south compression of the whole area, implying in a vertical juxtaposition of nearly orthogonal kinematics that may fit in the transpression-related Cenozoic inversion of European basins (Ziegler 1989).

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This paper adds to the structural analysis in the companion paper, and presents a detailed description and interpretation of the origin of the pillows and the mushrooms of structural level **L2** of the Fossil Forest cliff. As will be shown, the mushrooms are tectonic features most probably originated by thermal convection, and the detailed analysis of deformation around their rim synclines provides important elements to understand how the process evolves. The results in here show that systematic studies of particular outcrops may lead to alternative ways to understand natural features in the field, helping to constrain their possible interpretations. Adopting a similar kind of approach, Prof. J.G. Ramsay (1992) concentrated his attention to the small-scale structures of another particular outcrop situated about 10 km to the east of West Lulworth, and obtained results that allowed him to argue for caution on the indiscriminate application of the theory of propagation of thrust faults.

STRUCTURES WITHIN LEVEL L2 **The pillow-like structures** These features are restricted to a~ 0.5 m-thick layer of brown calcareous marl that West (1975) named Dirt Beds. Pillows are drawn in the rock by anastomosed 1 cm-thick zones where the rock acquires a brownish yellow color and an internal, border-parallel foliation (Fig. 1a), giving to the Dirt Beds the aspect of a collage of pillows, the geometry of which implies that the termination of the bodies commonly looks like a folded foliation (Fig. 1b) seen in surfaces of any orientation. Geometrically speaking, the pillows are oblate ellipsoidal bodies that on bed-parallel sections appear as ellipses with maximum axis no greater than a meter, and maximum / minimum axial ratio close to 1, whereas in bed-perpendicular sections they appear as ellipses with minor axis no greater than 10 cm and axial ratio between 3-5.

The mushrooms The process responsible for the mushrooms to develop certainly made them more resistant, as many (tens) remain higher than the surrounding layers (Fig. 2a), as typical dome-like structures, or true 3-D diapirs surrounded by rim synclines inside which the layers are strongly deformed. As a common characteristic, all mushrooms are build on evaporite layers and contain a rim of synclines where the layers situated above are enclosed and highly deformed.

On bedding-parallel sections most mushrooms display a circular shape with diameter around a meter, and contain an empty central tube perpendicular to bedding (Fig. 2a), like a cylinder or a tail with a sub-circular basal section with diameter around 0.5 m and a height of 50-60 cm. At a first look, these appear to be characteristic for all mushrooms, but a more careful search indicates other important particularities: **(1)** - Some mushrooms have central tubes with = 1.5 in-long axis disposed parallel to the beds, and their partial erosion results in a rather elliptic geometry (center of Fig. 2b); **(2)** - Mushrooms exposed to less erosion display a central tube only few centimeters wide (the left, Fig. 2b), or simply display a ring structure of the evaporite layers at their top, instead of the tube (Fig. 2c); **(3)** - A strong striae lineation (Fig. 2d-e) may be observed on the walls of the central tube, parallel to the tube axis; **(4)** - The mushrooms occur randomly across level L2, and are normally separated one from each other by a distance of one to more meters. At one particular place, two mushrooms shared space during their evolution and develop the geometry of an eight ("8") at the surface (Fig. 2f); **(5)** - Layers of bluish gray chert and light brown calcareous shale that lie on the top of the mushrooms are normally found entrapped and deformed inside the rim synclines (Fig. 3a-f, Fig. 4a-c), but the deeper hinge of the rim synclines is invariably built on folded evaporite layers (Fig. 3b-d). A set of closely-spaced partition planes is sub-parallel to the axial plane of the rim syncline and affects the chert (Fig. 3e); **(6)** - On the outer surface of the mushrooms, the contact between the evaporite layers and the chert (in the single place where it could be closely observed - Fig. 5a) is marked by a through-going ductile-brittle and ~ 1 cm-thick zone of deformation (Fig. 5b) that consists of a fine-grained matrix, probably of calcareous shale or marl, enclosing fragments of chert and evaporite. Otherwise, the contact may be normal and displaying a striae lineation that turns around the outer surface and points to the central tube (Fig. 5c); and finally **(7)** -The mushrooms with bedding-parallel central tube also display rim synclines with the same characteristics as those with bedding-perpendicular tube (Fig. 6a-b).

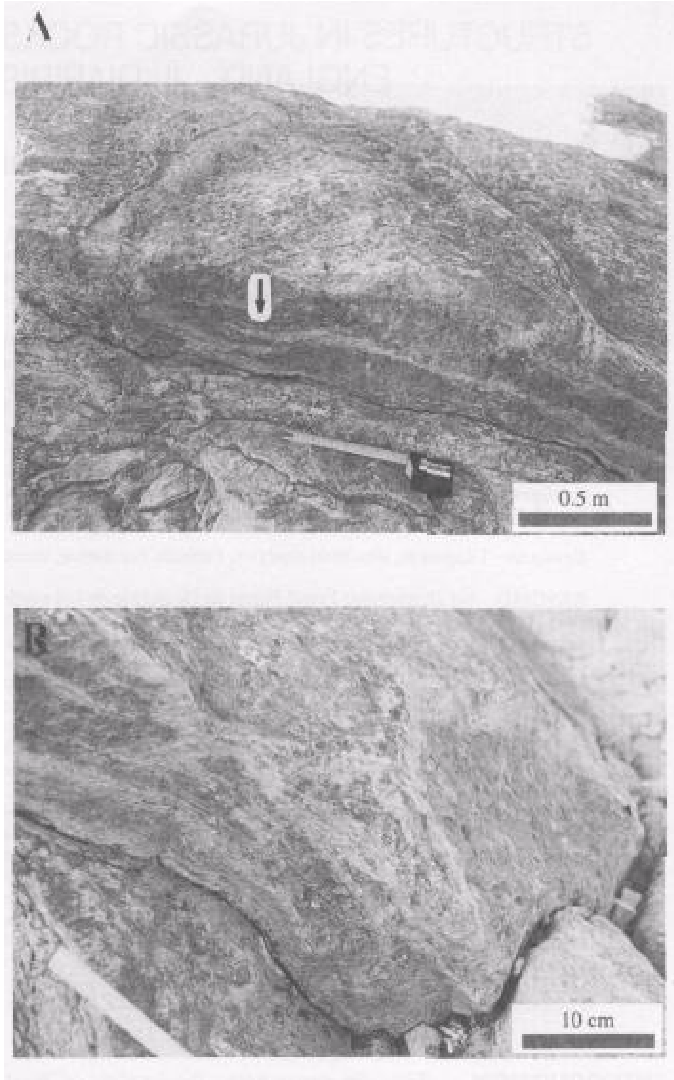

Figure 1 a-b : The pillows of level L2. These structures are bound by cm-thick anastomosed zones of brownish yellow material displaying an internal, border-parallel foliation, as pointed by the arrow in (a). The termination of the pillows often displays geometry of folds (b).

TIMING FOR EVOLUTION OF THE MUSHROOMS **Key** contact relationships, observed just a few meters to the west of the lower steps of the stairs that give access to the outcrop (see Fig. 3c in the companion paper), clearly indicate that some mushrooms stay higher than the basal detachment and that they pushed up and deformed the layers of structural level L3 and the tectonic melange of structural level L4 (Fig. 7a-d). These findings demonstrate that the mushrooms are tectonic features that must have developed soon after the initial displacement of the rocks of level L5 along the basal detachment, or after cessation of the entire movement.

Other evidence indicates evolution of the mushrooms under the same conditions of viscous flow as those for the evolution of the structures already described in level L3, in the first paper of this series. This evidence (ahead in this section), plus the lack of north trending lineations that could be indicative of a northward driven flow along the evaporite layers of levels L2 and L3, together with all the characteristics of the mushrooms described in the previous section, all indicate an evolution soon after the beginning of the displacement of the wedge to the west, still before the final tectonic inversion that led to overall tilting of the Purbeck Beds to the north.

TIMING FOR DEFORMATION WITHIN THE PURBECK BEDS Thus, by considering also the results of a companion paper, the following sequence of Cenozoic events that contributed for the

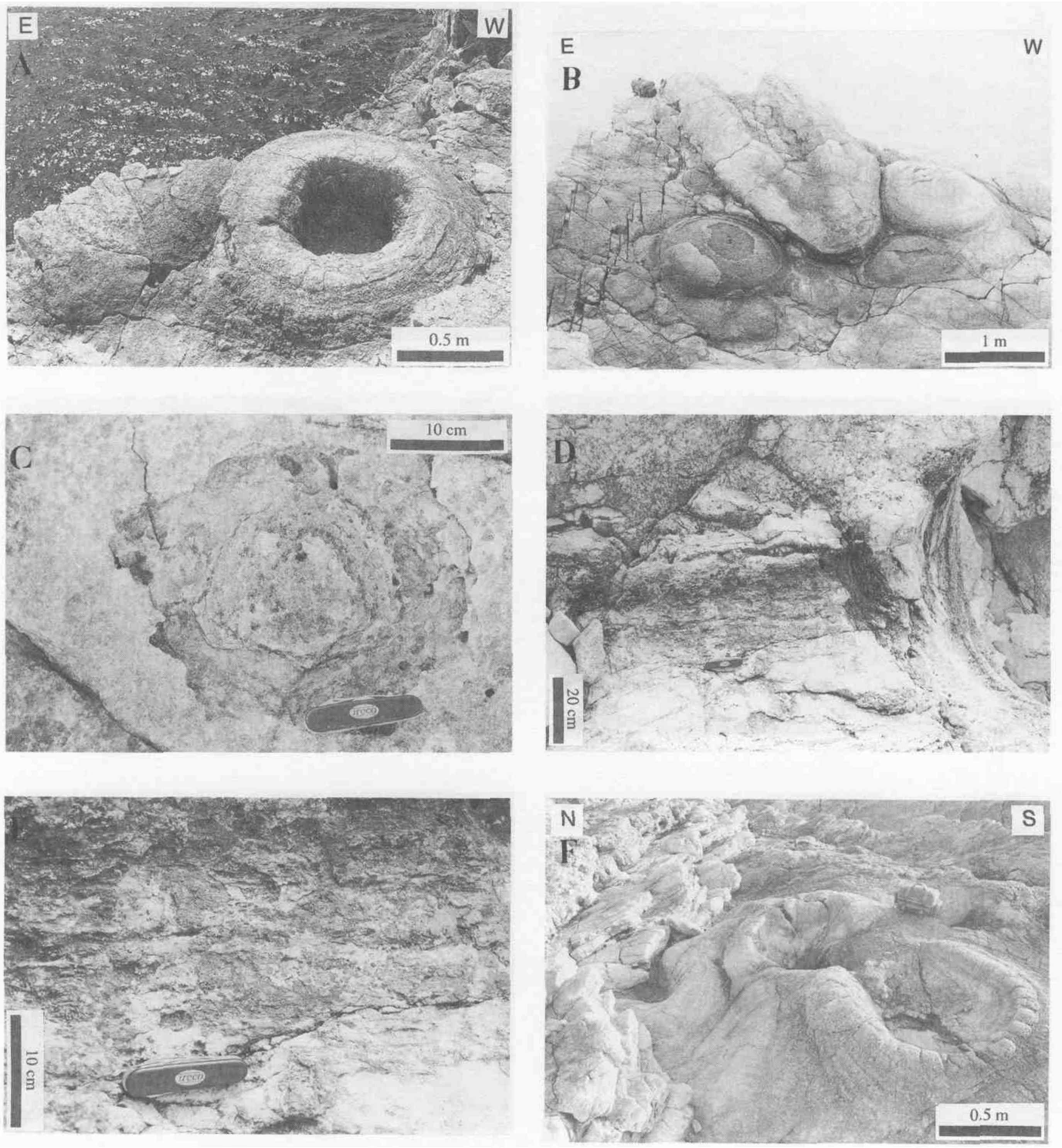

Figure 2 a-f: Typical mushrooms of structural level L2. The one in (a) displays a circular geometry with a totally empty neck perpendicular to the beds. The sea is at the background. Those in (b) display elliptic and circular geometries. The elliptic geometry results from erosion of mushrooms with a bed-parallel tube. The circular body to the right does not show the central tube, whereas the tube of the one to the left may be noticed through a 1 cm-wide circular hole, (c) Concentric rings of evaporite layers situated at the top of the mushrooms, (d) A strong striae lineation parallel to the axis of the central tube - shown in detail (e) parallel to the red knife, (f) Geometry resulting from the partial erosion of two mushrooms that shared room during evolution.

ultimate structural configuration of the Purbeck Beds in the Fossil Forest cliff may be envisaged: / - Start up of viscous How within the evaporite layers of level L3, leading to small-scale contemporaneous extension and contraction structures, followed by displacement of the layers above to form the tectonic melange (L4) and the Broken Beds (L5); 2 - Viscous How within the layers below the basal detachment leading to the mushroom and pillow-like structures of level L2; *3* - All the Purbeck Beds are tilted to the north, late in the tectonic inversion of the Wessex Basin. Further slip to the north took place within level L5 and contributed for the final shaping of the Broken Beds. This later deformation may have been facilitated by the large amount of a lubricant matrix of shale / argillite within level L5.

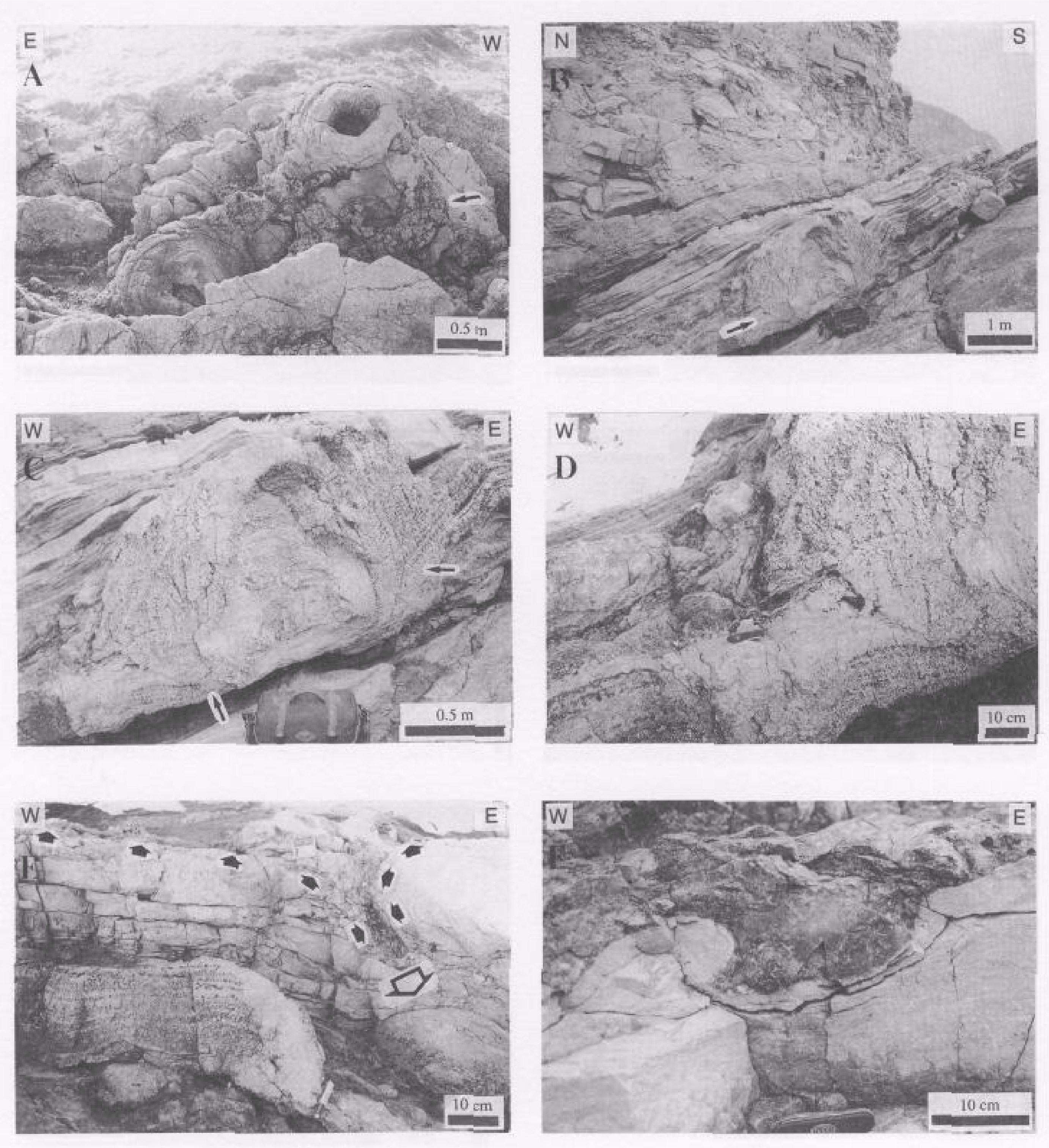

Figure 3 tt-f: The rim synclines and their evolution. Two typical mushrooms occur 1 m apart (a) with a lens of bluish gray chert (arrow) resting on the layer in between, (b) Vertical cross section of a mushroom to show that the lens of chert above arrow continues into the rim syncline indicated by the arrow itself - detail in (c). Note the thinning of the layers at the lop of I he mushroom. Layers of levels L3, L4, and L5 are shown above the mushroom, (c) More detailed view to show the two rim synclines (arrows) built in the same evaporite layers that turn around the head of the mushroom, (d) A close-up view of the previous picture to show chert entrapped in the rim syncline. (e) Two din-thick layers of evaporite that have been folded by down-sucking of the matter into rim synclines of partially developed mushroom. The pen rests along the axis of the lower syncline. whereas bluish gray chert fills the upper one. The black arrows point to the bottom of the chert and the larger arrow indicates the movement of the matter. The three upper arrows mark the original topographic position of the layer of chert before entrapment in the syncline. Note the thickening of the lens of chert at the top of the rim syncline, relative to the areas to the left and to the right, (f) Entrapment of chert inside two adjacent synclines of a 10cm-size and up-side down mushroom.

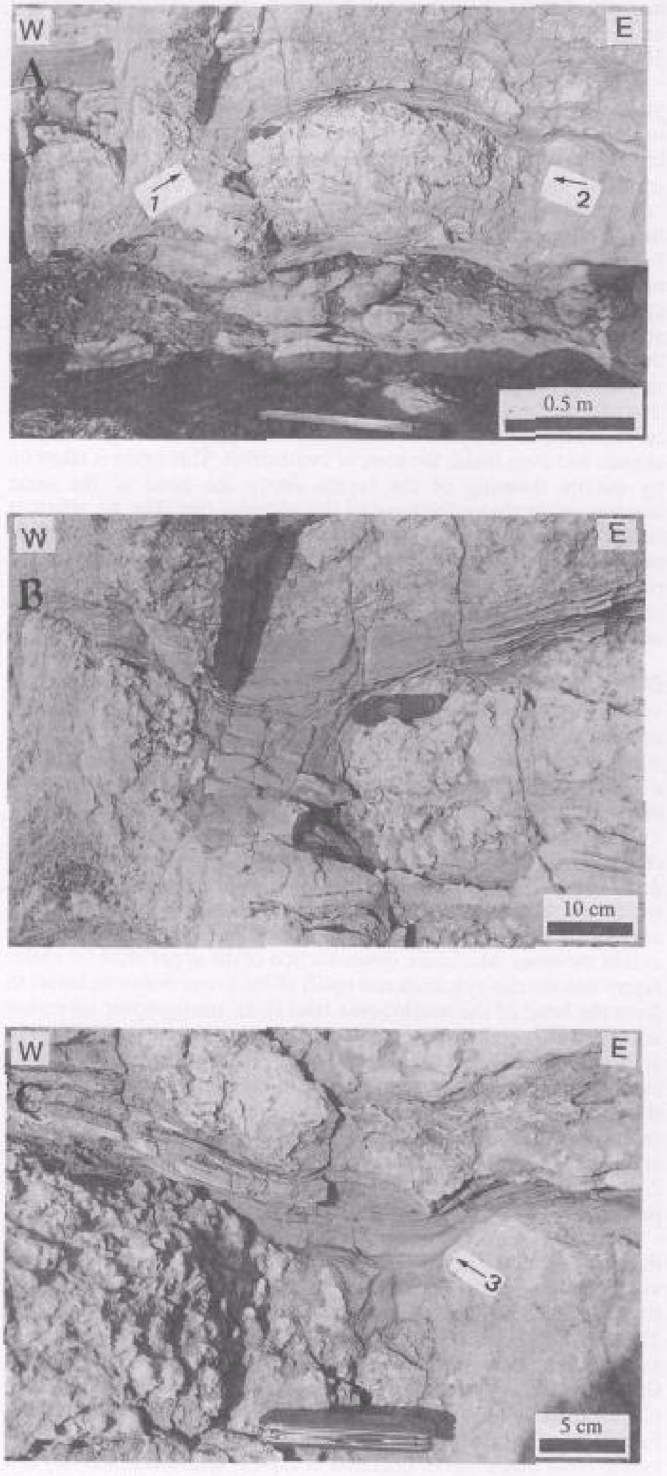

Figure 4 a-c : Progressive evolution of mushrooms, (a) The photograph shows the southern external wall of a mushroom that remains entirely preserved within the layers, to the north. Arrows I and 2 indicate the rim synclines. (b) Detail of the area around the knife [in (a)] to show the progressive thinning of the layers of shale, from inside to outside the rim syncline, and along its western and eastern upper borders. At the upper part of the syncline, the inner layers are iinconformably overlain by other layers (see above the knife) that preserve almost the same thickness laterally, (c) Detail of the rim syncline to the east [arrow 2 in (a)]. The layers of shale at the bottom of the syncline - the first ones to be entrapped - are pushed up by a vertical finger of evaporite (above the knife). Arrow 3 points to the upper border of the rim syncline where variation of thickness is noticed, similarly to (b).

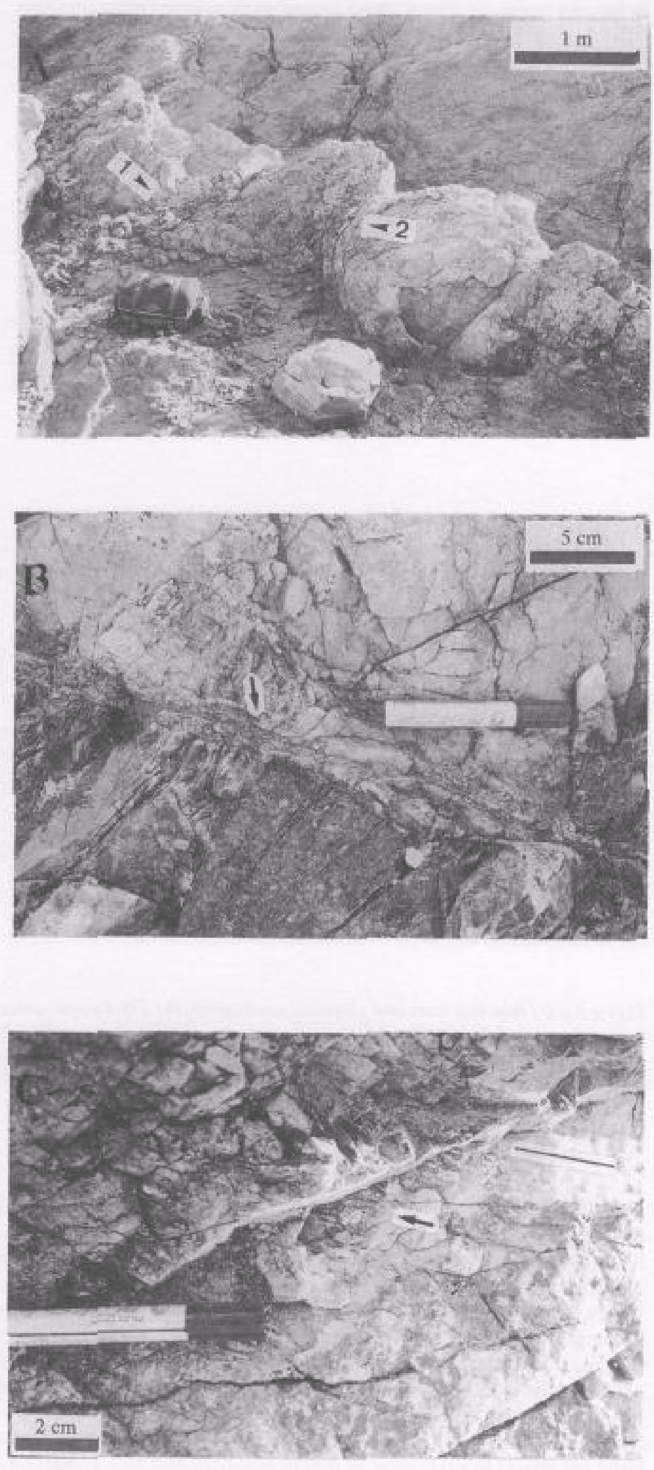

Figure 5 a-c : The outer surface of the mushrooms, (a) The preserved halves of two mushrooms with a chert layer entrapped in between and also in the syncline (between the arrows). Note the two pens for reference, (b) Detail of the area of arrow 1 (previous picture) to show a 1 cm-thick zone of ductile-brittle deformation (arrowed) developed along the chert-evaporite contact, (c) Detail of the area of arrow 2 to show a striae lineation (arrow) along the reference bar at the upper part of the photograph. The pen rests on the evaporite layer and the chert is to the left.

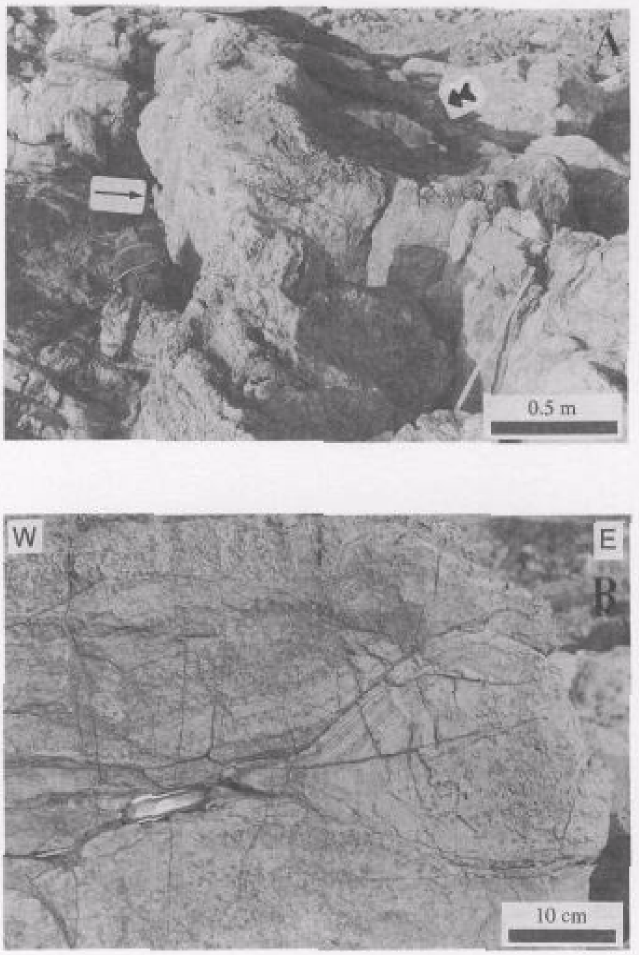

Figure 6 a-b : Rim synclines and elliptical mushrooms, (a) Thick arrow points to water accumulated in the ~ 1.5 in-long, east-west trending horizontal tube of an elliptical mushroom. Thin arrow points to the place detailed in the next pictures, (b) Lateral view of the mushroom with the knife at the hinge of a sub-recumbent rim svncline.

EVOLUTION OF THE MUSHROOMS In order to understand the evolution of the mushrooms, attention should be driven to key features provided by the layers of chert and shale that are entrapped and strongly deformed in the rim synclines (Fig. 3-4). In fact, chert layers commonly occurs in close association with the mushrooms, surrounding them or resting between two or more of these features (Fig. 3a). The chert layers are thickened inside the rim synclines, as well as at the upper part of these folds, relatively to the adjacent areas, and vanish towards the top of the mushrooms (Fig. 3b-d). The same is also valid for layers of shale. Going into the rim synclinc (Fig. 3e) the chert (or shale) is submitted to strong compression and acquires (in that particular case) a set of closely-spaced fractures, and the alignment of many of them leads to a set partition planes sub-parallel to the axial plane of the fold - such as a spaced cleavage.

The fact that chert (or shale) entrapped into the rim synclines is systematically well below its original topographic level (Figs. 3d-e) demonstrates that the mushrooms formed as a consequence of viscous flow during which layers of evaporite were pulled down and carried into the rim synclines, together with layers situated above (chert or shale) as indicated by the larger arrow in Figure 3c. Once the synclines turn around all the periphery of the mushrooms, the matter must have been pulled back and down towards a central point, like the one indicated by the blue bag in Figure 3c. In other words, the rim synclines correspond to the areas into which the evaporite layers were sucked down, and this movement led to a centripetal underthrusting of the evaporite layers and uplift of the top of the mushrooms. The vast majority of them are up-facing, but down-facing mushrooms of smaller scale may be also observed locally in the Fossil Forest outcrop (Fig. 3f).

The viscous flow is also demonstrated by evidence for a progressive evolution of the rim synclines, or suction zones, as in the locality of Figure 4, where the well-defined lamination of the light brown shale allows to identify subtle variations in thickness, from the inside to the outside of the rim synclines, as well as a kind of "unconformable" relationship between layers that are more internal in the synclines and others situated above (Fig. 4a-c).

Thickness variations and the "unconformable" relationship are tectonic features indicative of progressive entrapment into the rim synclines (Fig. 8): the first layers entrapped in synclines are thickened and leave no room for much more material to be sucked down, so that the last layers to enter in the rim syncline remain at the top of the folds and are only slightly thickened. The tectonic unconformity develops at that part because the suction of the layers into the rim syncline has to be accommodated by extension of adjacent parts of the same layers outside and even inside the zone of contraction. This strain is taken up by ductile thinning of the layers above the head of the same mushroom, or above the head of the adjacent one (Fig. 8), whereas layers coming later into the suction zone show less variation of thickness and truncate the borders of the layers that entered first in the rim synclines. Even the external limb of the syncline may be thinned or affected by extension faults, as a consequence of this process of underthrusting.

DISCUSSION Given that the mushrooms are a consequence of viscous flow within evaporite layers of level 2, and that this flow succeeded shortly in time the onset of the tectonic melange (level L4), why is it that the How in level L2 took place and why is it that it obeys a 3-D concentric pattern, rather than being directed to the west, as the initial flow in level L3 and above?.

The mushrooms of the Fossil Forest outcrop have all the characteristics of typical diapirs that Jackson et al (1990) described in detail in the Great Kavir of Iran, and interpreted as thermal convection structures: the overall shape, the rim synclines and the overall pattern of deformation associated, the central tube, the lineation parallel to the axis of the tubes. Moreover, down-suction of the upper chert (or shale) layers into the rim synclines and uplift of the lower evaporite layers to form the head of the mushrooms lead to an stratigraphic inversion normally associated to diapirism (Schenk & Jackson 1993). In addition, the contact relationships of Figure 5 may be taken as evidence for the radial friction between evaporite layers and others above, along the outer surface of the mushrooms. This friction and the central tube are due to the flow of the matter up and around the head of the diapirs (Fig. 8), as has been extremely well portrayed in Figures 2.8 and 2.9 of Jackson et al. (1990). But yet: why is it a thermal driven process?

Salt (or evaporite) layers have a viscosity that is naturally lower than that of other sediments, and is sufficiently close to the low viscosity that allows the critical Rayleigh number to be achieved, triggering thermal convection in these sediments (Jackson et al. 1990). These authors described thermal convection features much smaller or as big as the mushrooms of Lulworth Cove, and calculated that even a small increase in temperature is sufficient to make the natural viscosity of cvaporites equal to the critical value for onset of the process. Furthermore, the thermal conductivity of salt (evaporite) is a factor of two to three times higher than that of typical sediments, and this is a key factor for heat to be transported upwards, across the salt layers in order to facilitate thermal maturation of oil in the sediments above (Petersen & Lerche 1996). As the evaporite layers of structural levels L4 and L5 lost cohesion - giving rise to the melange and Broken Beds - they also lost the natural capacity for a sufficiently fast transport of the heat generated by friction along the basal detachment (level L3 / L4). Thus, it is quite realistic to think that going down into the cohesive layers of evaporites of level L2 the friction heat found a much more favorable way to dissipate. Finding a highly thermal conductive but sub-horizontal layer, heat had to dissipate very fast laterally, and thermal convection is the most efficient process if compared to other processes such as thermal radiation (Elder 1976). Another factor that may have significantly contributed for thermal convection to take place is the high salinity of the evaporite layers that West (1975) noticed

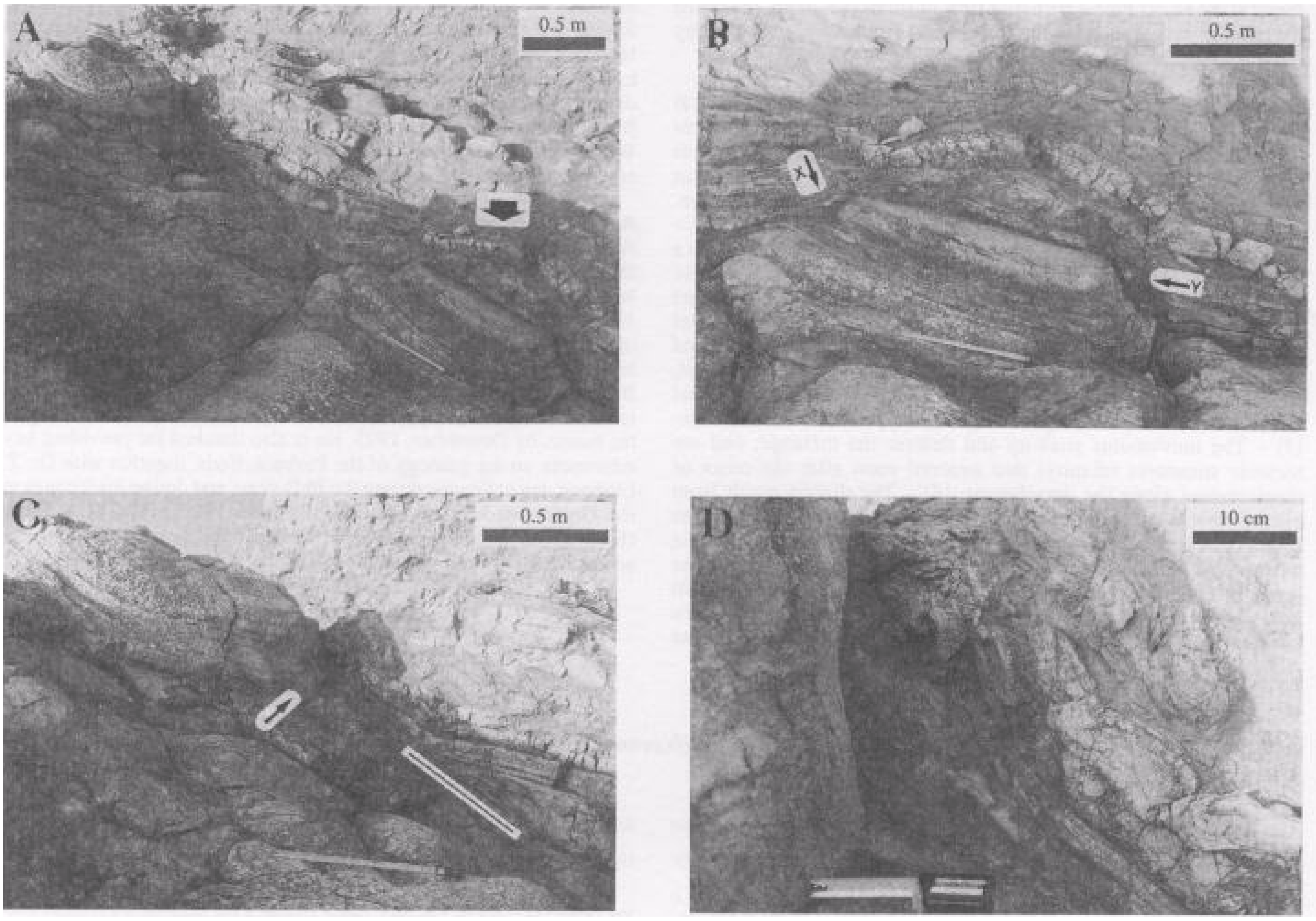

Figure 7 a-d : Mushrooms deforming levels L3 and L4. (a) Two mushrooms pushing up and deforming levels L3 and L4. The one to the right (thick arrow) deforms evaporite layers already incorporated to the tectonic melange, and the one to the left lies 50 cm above the level of the contact between levels L3 and L4. (b) Detail of the previous picture to show (arrow X) the tectonic melange curved down towards the rim syncline, and (arrow Y) the fracturing of a remnant of bottom layer of the melange, as it turned around the head of the mushroom, (c) Detail of (a) to show the mushroom 50 cm higher above the contact between levels L2 and L3 / L4 (just above the black bar). Arrow points to the place detailed in the next picture, (d) The layers of the interface L3 / L4 are strongly fractured / rotated and attain a sub-vertical dip around the mushroom.

across the southern coast of Dorset. High salinity is one of the factors that positively contribute to rendering the thermal convection process easier and more vigorous (Elder 1978). It may facilitate that micro electric-magnetic currents propagate within the layers: these currents are a key factor for convection of natural fluids, according to Van Heijst & Flor (1989) and, despite of the lack of further investigation, these currents may also be important for convection of rock matter with very low viscosity, such as salts and evaporites.

Once the bottom of the evaporite layers occur no more than 1-2 m below the bottom of the Broken Beds (West 1975, see Fig. 2b in the companion paper) and discounting the thickness of levels L4 and L3, then the best way for the quickest propagation of heat was laterally within the 0.5 m-thick blanket of level L2, where thermal conductivity should have been much higher than in the layers above and below. If so, the lateral propagation of heat within this horizontal corridor contributed for lowering even more the viscosity of the evaporite layers and helped to trigger thermal convection. This situation may explain the occurrence of the mushrooms along a single stratigraphic level at Lulworth Cove, and also across the several localities of the southern coast of Dorset, always at similar proximity to the lower contact of the Broken Beds (West 1975, his Figs. 2 and 3). His detailed study indicates that two stratigraphic levels with diapiric structures, such as those described here, are found only at the Perryfield Quarry, in the Bill of Portland (Fig. 2a of the first paper), and indicates that for all the localities the mushrooms are situated above layers of marl or the

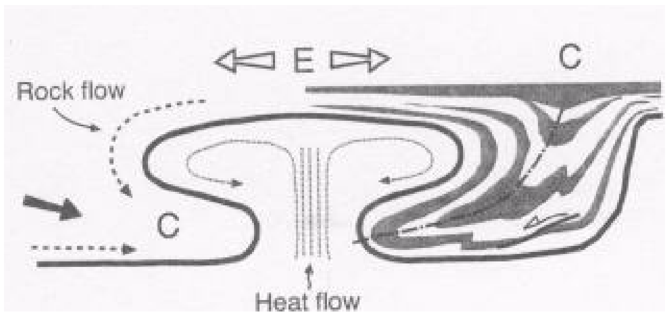

Figure 8 : Cartoon to represent the overall geometry of the mushrooms (thick line) and the main aspects of deformation of the layers outside. E = extension. C = compression. White arrows indicates flow of matter outwards of the top of the mushroom, and thick/ black arrow (left) indicates the vector of suction inwards the rim syncline, where layers are shortened by folding / thrusting (right).

Dirt Beds. These are the layers that contain the pillow-like structures found at the Fossil Forest cliff. The flow of fluids that likely generated the pillows may well mark the lower level significantly affected by dissipation of the friction heat.

CONCLUSIONS Among several other points of geological interest, the surroundings of West Lulworth, Dorset, southern England, also enclose outcrops of the Upper Jurassic Purbeck Beds along a cliff to the west of Lulworth Cove, at which tens of mushrooms and an impressive limestone breccia claim the observers' attention. Abundant field data summarized in this paper demonstrate that: (1) - The mushrooms are ~ Im-scale diapiric structures developed within a single set of evaporite layers that overly a set of marls and these display = 1 cm-thick pillow-like structures formed by an anastomosed array of zones where the rock acquires an internal, layer-parallel foliation; (2) - Mushrooms and pillows form a " 1 m-thick structural level situated above non deformed limestones and below another level, as thick as =1.3 m, in which a top-down to the west extensional detachment developed and gave Origin to a typical tectonic melange; (3) - The mushrooms push-up and deform the melange, and are tectonic structures (diapirs) that evolved soon after the onset of displacement along the detachment; (4) - The diapirs result from viscous flow in the evaporites, under a progressive down-suction of the layers back in the direction of an imaginary central point within the mushrooms - a centripetal movement leading to contraction of the layers by underthrust and formation of the rim synclines that exist all around. A sequence of progressive tectonic events has been established: *1* - A ~ 10 m-thick wedge of layers of evaporite, limestone and shale / argillite moved to the west, above the extensional detachment. Intra- and inter-layer slip within the wedge resulted in folding and fracturing of the layers and formed the Broken Beds. 2 - Heat due to friction along the basal detachment found the easiest way to dissipate along the evaporite layers situated below, generating the diapirs by thermal convection. *3* - Tilting of the whole set of Purbeck Beds to the north, as the result of the ultimate tectonic inversion of the Wessex Basin, with further movement within the Broken Beds contributing for its final chaotic appearance.

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