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CLAY DIAPIRISM IN THE LOWER EMSIAN LA VID SHALES NEAR COLLE, CANTABRIAN MOUNTAINS, NW-SPAIN

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ABSTRACT

Faults, tension-rupture, slumplike- and load-and-flamelike structures in thin carbonate intercalations in the Upper La Vid (Lower Emsian) shales NW of Colle are described. They are argued to have been caused or accentuated by clay diapirism. The paleoslope probably had no influence on this deformation process.

INTRODUCTION

This paper deals with certain irregularities in a mudstone unit with typical limestone banks and a limestone unit in the Lower Emsian Upper La Vid shales NW of Colle in the Cantabrian Mountains. Here, the Upper La Vid is very well exposed in an escarpment at long. 1° 33′ 47″ W. and lat. 42° 50′ 39″ N. The sequence is depicted in Fig. 1.

The upper part of the formation contains a large number of carbonate intercalations in a sequence of brown splintery, unfossilliferous shales.

The units A and C of Fig. 1 contain limestone intercalations. They are separated by shales of unit B, which show a fissility parallel to the bedding as given by the carbonate units. The same applies to the fissility in the shales on top of unit C and below unit A. Unit C contains the only known coral-biostrome of the La Vid Formation (B r o u w e r, 1964). Under the influence of heavy storms, which temporarily interrupted the anoxic conditions during which the shales were deposited, the fauna of unit A and C was able to develop (S t e l, 1975). The recognition of individual levels within these units has permitted to determine the displacement of parts of the units.

DESCRIPTION OF THE UNITS A AND C

Mudstone unit A (Fig. 2) can be subdivided into three sub-units, which are A_1-A_2-A_3. It appears that the completely developed unit has a very limited extension. Some hundreds of meters NW of Colle only A_1 and A_2 are found.

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Sub-unit A_1 consists of blue-grey mudstone. Its lower limit is characterised by thin marly limestone strata (Fig. 2). Locally, the mudstone gradually passes in the underlying dark-brown shales which frequently contains early diagenetic, marly and ferrigenous, yellow-brown concretions. In the mudstone only a few fossiltypes occur, the most typical of which are: *Euryspirifer paradoxus, Devonochonetes* sp., *Uncinulus pila, Platyceras* sp.

Sub-unit A_2 consists of nodular dark-grey limestone with a sharp basal and upper limit (Fig. 2). It is a close to very close-packed bioclastic packstone with a shaly matrix. The bioclasts are mainly from crinoids and brachiopods. Deformation structures like overthrusts and pull-apart structures are well observable in A_2.

In the other sub-units they are difficult to pursue due to homogeneity of the rock. A_2 has been interpreted as a storm deposit (S t e l, 1975).

Sub-unit A_3 consists of blue-grey mudstone like A_1. It has a sharp contact with A_2 and gradually passes into the overlying dark-brown shales of unit B. The fossils are similar to those found in A_1, but more individuals occur. *Uncinulus pila* is frequently found. In some places thin, dark-grey, marly limestone levels occur with the same fossil content as the mudstone. These levels probably developed diagenetically.

Limestone unit C (Fig. 1 and 3) is subdivided into four sub-units, which are C_1-C_2-C_3-C_4. To the NW of Colle unit C is exposed over a distance of 2 km. To the south the unit is traceable over a distance of 100 m only.

Sub-unit C_1 consists of dark-grey limestone which is very similar to that of A_2 and which has also been interpreted as a storm deposit (S t e l, 1975). C_1 has a sharp contact (Fig. 3) with the underlying dark-brown shales. Its base exhibits load- and flamelike structures. The upper part gradually passes into the cemented debris of C_2. Faults are well traceable into overlying levels.

Sub-unit C_2 mainly consists of fragments of *Disphyllum* sp. in a shaly matrix. Tabulate corals, a majority of which has been preserved in life position, are represented by favositids and alveolitids. Stromatoporoid sponges occur. They sometimes have a diameter of about 75 cm. Brachiopods are rare except *Atrypa reticularis*. Locally the matrix has slightly

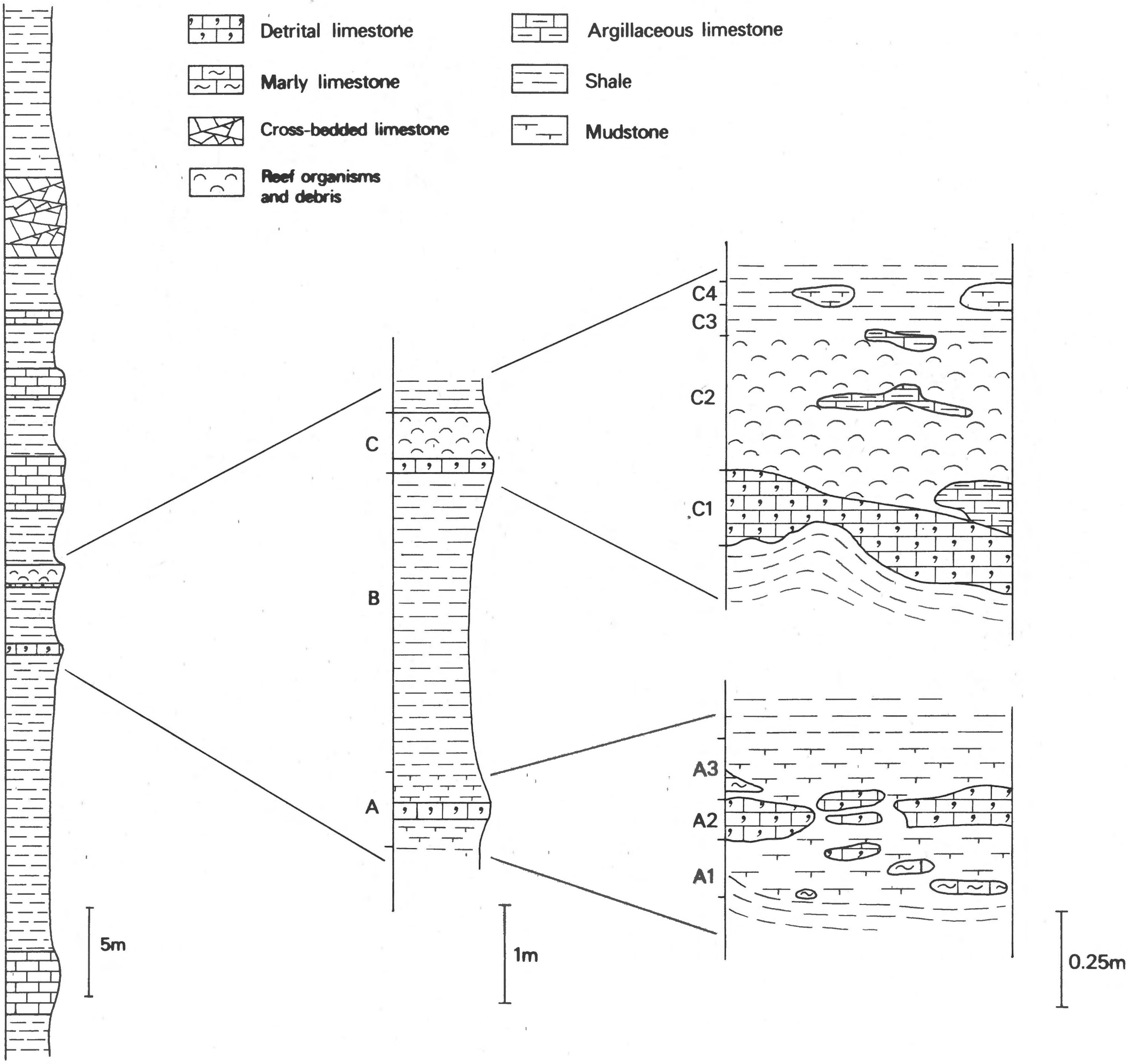

Fig. 1
Lithological column of the Upper La Vid NW of Colle and composition of the units A and C.

been calcified diagenetically as a result of which limestone levels developed.

Sub-unit C_3 consists of thin dark-brown unfossiliferous shale beds in and on top of C_2 (Fig. 3). The shale is very similar to that of unit B.

Sub-unit C_4 consists of nodular, light-grey, limy mudstone. It is about 5 cm thick. The fauna consists mainly of very small brachiopods as *Dalmanella* sp.

STRUCTURES IN THE UNITS A AND C

Faults. Both units are frequently disrupted by normal faults. Fig. 2 shows a southward directed overthrust in unit A with a horizontal displacement of about two meters.

In the footwall, unit A exhibits a large number of normal faults with a sense of displacement opposite to that of the overthrust. The number of normal faults increases northwards.

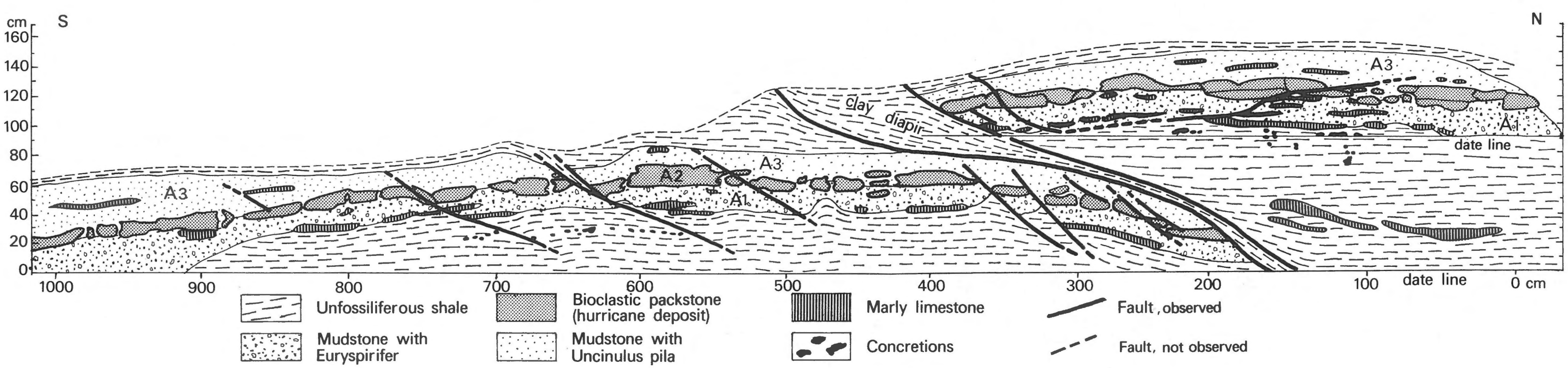

Fig. 2
Section of unit A from the Upper La Vid at 100 m. SE of the Ermita de Colle. This unit can be subdivided into three sub-units, which are A_1-A_2-A_3. Unit A lies amidst shales with a good bedding fissility and no benthic organisms. The lower permeability of unit A compared to that of the underlying clays created an obstacle for the escape of pore water from the clay. This results in an increased fluid pressure which eventually was able to break and partly lift unit A at weak points as for example where thinning is a primary feature. The expulsion of water caused clay diapirism. The developing diapir lifts one part of the unit and together they overthrust the other part. This lower part sinks into the clay and as a consequence breaks along normal faults. The increase in length of the footwall due to this faulting and the lack of comparable deformation in the overthrust part supports the idea that the kinematic pattern was of underthrusting of largely stationary residual lenses.

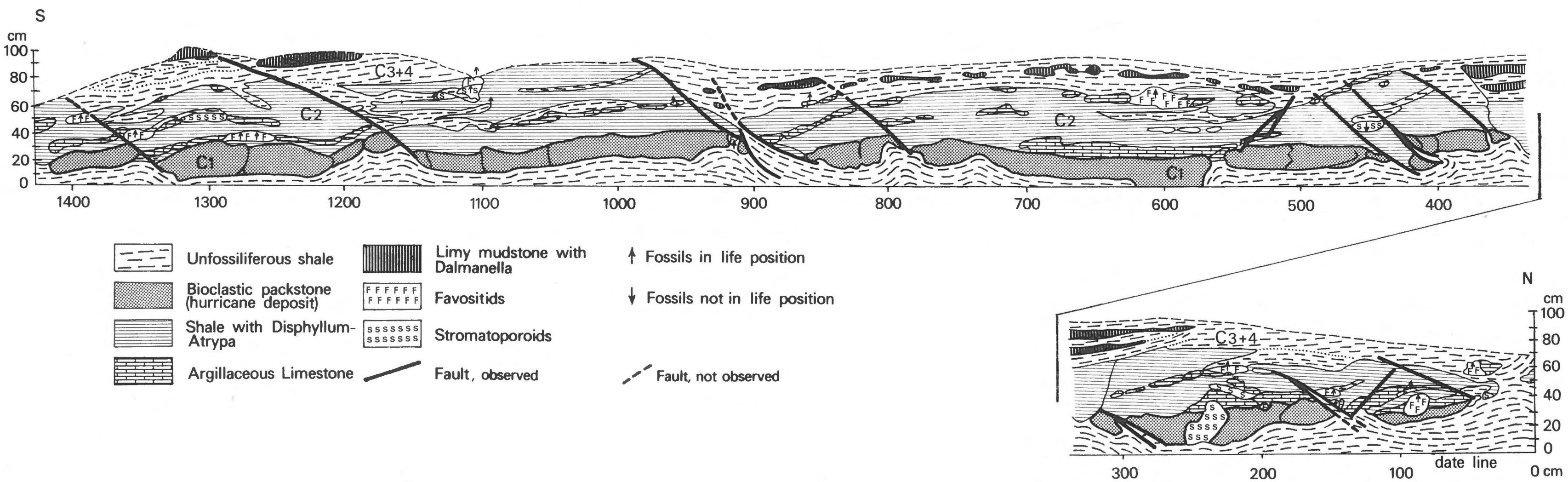

Fig. 3
Section of unit C from the Upper La Vid at 100 m. SE of the Ermita de Colle. The unit can be subdivided into four sub-units, which are C_1-C_2-C_3-C_4.

Fig. 4
Slumplike structures in unit C at 125 m. SE of the Ermita de Colle. The structure is the result of clay intrusion.

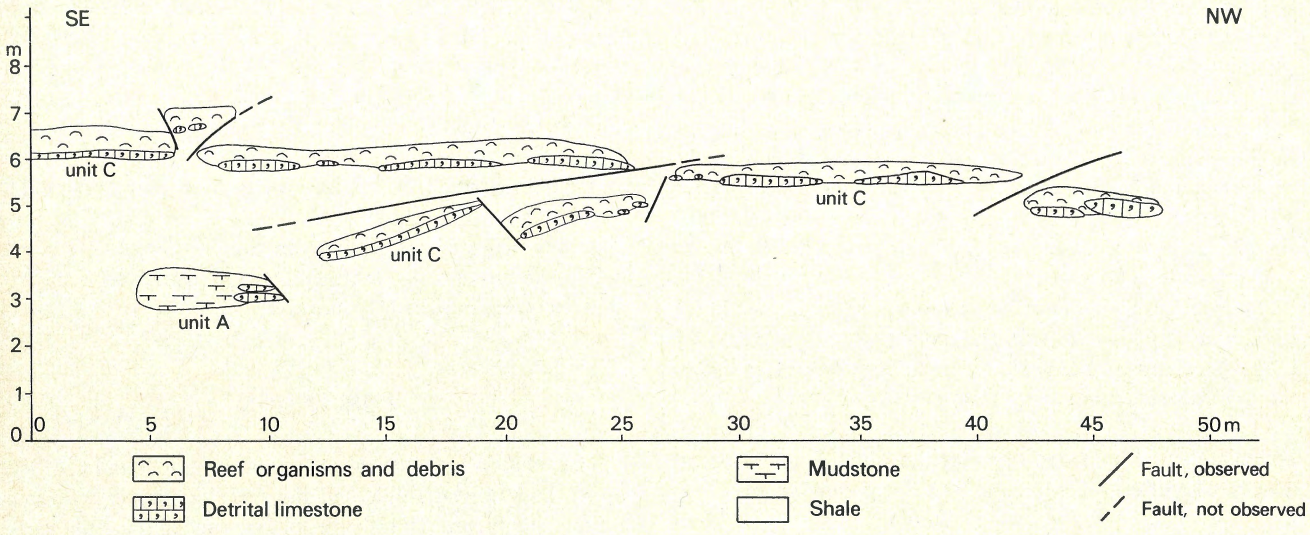

Fig. 5
Schematized section of unit C about 750 m. NW of Colle. The SE part of unit C has been thrust over the NW part over a distance of fourteen metres, as the result of clay diapirism.

Locally the overlying clay of unit B forms wedges into unit A along fault planes. The overthrust is characterised by a zone of shale with thrust-parallel orientation of the fissility, which is at an angle with that of the surrounding rock. This shale zone will be argued to represent a clay diapir. Fig. 3 shows comparable structures in unit C.

It can be observed that the normal fault located at point 900 cm., caused a separation of the top of C_2 of about 80 cm. The normal fault located between 1,300 and 1,400 cm., shows a colony of *Favosites* sp. to be displaced over a distance of 25 cm. Both fault walls show slickenslides in dipslip direction on the fragments of the colony.

At some localities unit C thins out completely. The fissility of the shale on both sides of the unit remains parallel to it (see Fig. 3, point 20 cm.). These structures are interpreted as tension-rupture structures.

Apart from the above mentioned small displacement during which the units were not disrupted, dislocations are also found in which parts of unit A or C were transported over a distance of several metres (Fig. 2). In these cases the fissility of the shale parallels the faults and is at an angle with the normal bedding fissility. The vertical displacement was mostly less than one metre.

The structures described above are the result of local lengthening and shortening of the unit in horizontal direction.

Load- and flamelike structures. These structures have only been observed in unit C. During the deposition of C_1 load and flame structures probably developed. As the fissility of the underlying shale parallels the lower contact of C_1, even in these structures, most of the original load and flame structures are supposed to have been accentuated during the deformation of unit C. Flamelike structures developed by injection of clay along fault planes or by slumping of parts of the unit (Fig. 3, point 400 cm.).

Diapiric structures. The fissility of the shales below and on top of unit A (Fig. 2) is related with the deformation structures of the unit. Normally it parallels the lower and upper limit of the unit. Where fault planes cut the unit, the fissility is however subparallel to these phenomena (Fig. 2). Similar structures are found in unit C (Fig. 4 and 5). They are considered as clay diapirs. In unit A only one diapir was found but in unit C several diapirs occur with different or even opposite inclination.

The thickness of the units was probably important in the development of the diapirs. The limestone beds above unit C (Fig. 1) are mostly between 2 and 2.5 metre thick and show no diapiric structures but only a gentle flexuring. About 1.5 km NW of Colle their thickness is less and structures comparable to those described in the units A and C occur. The spacing of clay diapirism in unit C is about 100 m.

HYPOTHESIS

Structures of similar appearance to these described are frequently reported from turbidity current deposits (D z u l y n s k i & W a l t o n, 1965). However this depositional mode does not apply to the rocks of the units A and C. C l o o s (1961, 1964) considers similar structures to have been developed by bedding plane slip under the influence of gravity. The contrasting directions of the structures near Colle do not point to such a mode of origin. C r o w e l l (1957) gives some photographs of pebbly mudstones with structures that show a morphology similar to those found near Colle. He explained them as the result of mixing and slumping at the sea-bottom when gravel was deposited upon mud.

Relevant to an explanation of the structures is that the La Vid shales do not show true cleavage but a bedding plane fissility, and that within the units the fissility of the shales parallels the faults (Fig. 2). This points to a plastic behaviour of the clay during the deformation process. It is not possible to explain the structures as the result of the folding of the area because firstly no dominant direction of the diapirs occurs. This would be expected if the structures had developed as minor folds on the limbs of the Felechas syncline. Secondly tectogenesis of the area is of Westphalian age (R u p k e, 1965) and by then at least 1,200 m. of sediment had been deposited upon the La Vid which would have resulted in compaction of the clays to such a degree that plastic behaviour of the clay, as suggested by the diapirs, could probably not occur.

It is thought that during the early compaction of clays the fluid pressure increases. This pressure depends on the rate of formation of pore water and on the rate of escape of this water (P o w e r s, 1967). If the escape is slow the fluid pressure may exceed the overburden and eventually disrupt the unit.

If we assume that the units A and C originally possessed a lower permeability than the underlying clays it may be postulated that an increasing fluid pressure built up below these units. This led to an unstable situation which was triggered by an earthquake or tidal wave, causing disruption of the unit and clay diapirism. As destinctly different directions of the diapirs were found, the paleoslope seems to be of little influence on the process. Slumplike folds (Fig. 4) in unit C are ascribed to bending of parts of this unit at the contact with a diapir and as the result of the clay intrusion. The uninterrupted parts have an average length of about 100 m. The hypothesis outlined above is illustrated with two field examples in the Fig. 2 and 6.

CONCLUSION

The relation between the structures in unit A and C of the Upper La Vid near Colle, and the shale fissility is explained by clay diapirism. This diapirism occurred during the early compaction of clays. The direction of the diapirs shows that tectogenesis of the area did not influence the structures and that the paleoslope was not important during the deformation process.

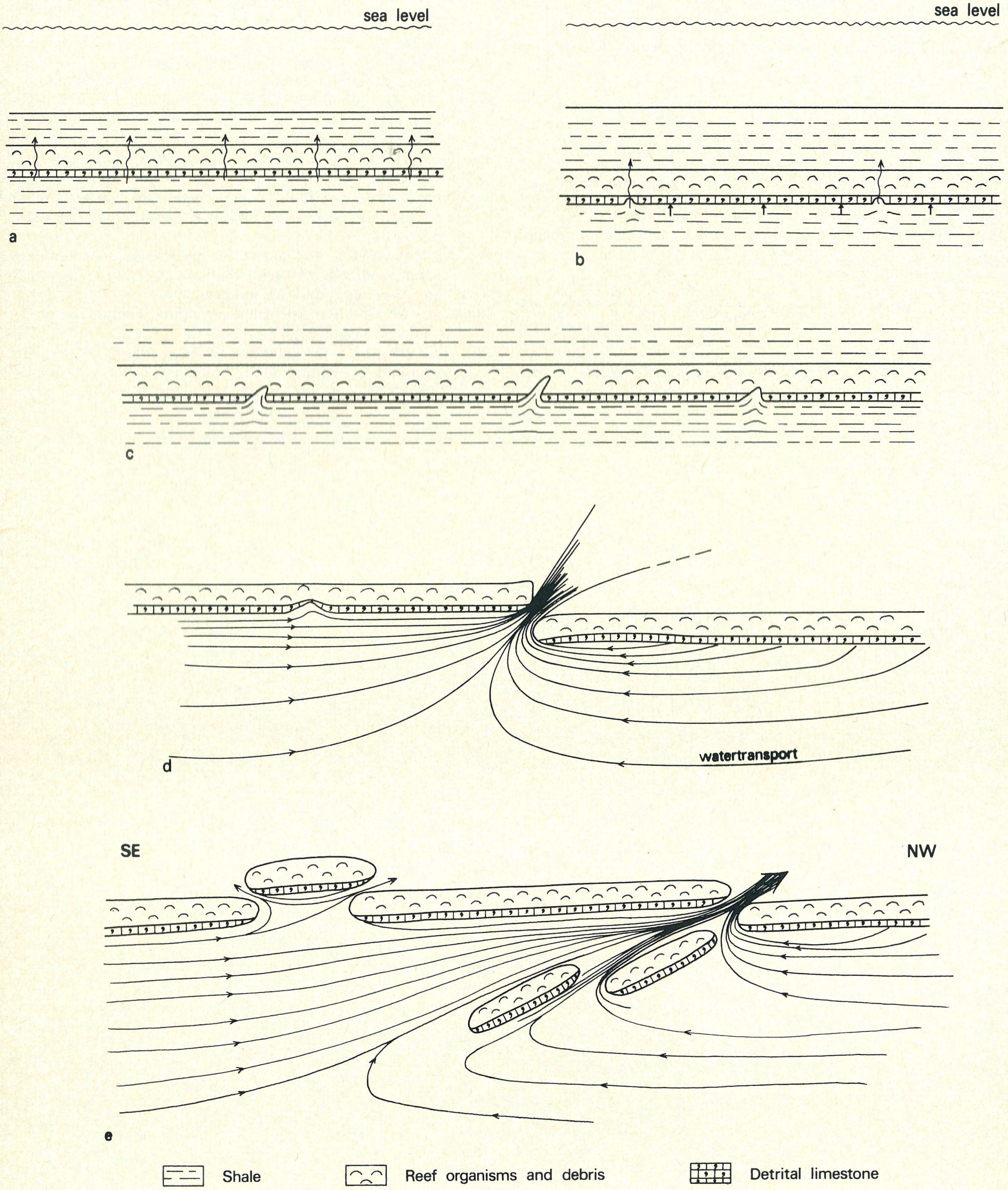

Fig. 6
Deformation model of the section depicted in Fig. 5. The difference in permeability between unit C and the shales causes a stress to build up (a). This results in the enlargement of deformation marks (b, c). When these break through the unit, a self generating clay diapirism starts (d) during which peripheral sinks and pull-apart structures develop (e). The boxlike fold in the SE part of the section probably started to develop under the influence of a secondary diapir.

The thickness of the limestone units was probably important. The spacing of clay diapirism in unit C is about 100 m.

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