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OCCURRENCE OF CALCITE PSEUDOMORPHS AFTER GYPSUM IN THE LOWER CARBONIFEROUS OF THE VESDER REGION (BELGIUM)

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ABSTRACT. - A 5 m thick palisade calcite member occurs on top of the Vesder dolomite and below the Vesder breccia member. It is distinguished by an accumulation of several successions consisting of three subunits : (A) an intraformational conglomerate containing fragments of calcite rosettes eroded from subunit C; (B) a grumelous microsparite-micrite layer; and (C) the palisade calcite. The latter subunit is composed of large vertically oriented conical calcite rosettes. They are interpreted as calcite pseudomorphs after gypsum. Indeed, they show similar features as the gypsum clusters described from the Solfifera Series (Messinian) of Sicily. The successions are deposited in an environment ranging from intertidal to supratidal and restricted.

The recognition of the palisade calcite as pseudomorphs after gypsum gives a better understanding of the many phenomena associated with evaporitic sedimentation conditions and evaporites.

INTRODUCTION. - The discovery in the Lower Carboniferous of Belgium of evaporite deposits in the St-Ghislain bore-hole (DEJONGHE et al. 1976, DELMER, 1979), of silicified nodules of anhydrite near Vedrin (HENNEBERT and HANCE, 1980) and of pseudomorphs after gypsum, anhydrite and possibly halite in the Ourthe Breccia and in the overlying Visean strata (JACOBS et al., 1981) has greatly renewed the interest in these strata. The recognition of evaporitic sedimentation conditions has important implications for the paleogeography, for the possible occurrence of energy resources and for the metallogeny of ore deposits. The relation between evaporites and ore occurrence, however, is not yet well understood e.g. the role played by solutions derived from dissolving evaporites as metal carriers and as a control in channeling the ore solutions from deeper parts of geological structures.

The present paper is intended as a first report on the presence of fibrous palisade calcite beds in the Lower Carboniferous in E. Belgium. Their interpretation as pseudomorphs after gypsum and their sedimentary environment will be discussed.

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OCCURRENCE AND GEOLOGICAL SETTING.

The fibrous palisade calcite beds occur in the Vesder syncline. They are well exposed in the limestone quarry near Walhorn (Figure 1).

The general stratigraphy of the Dinantian near the Tournaisian-Visean boundary (Ivorian-Moliniacian) is given in figure 1. Paleogeographically, the Dinantian carbonate rocks are deposited in a semi-restricted shallow shelf environment. To the north, the Brabant Massif and the Booze-Le-Val Dieu high occurred; to the south and southeast the so-called Aachener shoal was present (BLESS et al. 1980).

The lower unit consists of brown to brown-grey dolostones and belongs to the Formation of the Vesder Dolomite. Chert nodules, geodes and crinoids are present in varying amounts. The occurrence of mud cracks and of relicts of birdseyes near the top of the dolostones indicates an inter- to supratidal sedimentation environment for the original carbonate phase (SHINN,1968). The lithogeochemistry (SWENNEN and VIAENE, 1981, and research in progress) of these dolostones is characterized by relatively high Na contents (Na : $\bar{x}$ about 180 ppm) pointing to a hypersaline nature of the dolomitizing solutions.

The top zone of the Formation of the Vesder Dolomite consists of two members : the palisade calcite, and the Vesder breccia. The palisade calcite member is composed of grey to blue-grey limestones, often characterized by rosettes of coarse-grained, fibrous and radiating calcite crystals. The Vesder breccia member is composed of greybrown dolostone fragments of different size cemented by a brown fine-grained dolomite. Slumping and collapse structures are present. Both members are well exposed in the Walhorn section. In other sections, however, the palisade calcite is absent and the Vesder breccia, if present, is very reduced in thickness. The top of the Vesder breccia shows a thick dedolomitization zone, indicating a paleo-surface.

The dolostone breccia is followed by a limestone breccia, equivalent with the Ourthe breccia of the Dinant basin, which is of V1b age (Lower Moliniacian). It is composed of bluish grey limestone fragments of different size in a grey matrix of micrite and microsparite. This limestone breccia as well as the Vesder dolostone breccia are interpreted as evaporitic collapse breccias (JACOBS et al. 1981). The main arguments for this interpretation are the occurrence of slump and collapse structures and of calcite pseudomorphs after gypsum, anhydrite and probably halite (Plate 1A).

On top of the limestone breccia, an important sequence of limestones of V2a age (Upper Moliniacian) starts. It is characterized by oölites, pellets and intraclasts. It can be correlated with the Formation of Terwagne and Neffe of the Dinant basin and with the Vaughanites oölites of the Aachen region (KASIG, 1980). An inter- to subtidal sedimentation environment is supposed.

In the following paragraphs, the petrography and features of the palisade calcite member are described in detail. They were obtained by peel replicas (KATZ and FRIEDMAN, 1965) and thin sections.

THE PALISADE CALCITE.

The total thickness of the palisade calcite member, as exposed at the Walhorn section is about 4.80 m. It is composed of

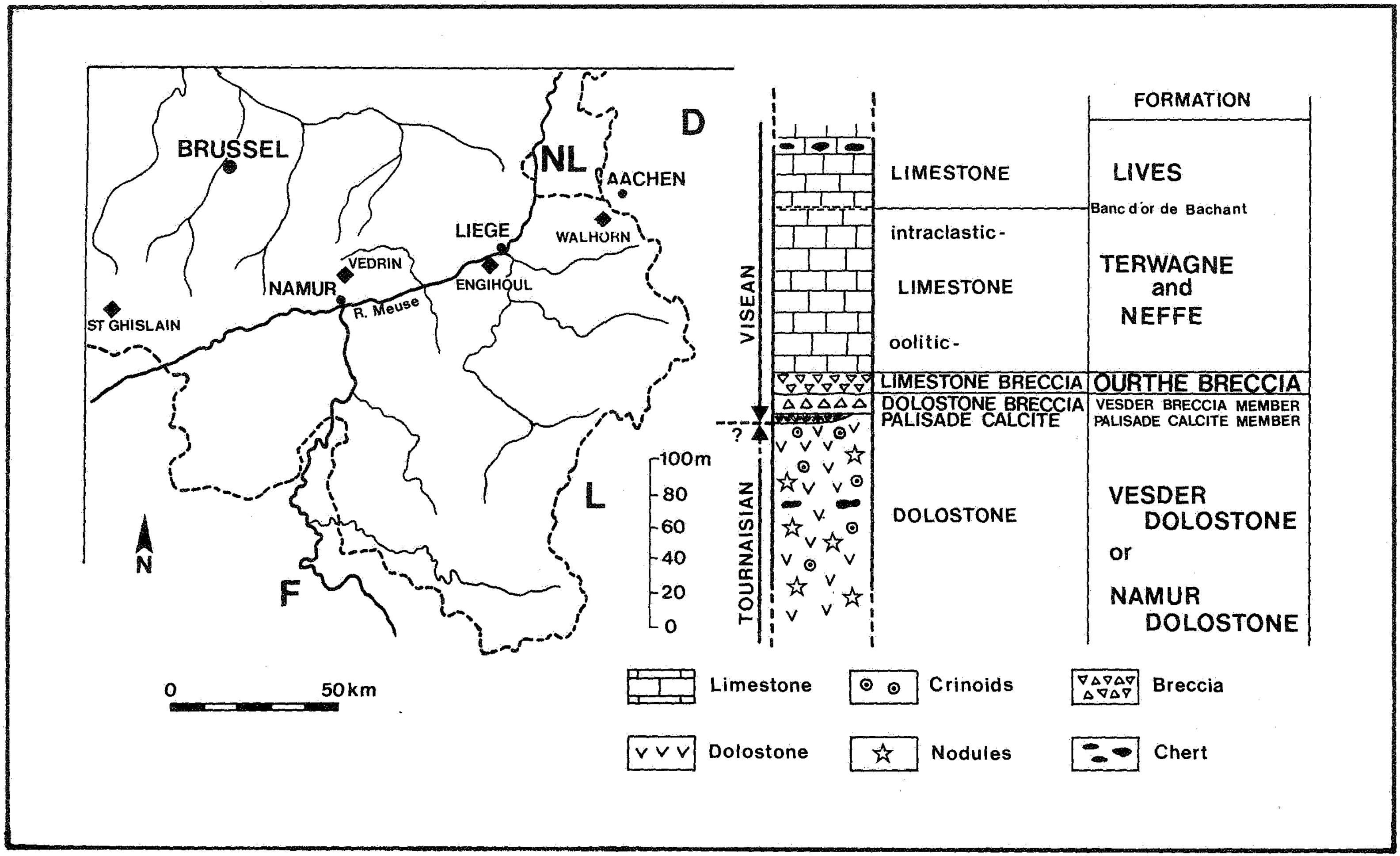

Figure 1 - Situation map and general stratigraphy of the Dinantian (Tournaisian-Visean boundary) in the Vesder basin.

concordant layers, displaying sharp contact with the underlying dolostones and the overlying breccia. The bluish grey limestones are macroscopically often characterized by rosettes of fibrous radiating calcite crystals. The maximal lenght of the crystals is about 2 cm. In other zones a conglomeratic to pseudo-breccoid character can be distinguished.

Detailed microscopical examination of acetate peels and of thin sections revealed a generalized sedimentpetrographical succession of three subunits (Figure 2).

Subunit A : INTRAFORMATIONAL CONGLOMERATE AND BRECCIA.

Subunit A is characterized by coarse fragments of monocrystalline calcite (Plate 1 B) and of micritic to microsparitic limestone. The fragments normally measure 3 to 6 mm but may also reach 5 cm. They are mostly rounded, but sometimes they are irregular. The long axes of the fragments lie very often parallel to the bedding. The fragments are frequently broken into smaller pieces, still fitting into each other. Some fragments consist of entire or broken calcite rosettes (Place 1C). Initial micritization of the calcite fragments is often present. It always starts from the matrix, causing an irregular border or a semi-poicilitic texture in the fragments.

The matrix itself consists of a mixture of micrite and calcite sand with a grain size ranging from 80 to 500 μm.

Subunit B : GRUMELOUS MICROSPARITE-MICRITE.

This subunit is characterized by microsparitic to micritic limestones, often vaguely pelletoidic and with a grumelous and mottled texture. Adjacent pellets may be intergrown. Locally a laminated texture is present by the alternation of grumelous micrite and microsparite patches (Plate 3A).

Some broken ostracod shells and algae are present. A zone with some broken foraminifera tests has been observed only once. The fossils are partly micritized. The following fossils could be recognized : *Palaeobereselleae (kamaena ?)* and *Pachysphaerina pachysphaerica*. The last fossil points to a Visean age (CONIL and LYS, 1964). The fossil enriched zones are always associated with birdseye structures. In this subunit, irregular fragments of dolostone are also present. Detritical quartz grains are found over the whole unit. Authigenic quartz, however, is only present in purely micritic patches.

Subunit C : PALISADE CALCITE.

More or less vertically oriented conical calcite rosettes or clusters with a cauliflowerlike surface, are the most spectacular feature of this subunit. Frequently several subsequent layers of rosettes occur. They are always oriented in the same way with their nucleus at the bottom and their fan at the top (Plate 2). The nucleus is micritic to microsparitic; from the nuclei coarse triangular crystals are developed. A preferred orientation is demonstrated by the common optical extinction of adjacent crystals. Part of the crystals are twinned; their twin plane is always perpendicular to the bedding (Plate 3B).

Locally, growth rhythms are found in the palisade calcite (Plate 3C, 4B). They are marked by thin layers of microsparite; crystals of the lower rosette sometimes act as nuclei for the

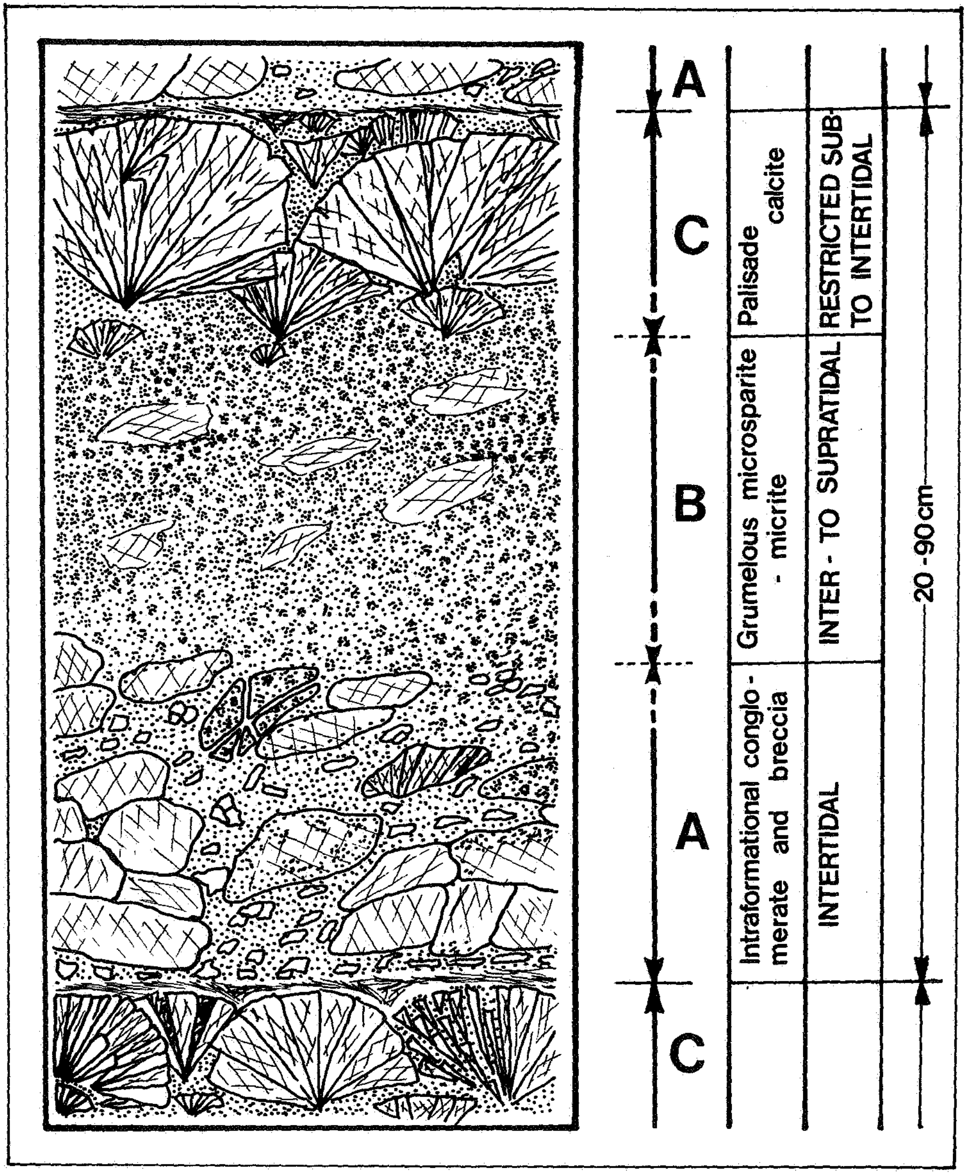

Figure 2 - Generalized sediment-petrographical succession of the palisade calcite member.

following layer of rosettes. The palisade calcites are rarely dolomitised. In contrast with the irregular dolomite fragments of subunit B, the dolomite crystals here occur as poorly developed rhombohedrons, scattered over the rosettes. Many detritical quartz grains also occur as inclusions.

Another striking feature is the occurrence of broken crystal fragments between larger well-developed crystals of the rosettes (Plate 4A). Also microsparite occurs between the crystals. Moreover the tops of the crystals are often corroded.

The last palisade rosettes of each succession, often partly eroded, are always covered by a thin layer of clayey material with mud cracks. In this clay-rich layer many small pyrite crystals are found.

The sequence given in Figure 2 is idealized. In the studied section, it is often incomplete and gradual transitions between the different subunits are apparent. The average thickness of a complete succession ranges between 20 and 90 cm. Subunit A, the intraformational conglomerate is thicker in the lower part of the member while the palisade calcite predominates in the upper part. Dolomitization also increases to the top of the member.

INTERPRETATION.

The main features i.e. the constant orientation of the calcite rosettes, the different sequences, the development of growth rhythms, the occurrence of broken crystal fragments between crystals of the rosettes, as well as the reworked conglomeratic palisade crystal fragments of subunit A, all point to a sedimentary origin of these structures. The interpretation by BOONEN (1981) of the palisade calcite of Walhorn as sparry infillings of cavities and holes can not explain the observed features. A correlation of this unit with the "fibrous (palisade) calcite spar" in the Aachen region (KASIG, 1980) seems probable, but has to be verified.

The problem, however, remains how calcite could grow in a sedimentary environment to form the rosette structures. Because of the morphology and the twinning of the crystals it is more acceptable that the palisade calcite crystals are pseudomorphs after gypsum (variety : selenite), which have grown in an evaporitic environment. This interpretation is also supported by the fact that the overlying dolostone breccia and the Ourthe breccia correspond to evaporitic collapse breccia (JACOBS et al., 1981). Similar gypsum structures, not altered to pseudomorphs however, are described by RICHTER-BERNBURG (1973) and HARDIE and EUGSTER (1971) from the Miocene Mediterranean basin, by ILLING et al. (1965) from the Persian Gulf and also by HARDIE and EUGSTER (1971) from Australia, in recent formations.

RICHTER-BERNBURG (1973) divided the coarse crystalline gypsum into two categories : a "grass-like" form with crystals between 5 and 50 cm and a "cavoli-cabbage or cauliflower" form with crystals between 1 and 10 m. In spite of the difference in size, we believe that the "cavoli-cabbage or cauliflower" form with its original structures (e. g. the vertically oriented rosettes, the cauliflower-like surfaces, the twinned crystals) have been preserved through the pseudomorphism in the palisade calcite member from the Vesder basin. The original gypsum composition may also explain the fact that this member has not been dolomitised in contrast with the under- and overlying strata.

From this new interpretation, the observed succession (Figure 2) in the palisade calcite member can be paleogeographically explained.

Subunit A, the intraformational conglomerate, contains fragments of the underlying gypsum rosettes. The gypsum sand, now described as calcite sand, also originates from erosion of the gypsum crystals. This unit could be the equivalent of the "resedimented calciumsulphate, rudites, arenites and arenitic marls" of SCHREIBER et al. (1976) or of the "gypsum crystal conglomerates" of HARDIE and EUGSTER (1971). The transported fragments as well as their orientation indicate a strong erosion and a current agent. Subaqueous transport probably took place over short distances, before sedimentation occurred for instance along a coast-line zone. Such strong currents were also supposed by HARDIE and EUGSTER (1971) to explain parts of the Solfifera Series in Sicily. It is to be remarked that crystal fragments of up to 5 cm occur in the conglomerate. Such large crystals are not exposed in the Walhorn section. Therefore it is not excluded that not far from the described palisade calcite large crystals have been developed. The conglomerate fragments clearly show initial micritization, which causes sometimes a poicilitic texture. This micritization seems to be related to a shallow sedimentation environment. The above-mentioned features point to an intertidal sedimentation environment.

Subunit B, the grumelous microsparite-micrite shows the common features of calichification textures in the sense used by WILSON (1975). The rare occurrence of broken foraminifera tests and of ostracod shells, as well as the dolostone fragments are of inflow origin. An inter- to supratidal sedimentation environment for this subunit is also indicated by the birdseye structures.

Subunit C, the palisade calcite, has been interpreted as pseudomorphs after gypsum in the foregoing paragraphs. The uppermost rosettes are often eroded and broken crystal fragments are found between larger crystals. They form the link to subunit A. The constant orientation of the gypsum rosettes can only be explained by free growth e.g. in an evaporitic basin. This indicates a restricted sub- to intertidal sedimentation environment. For gypsum deposits with similar morphological features, HARDIE and EUGSTER (1971) and SCHREIBER et al. (1976) also suggested a sub- to intertidal precipitation of selenite. Nevertheless, a supratidal growth of gypsum is also known from recent formations (e.g. MASSON, 1955, KERR and THOMPSON, 1963).

CONCLUSIONS AND DISCUSSIONS.

Detailed examination of the palisade calcite member of the Walhorn section in the Vesder basin gave evidence of calcite pseudomorphs after gypsum. Many characteristics are similar to the evaporitic gypsum deposits described in the Messinian strata of Sicily and of the Northern Apennines.

Several sequences composed of three distinct subunits were recognized, indicating a cyclic sedimentation. Subunit A is an intraformational conglomerate containing pseudomorphs after gypsum fragments; it is a strong current layer. Subunit B is a grumelous microsparite-micrite. Subunit C consists of the calcite pseudomorphs after gypsum. The sedimentation environment of this succession ranges from intertidal to supratidal and eventually restricted.

Above the palisade calcite member, a collapse breccia occurs (JACOBS et al. 1981). It is possible that the described pseudomorphous layers after gypsum are a relict of the dissolved interlayered gypsum beds of this breccia. However, it is far from clear why the palisade unit has undergone pseudomorphism and has thus been preserved. The original thickness of the overlying strata, now the dolostone breccia and the Ourthe breccia, is not known either. Possibly the breccia fragments are analogous to the intercalated carbonate layers, as described by SCHREIBER and FRIEDMAN (1976). In this case, the breccia in its original state, must have been of considerable thickness.

It is believed that similar palisade calcite pseudomorphs could exist elsewhere in the Vesder basin. However, they may also be eroded, since a thick dedolomitization zone, corresponding with an erosion surface, occurs on top of the Vesder breccia member. Equivalent palisade calcite units may occur in other basins e.g. in the Namur basin. The importance of the recognition of evaporitic conditions and their implications, justifies detailed sediment-petrographic examinations of possible evaporitic sequences. The authors hope that a general compilation of the distribution of evaporitic sequences will be drafted around the Brabant-Wales Massif in the Lower Carboniferous strata. In this context, it is worth mentioning the already known evaporitic deposits from the Carboniferous in Northern Ireland (WEST et al., 1968), in England (e.g. LLEWELLYN et al., 1969) and in South-Wales (BHATT, 1975).

APPENDIX : PALISADE CALCITE IN THE NAMUR BASIN.

In the Namur basin so-called columnar crystals of calcite occur in the Tournaisian dolostones from Charleroi to Flémalle (MICHOT, 1955). They have diameters of up to 1 cm and often constitute volumes of several dm^3. This fibrous calcite has been interpreted as open void infillings of karst cavities (DAMIAEN, 1956; PIRLET, 1970).

The columnar calcite crystals are well exposed in the Engihoul quarry. Here, the top of the Formation of the "Grandes dolomies de Namur", is characterized by 9 m of dark grey dolostone breccia. The lower part of this unit consists of dolostones with intercalations of concordant lenses of limestone with columnar calcite crystals. The upper part consists of a real dolostone breccia. A sandy shale layer with large fluorite crystals covers the breccia. On top of these, we find two beds of greyish brown limestone with small columnar calcite crystals and two beds of large brownish columnar calcite, separated by a brown clay layer. The contact with the overlying Visean crinoidal limestones is sharp.

Sedimentological and morphological features of the calcite crystals allow us to distinguish three types :

1° Small calcite rosettes : they show very similar features as those in the Vesder basin and are present in several limestone beds. They often occur as brecciated fragments but also as vertically oriented crystal aggregates. Cyclic successions as in the Vesder basin are not yet clearly recognized, although the different subunits (i.e. conglomerate, grumelous microsparite-micrite and palisade calcite) have been found. These rosettes can also be interpreted as calcite pseudomorphs after gypsum.

2° Concordant beds of vertically oriented triangular palisade calcite crystals (Plate 5). These beds consist of large columnar radiating crystals up to 50 cm long, which have often grown in several stages, marked by thin coloured zones. Crystals frequently display swallowtail twins. These mega-rosettes are covered with thin layers of laminated limestone. The surfaces of the beds are shaped as "cauliflower surfaces There is a striking resemblance with the gypsum (selenite) cavoli structures of the Messinian evaporites in Sicily (RICHTER-BERNBURG, 1973, Plate 1, fig. 3 and 4). The different features show that the columnar calcites are also calcite pseudomorphs after gypsum.

3° Palisade calcite cement. This calcite occurs as a cement between the angular fragments of the dolostone breccia. It forms fringes around the dolostone fragments but also successive layers intercalated with sandy shales. The shale may contain up to 60 % angular quartz grains; some micas also are present. Possibly this dolostone breccia is of collapse origin.

The detailed sedimentary and geochemical characteristics of the palisade calcites occurring in the Tournaisian dolostones of the E part of the Namur basin will be published elsewhere.

MICHOT (1955) described Visean 1 and Visean 3a limestone breccias with a columnar macrospherolitic calcite cement in the E part of the Namur basin. He interpreted these breccias as parasedimentary breccias formed by internal fracturation of a sedimentary mass below a small carbonate cover, due to a subaqueous gliding. The authors believe that a detailed sedimentpetrographic study of the palisade calcite in these limestone breccias may lead to an analoguous interpretation of pseudomorphs after gypsum.

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PLATE 2

A

PLATE 2 - A. Palisade calcite (subunit C) with several calcite clusters in subsequent layers (sample ⋆ 4 a/b) Bar : 0,25 cm.

PLATE 1

A. Pseudomorphs occurring in the Ourthe Breccia

a. pseudomorphs after gypsum (sample Wt 49.1)
Bar : 200 μm

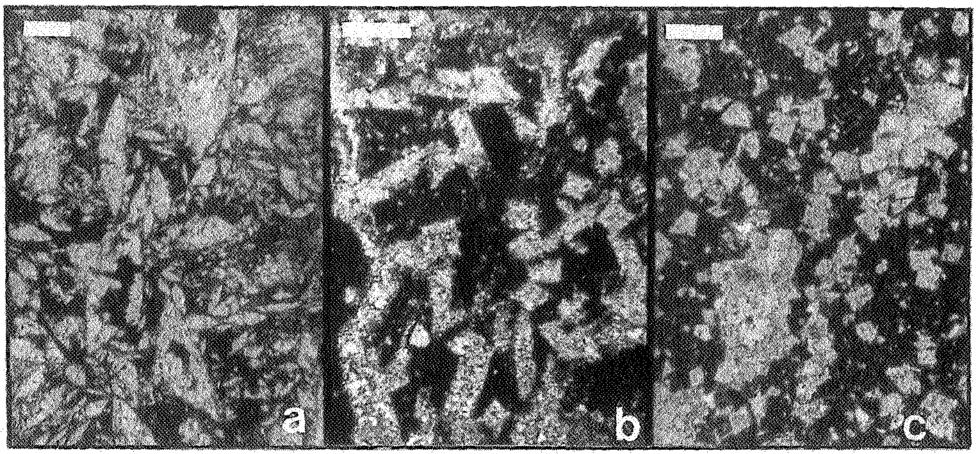
b. pseudomorphs after anhydrite (sample X39)
Bar : 200 μm

c. pseudomorphs probably after halite (sample Wt 52)
Bar : 200 μm

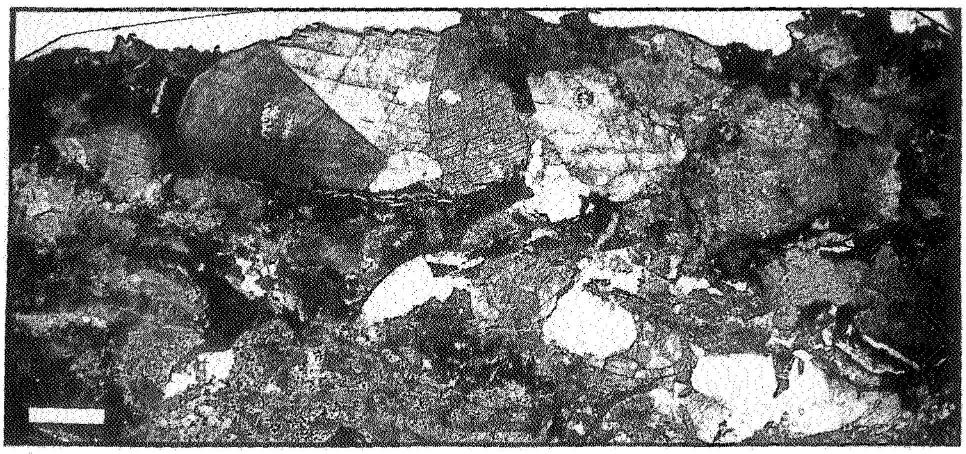
B. Coarse-crystalline calcite fragments in the intraformational conglomerate (subunit A). The long axes of the crystal fragments are mostly parallel to bedding (sample * 8b) Bar : 0,5 cm

C. Palisade calcite rosette with micrite, as fragments in the intraformational conglomerate (subunit A). The fragments are brecciated. The palisade rosette show growth rhythm (arrow) (sample * 1a) Bar : 0,25 cm.

PLATE 1



(A)



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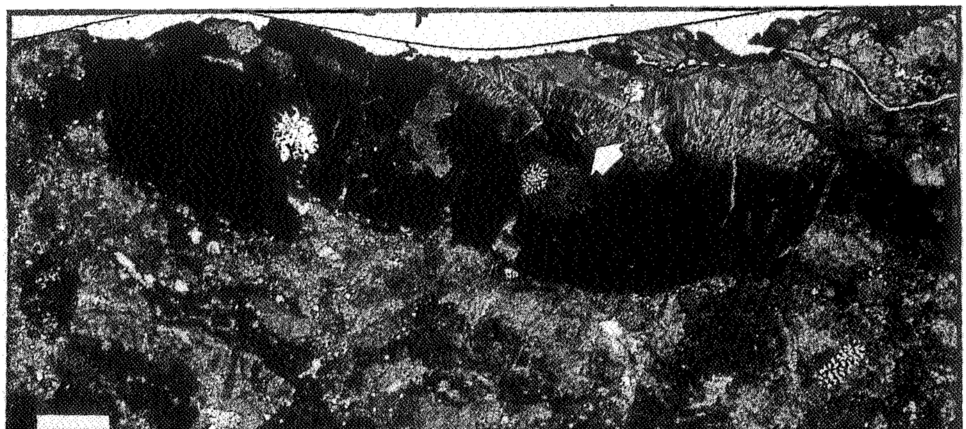


(C)

PLATE 3

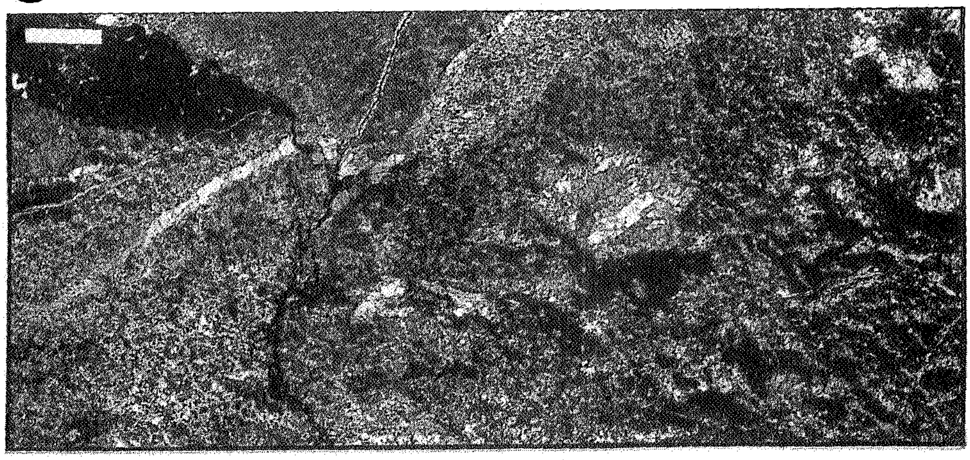
A. Grumelous microsparite-micrite (subunit B). Intergrowth between adjacent pellets is present (sample * 7 c) Bar : 1,5 mm.

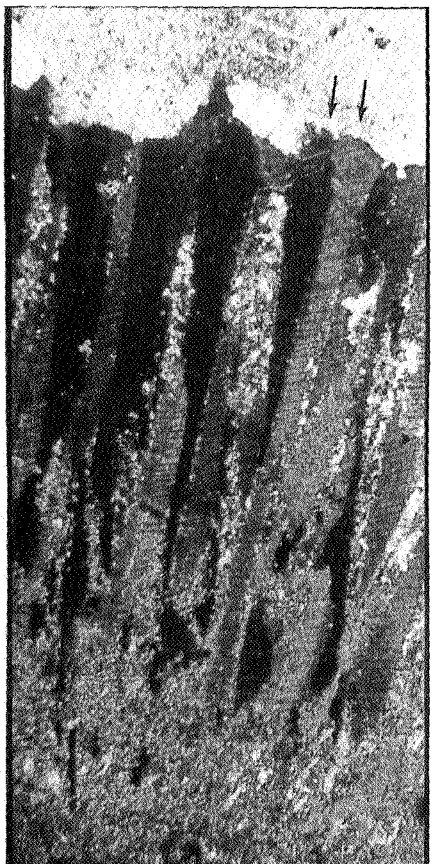
B. Palisade calcite rosette with twinned crystals (arrow), with their twin plane perpendicular to the bedding. Microsparitic grains occur between adjacent palisade calcite crystals (sample * 4a) Bar : 0,1 cm.

C. Palisade calcite with growth rhythm (arrow) (sample * 1 d) Bar : 0,1 cm.

PLATE 3

A





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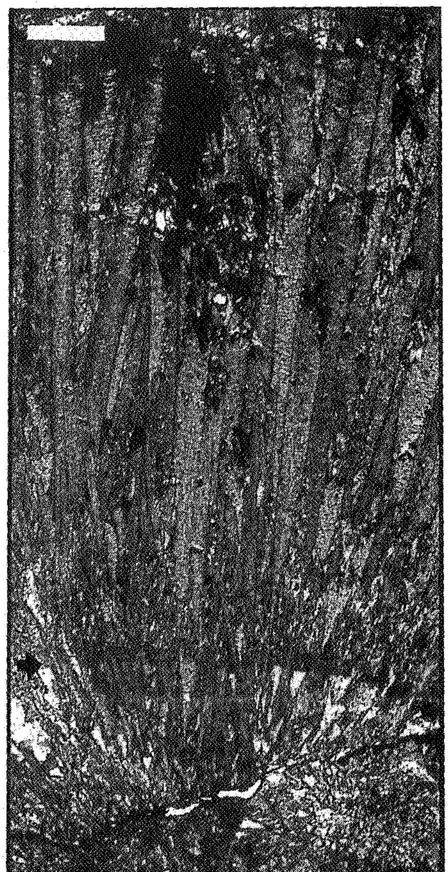
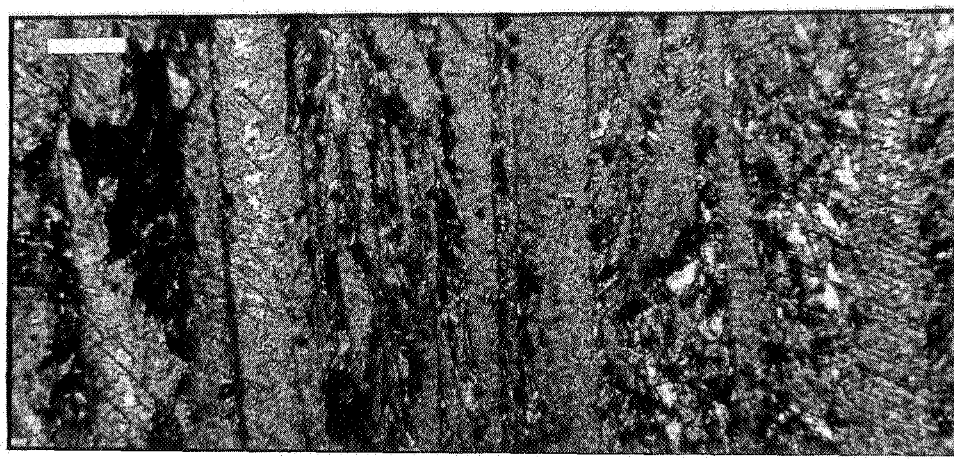
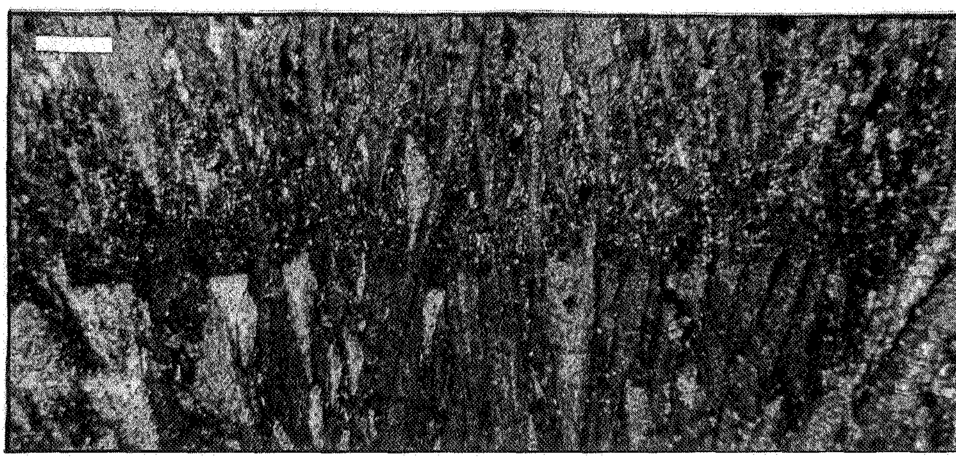


C

PLATE 4



(A)



(B)

PLATE 4 – A. Part of a palisade calcite cluster with broken crystals between well-developed crystals (sample * 1d) Bar : 250 μm.

B. Detail of a palisade calcite rosette with growth rhythm (sample * 1b) Bar : 300 μm.

PLATE 5

PLATE 5 - One bed of vertically oriented triangular palisade calcite crystals. The mega-rosettes are covered with a thin layer of laminated limestone. The surface of this bed is typically shaped as a "cauliflower surface". (sample Engihoul Quarry). Bar : 1 cm.