Bulletin de la Société belge de Géologie	97-3/4(1988)	pp.473-479	Bruxelles 1990
Bulletin van de Belgische Vereniging voor Geologie	97-3/4(1988)	pp.473-479	Brussel 1990

LIMESTONES AND SANDSTONES OF THE IEPER FORMATION THEIR NATURE AND STRATIGRAPHIC SIGNIFICANCE

by

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(with 3 figures and 1 plate)

ABSTRACT

The petrography, grain size distribution and mineralogy of lime- and sandstones of the Ieper Formation were studied. In the Mons-en-Pévèle sand, nummulitic limestones occur, that were deposited by storm activity. The composition of the calcite cement indicates diagenesis in fresh water and a reducing environment. Similar conclusions are drawn for limestone layers that occasionally occur in the Roubaix Clay. Sandstones with an opaline cement are also found in the Ieper Formation, probably at two levels: the Mons-en-Pévèle Sand and the Egem Sand. They were formed by recrystallisation of biogenous opal.

Key words: Ypresian, Nummulitic limestone, silicification, storm deposits, diagenesis.

SAMENVATTING

De petrografie, de korrelgrootteverdeling en de mineralogie van de kalksteen- en zandsteenbanken uit de Formatie van Ieper werden onderzocht. In het zand van Mons-en-Pévèle komen nummulietenkalkstenen voor, die afgezet werden door stormactiviteiten. De samenstelling van het calcietcement wijst op diagenese in zoet water en reducerend milieu. Vrijwel gelijkaardige conclusies kunnen getrokken worden voor kalksteenbanken die sporadisch worden aangetroffen in de Klei van Roubaix. In de Formatie van Ieper komen ook zandstenen met een opaalcement voor, vermoedelijk in twee niveau's: het zand van Mons-en-Pévèle en het zand van Egem. Zij zijn ontstaan door herkristallisatie van opaal van biogene oorsprong.

Sleutelwoorden : Ypresien, nummulietenkalksteen, verkiezeling, stormafzettingen, diagenese.

RESUME

La pétrographie, la granulométrie et la minéralogie des bancs de calcaire et de grès de la Formation d'Ieper ont été étudiées. Dans le sable de Mons-en-Pévèle, on trouve des calcaires nummulitiques, déposés par des tempêtes. La composition du ciment calcitique indique une diagénèse dans de l'eau douce et en milieu réducteur. Des conclusions semblables ont été tirées pour les bancs de calcaire qu'on trouve sporadiquement dans l'Argile de Roubaix. Dans la Formation d'Ieper, se rencontrent aussi des bancs de grès à ciment d'opale, probablement dans deux niveaux: le sable de Mons-en-Pévèle et le sable d'Egem. Ils ont été formés par la recristallisation d'opale d'origine biogène.

Mots clés: Yprésien, calcaire à nummulites, silicification, dépôts de tempête, diagénèse.

1. INTRODUCTION

The presence of limestone and sandstone beds in the Ieper Formation has been mentioned by many authors. At Mons-en-Pévèle, HERENT (1895) described and outcrop with two limestone beds with *Nummulites planulatus* and one sandstone with *Turritella*. However most of the authors only noticed their presence without giving further details. The most famous localities are: Moeskroen (FEUGUEUR 1951), Kortrijk (HALET 1939), Ronse (DELVAUX 1881), Mont-Saint-Aubert (DELVAUX 1884), the Dender valley near Geraardsbergen, where the limestones have been quarried in the past (GULINCK 1949), Vilvoorde (HALET 1930) and Vorst (MOURLON 1910). More recently, DE MOOR and GEETS (1973) found sandstones in the neighbourhood of Gent. The most eastern localities where Ypresian limestones and sandstones have been recognized are the Oostham and Kwaadmechelen boreholes (ASSELBERGHS, 1926 & 1927).

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2. STRATIGRAPHY

For the moment, the lithostratigraphy of the Belgian Ypresian is fully in discussion. In this text the term Ieper Formation stands for the classical Ypresian units of the geological map: Yc and Yd. The terms Roubaix and Aalbeke Clay, and Mons-en-Pévèle and Egem sands are used according to the definitions of STEURBAUT & NOLF (1986).

The *Nummulites planulatus* limestones have always been considered to be a part of the Yd sands of the geological map, known as Mons-en-Pévèle, Vorst or Egem sands. MARECHAL *et al.* (1964) noticed that large parts of the Yd of the geological map in West Flanders are in fact a silty facies of the middle part of the Yc clay. Recently, STEURBAUT and NOLF (1986) published a correlation model of the Belgian Ypresian, in which they further restricted the extension of the classical Yd sands (Egem Sands). In that paper, the deposits with the nummulitic limestones (the Mons-en-Pévèle sands) are thought to correspond to the middle part of the Ypres Clay (Yc of the geological map), named Roubaix Clay by STEURBAUT & NOLF; while the Egem Sands are considered to be younger, overlying the topmost beds of the Ypres Clay (= Kortemark Silt *sensu* STEURBAUT & NOLF). Following these new concepts of correlation, coherent rocks occur in the Mons-en-Pévèle sands, in their lateral equivalent the Roubaix Clay and locally in the Egem sands.

3. ORIGIN OF SAMPLES

The most important problem during this study was the nearly complete lack of good exposures. Only in the Marke clay pit and perhaps along a hollow road side south of Ronse, samples were found *in situ*. Most of the material was found as reworked fragments. Samples from the collection of the Belgian Geological Survey were also studied, taken from boreholes and former outcrops, mainly in the area from Oudenaarde to Brussels. Larger blocks of the nummulitic limestones can be observed in ancient buildings, mainly in the Province of East Flanders, which offer good occasions to study the sedimentological structures, although sampling is somewhat problematic!

The limestones used as building stone show alternations of nummulite-rich lenses with fossil-poor zones, often displaying plane laminations. The layers are characterised by many erosion surfaces and scour-and-fill structures (plate, fig. a).

The nummulitic limestones have been named « Grès de Pève » by HERENT (1895). In the Dender Valley, the building stones are known as « Zandbergse Steen ».

4. METHODS

The samples were studied with the petrographical microscope. Thin sections were stained with Alizarine red S and K-ferricyanid, following the method of EVAMY (1963). This method allows the distinction between ferrous (blue) and non-ferrous (red) calcite. Limestone samples were dissolved in HCL for granulometric analysis of the siliciclastic fraction (see FOBE, 1986).

5. THE NUMMULITIC LIMESTONES

5.1. Petrography

The nummulitic limestones are cemented by a clear and rather coarse (100-150μm), ferrous sparite (plate, fig. b). The nummulites are very abundant (30-70 %). Between 10 and 20 % of fine quartz grains is recorded. Large glauconite grains are present (10 %). Two different textures are observed within the cement. The nummulites and other calcareous fossils are surrounded by a rim of elongated calcite crystals, optically continuous with the structure of the underlying test or shell. The remaining cement consists of equidimensional grains. Some of them have also been recognized as a monocrystalline epitaxial rim that has grown upon a similar fossil (e.g. echinoid spines). Some calcareous mud may be locally present, mainly arranged as pellets. Ghosts of gasteropode shells are often observed. They consist of sharply limited, circular, to slightly elongated zones without quartz and with extremely large calcite crystals (up to 500 μ). Some geopetal lime mud can be present. The nummulites may have been partly dissolved and filled up again with chalcedony.

The limestones without nummulites (plate, fig. c) have higher amounts of quartz grains (35 %). Epitaxial rims are observed around some mollusc shells, but most of the cement consists of equidimensional grains. Laminations are due to an alternation of coarser and finer textures. The former are rich in quartz and show a clear sparite cement. The fine grained laminae are richer in micrite, calcareous fossil fragments and glauconite, and they contain less quartz grains.

5.2. Granulometric analysis

After dissolving the calciumcarbonate of the nummulitic limestone through HC1 treatment, the siliciclastic fraction of the average nummulitic limestone contains about 50 to 60 % of sand, which is mostly finer than 90μm. The fraction coarser than 125μm is nearly completely formed by glauconite. Some 10 % of silt is present, and 20 to 30 % of clay (fig. 1). This clay is not observed in the thin sections, but it must be remembered that 70 to 80 weight % of the limestone is dissolved before the analysis can be done, what means that the total amount of clay is not higher than 5 %. The results cannot be compared to the surrounding sediment, as good exposures are lacking. On the other hand, for a complete sedimentological analysis, the whole mass of large nummulites should have to be taken in account.

The siliciclastic fraction of the nummulitic limestones contains more clay than the Egem sands, to which they were formerly attributed. On the other hand, the limestones show all

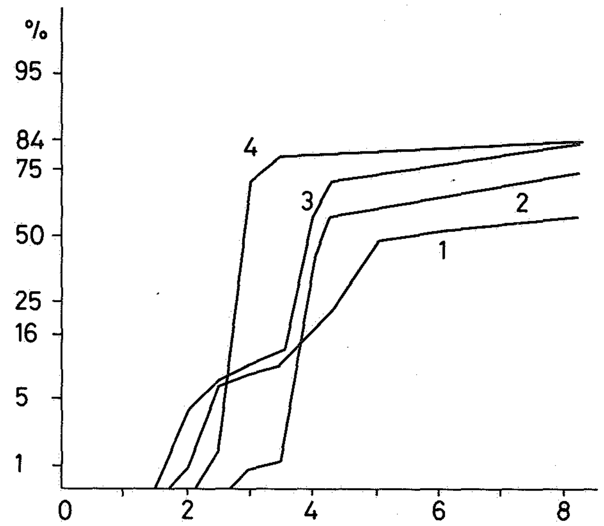

Fig. 1

Grain size distribution curves of three nummulitic limestones (1 from Anvaing, 2 and 3 from Zandbergen), compared to a curve of a sample from the type locality the Egem Sand (Ampe quarry) (4). The sand is clearly coarser.

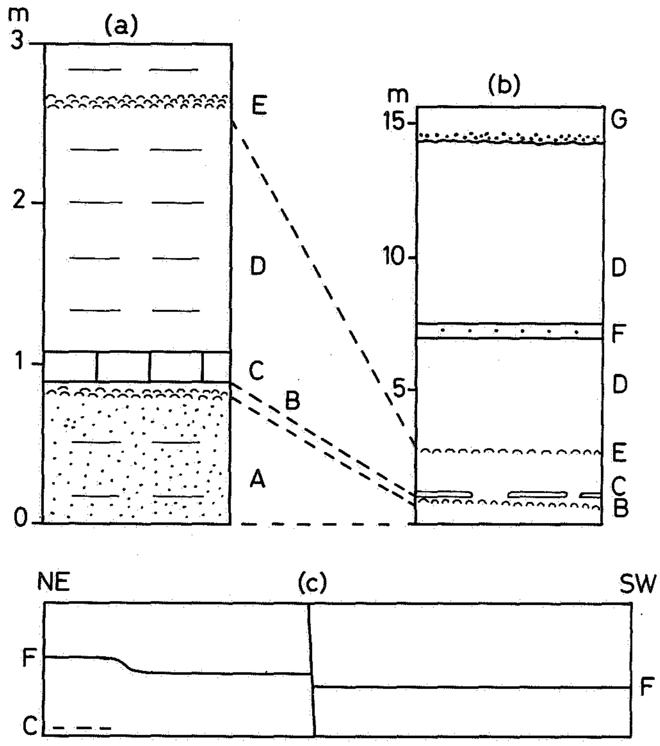

Fig. 2a

Detailed section of the base of the Marke claypit:
A : silty clay with large glauconite grains.
B: shell bed.
C: limestone layer.
D: silty clay.
E: shell bed.

Fig. 2b

The complete section of the Marke pit, northeastern part (1985 - 1987).
F: darker layer, clearly visible when the section has dried up for some time.
G: quaternary gravel and loam.

Fig. 2c

Along the exploitation front (lenght = ca. 220m), two important disturbances are observed. Between the northeastern and the southwestern edge, layer F descends about 5m. Limestone layer C probably continues below the base of the pit.

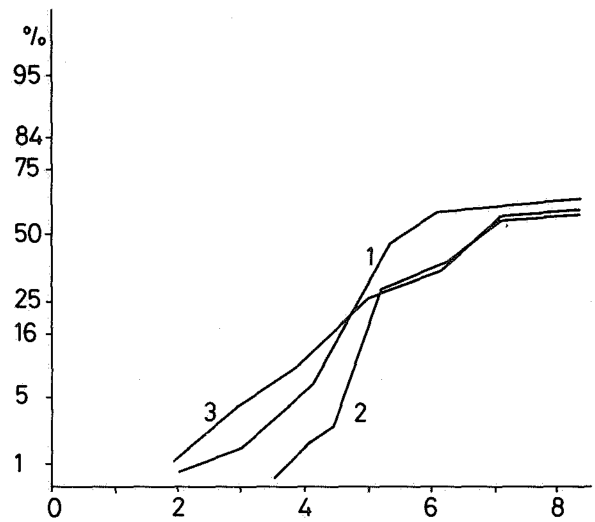

Fig. 3

Grain size distribution curves from the Marke limestone (1), the surrounding clay (2) and a shell bed (level B, fig. 5a) (3).

characteristics of a relative high energy deposit, and thus a lower amount of clay should be expected. The relatively high clay content may confirm the viewpoint of STEURBAUT & NOLF (1986) that the limestones with *Nummulites planulatus* have to be associated with the more clayey sands of Mons-en-Pévèle, a lateral equivalent of the Roubaix Clay, which are situated in the middle part of the Ieper Formation.

6. THE MARKE LIMESTONE

A limestone layer was found in the Roubaix Clay in the Marke clay pit (fig. 2). It is a blue, very compact limestone with a thickness of about 10 cm. It is often rich in bivalve shells. Sometimes it shows horizontal laminations. The layer was discovered in 1985, when the pit was deepened. As the limestone can hardly be distinguished from the clay, considerable damage was caused to the dredges. Because of deformations of the clay, the layer was only visible in the northern part of the pit (fig. 2c).

The layer occurs in a fossiliferous silty clay, which also contains beds of shell hash and clay flakes. It is found near to the top of a glauconitic clay sequence and about 10-30 cm above a shell bed.

The main components of the limestone layer are fine quartz grains and a small amount of shell hash. The cement consists of fine ferrous sparite. Epitaxial rims are observed around the fossil fragments. The laminations observed in the beds are due to differences of the quartz content. Generally, the quartz grains look finer than those of the nummulitic limestones.

A weight loss of 60 % is observed after dissolution in HC1 (20 % in the surrounding clay, 83 % in the lowermost shell bed, which contains pyrite concretions up to 1 cm). The remaining siliciclasts in the stone layer and the shell bed are slightly coarser than in the surrounding clay. The sand fraction of the clay (2 %) is rather low compared to the limestone and the shell bed (7.5-9 %). The amount of clay is more or less comparable (40-45 %). The limestone and the shell bed differ in the amount of coarse silt, which is higher in the hardened layer (fig. 3). The clay in the shell beds occurs mainly as reworked slabs.

7. DIAGENESIS

The formation of ferroan calcite requires a reducing environment (EVAMY 1969) and fresh water, especially free of sulphate ions (RICHTER & FUCHTBAUER 1978). When the seawater was replaced by fresh water, unstable aragonite and magnesian calcite were dissolved. The concentrations of nummulites and other calcareous fossils acted as zones of supersaturation and trapped much of the ions in solution. Precipitations took place upon the fossils, which acted as large crystallisation nuclei. Epitaxial calcite grew into the open void spaces between the nummulites. No exact dating can be given for the diagenesis, as no reworked limestones are found in the overlying strata.

The most probable occasion for diagenesis may have occurred in the period between the deposition of the Brussel and Lede Formations, which are separated by an important erosional surface. Fresh water may then have entered the Mons-en-Pévèle sands in the Brabant area, where the protecting Aalbeke Clay had been removed by the pre-Brusselian erosion. In such way contact was made with the aquiferous Brussel sands. Fresh water could also have penetrated the Ieper Formation in the Artois Rigde area in Northern France.

The ferroan calcite cement of the Marke limestone indicates diagenesis in a similar environment. Comparison has been made with the septaria of the Boom Clay (VANDENBERGHE & LAGA, 1986). An important difference is the absence of septa in the Marke Limestone. The septa in the Boom Clay are formed because dehydration of the carbonate took place before dehydration of the surrounding clay. The absence of these structure in the Marke limestone may be caused by the higher permeability of the essentially silty-calcareous layer, or by a diagenesis during a later stage, after dehydration of the clay.

8. SEDIMENTOLOGY

The problem of nummulite concentrations has been treated recently by AIGNER (1983), who developed a model for the origin of nummulite reefs in Egypt. The shallow parts or the sea were favorable for the proliferation of nummulites because of the better conditions of aeration and temperature. This shallow area is more vulnerable to the influence of storms, taking away the fine sediments but not the large nummulites. The result is a rather clean concentration of nummulite tests.

The condition of a higher temperature may have been especially important in the Belgian Basin. As BLONDEAU (1972) stated, nummulites species were abundant in the Mediterranean and the Paris Basin. The sea water of the Belgian Basin was cooler, so that, during the Eocene, only three nummulite forms could adapt to these conditions. It may be expected that the large growth of *N. planulatus* took place on the shallower parts of the sea bottom, where more sunlight was available than in deeper water.

The sedimentological structures of the nummulitic coquinas in the Ieper Formation, which show an alternation of coarse nummulite lenses and plane laminated sand, may be caused by storm activity (ALLEN 1982).

LIMBOURG (1986) suggested that the nummulitic beds were deposited during a short span, because of emersions of the chalk in Northern France, providing large amounts of calcite.

Alternatively, the nummulite concentrations may be considered as condensed sequences. Because of their shallower position, the net sedimentation rate was rather low. During the same span of time which was needed to form 15 to 20 cm of coquina, a thicker layer of calcareous sand was deposited in the neighbouring deeper areas, containing dispersed nummulites.

The sedimentology of the Marke limestone also indicates relative high energy conditions. The limestone is locally associated with shell beds (fig. 2), shows plane laminations and contains large mollusc fossils. Probably, they represent the fine-grained sequence of storm deposits, of which the shell beds are the coarse parts. These shell beds were not cemented because the main source of the cement, the calcareous silt and mud, was mainly deposited in the fine grained deposit, the actual limestone bed. A similar feature is observed in the tempestites of the Lede Formation, of which the finer sequence is generally better cemented than the coarser, fossil-rich parts. Circulation of ions was inhibited by the clayey sediment in which the Marke limestone occurs. Here is thus another difference between the septaria of the Boom Clay, which were formed in low energy environments, as it is indicated by the presence of molluscs in life position (VANDENBERGHE & LAGA, 1986).

9. SILICEOUS SANDSTONES

X-ray diffraction showed that the silt fraction of the nummulitic limestones contains zeolites of the clinoptilolite-heulandite type. DE GEYTER (1980) and D'HUYVETTER (unpublished) mentioned the same feature, respectively in the calcareous facies of the Landen and Brussel Formations, which both contain alternations of limestones and silicified sandstones. In the Egem and Mons-en-Pévèle sands, silicified sandstones are also found, sometimes together with nummulitic limestones (HERENT 1895). Material was studied from the Mons-en-Pévèle Sands (*sensu* STEURBAUT & NOLF, 1986) of the Vilvoorde area (borings of the Belgian Geological Survey) and from the Egem Sands around Gent (borings and the Merelbeke lock-outcrop). Generally only few differences are observed between the sandstones from Vilvoorde and Gent. Both are relatively loose packed (40 to 55 % of mainly opaline cement) and contain calcareous fossils, as well as unnumerable calcite particles in the matrix. The cement was derived from siliceous sponge skeletons, of which some dissolution molds are preserved. These silicified sandstones are quite similar to those of the Pittem Clay and the calcareous facies of the Brussel Formation.

Samples of the so-called *Turritella*-sandstone were found along a road near Mainvault and in a hollow road near Mons. It is a fine grained sandstone, rather closely packed, with an opaline cement. Molds of dissolved gasteropode shells and nummulite tests are frequent.

10. CONCLUSIONS

1) The limestones and siliceous sandstones of the Ieper Formation were formed at levels of particular biogenic sedimentation, respectively rich in calcareous and siliceous fossils.

2) The limestone layers, both in the Roubaix Clay and the Mons-en-Pévèle Sand were deposited during relative high energy conditions, probably storm activity, which concentrated calcareous nummulites and mollusc shells in the shallow parts of their proliferation area.

ACKNOWLEDGEMENTS

This paper is mainly based on the results of FOBE's Ph. D. Thesis, which was sponsored by a grant from the I.W.O.N.L., Brussels. The staff of the Belgian Geological Survey is thanked for providing samples from borehole and outcrop sections.

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Fig. 1

Structures on the surface of nummulitic limestone, used as building stones (scale bar represents 5 cm).

Fig. 2

Nummulitic limestone. The nummulite tests and the broken bivalve shell consist of non-ferroan calcite (red). The epitaxial rims around the fossils, and the sparite crystals show a blue stain, indicating the presence of ferrous irons in the calcite. Glauconite is found as large grains and as infilling in a foraminifera test. In the large nummulite in the center, the difference between the epitaxial rims and the micritic sedimentary infilling is clearly observed. (Belg. Geol. Survey borehole at Flobecq, 99 W 2/26; scale bar represents 1 mm).

Fig. 3

Thin section of a part of a limestone layer without nummulites. Lamination, due to an alternation of quartz-rich and calcareous deposits, is clearly visible. the cement consists of ferroan calcite. (Zandbergen cemetry, scale bar represents 1 mm).

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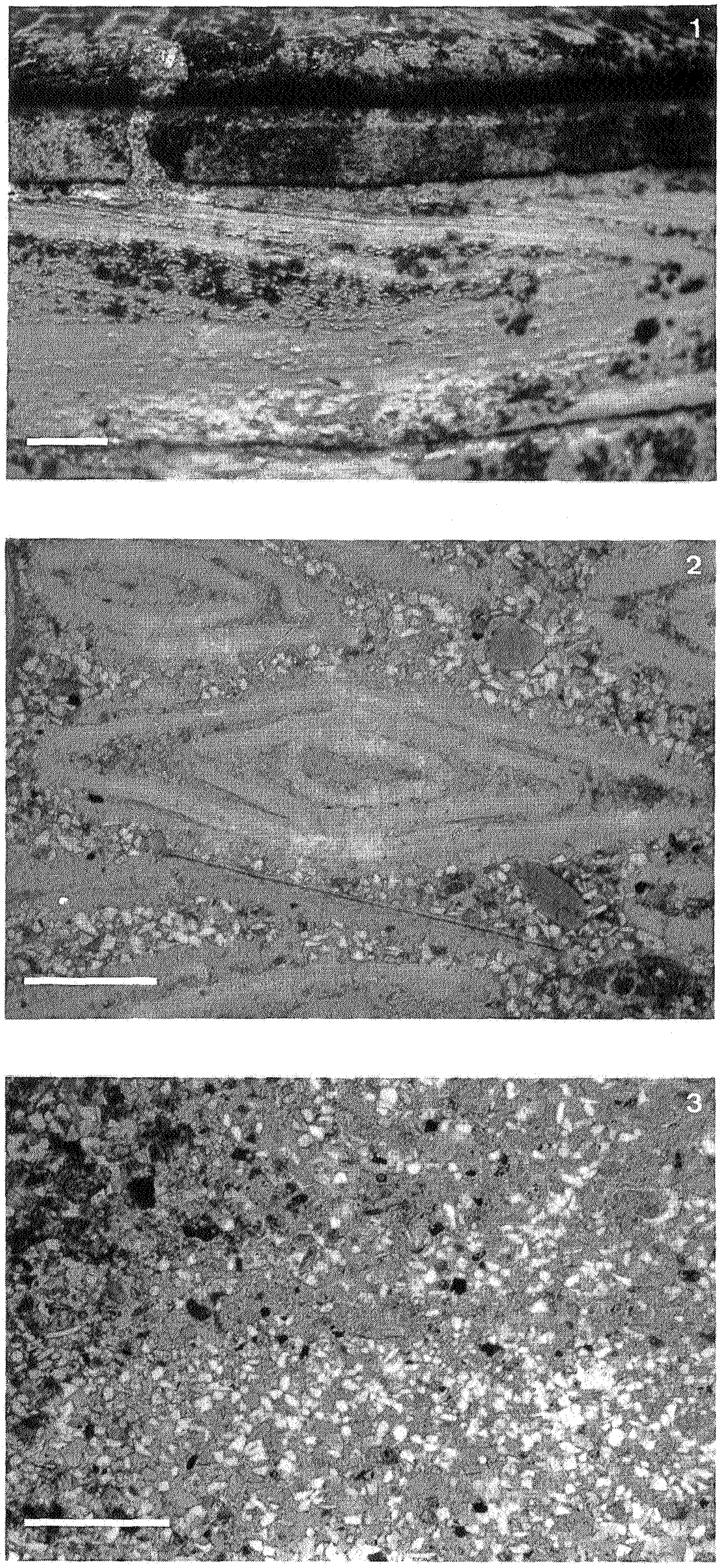
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