

SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 796 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 76 NR 9

BJÖRN SUNDQUIST

CARBONATE PETROGRAPHY
OF THE WENLOCKIAN SLITE BEDS
AT HAGANÄS, GOTLAND



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ABSTRACT

Sundquist, Björn, 1982-08-02: Carbonate petrography of the Wenlockian Slite Beds at Haganäs, Gotland. Sveriges geologiska undersökning, Ser. C, No. 796, pp. 1-79, Uppsala 1982.

In the Wenlockian (Middle Silurian) Slite Beds of Gotland, a sequence of 2.73 m has been petrographically and sedimentologically studied in detail. The sequence covers the transition from fine-grained, micritic and microsparitic, carbonate rocks with intercalations of calcareous shales and silty claystones (Slite Marl), to coarse- and very coarse-grained limestones with intercalations of calcareous shales and microsparitic carbonates (Ryssnäs Limestone). A comprehensive description of study methods, including laboratory treatment, thin section point-counting, and defined constituents and terminology, is given. The sequence was investigated by means of petrographic modal analysis, time-trend analysis, continuous lithologic analysis, and principal components analysis. The analyses enable a lithologic four-partition of the sequence, and indicate that the depositional environments of these rocks were in the shallow subtidal-intertidal zones. It is suggested that the lithologic changes in the sequence are reflections of variation in exposure to the open sea rather than of variation in water depth. The inferred palaeobathymetric and environmental situation is in opposition to current opinion.

INTRODUCTION

The Silurian bedrock of Gotland was generated in intracratonic shallow marine and perimarine environments at tropical latitudes. It is made up of a variety of carbonate rocks, including reefs, and calcareous shales, claystones, and fine sandstones. Petrographic and sedimentologic evidence for the shallow nature of these deposits have been reported by, e.g., Hadding (1941, 1956, 1958, 1959), Jux (1957), Stel & de Coö (1977), Laufeld, Sundquist & Sjöström (1978), Jaanusson (1979), Watts (1981), Sundquist (1982a, 1982b). Several sedimentation breaks and periods of erosion have been recorded by, e.g., early workers as Munthe and Hedström, Hede in his map descriptions (for bibliographies, see Laufeld 1974a), and Spjeldnaes (1950). Studies in progress also indicate episodes of subaerial exposure and weathering (Sundquist, in prep.). For general information about the geology and stratigraphy of Gotland, reference is made to Manten (1971), Laufeld (1974b: 7-13), and Laufeld & Bassett (1981).

In 1958 and 1960 Hede summarized in English his opinion about the stratigraphy of Gotland, founded on more than 20 years of mapping experience on the island. His 13 topostratigraphic units, and a number of subunits, still form the framework for all geologic and palaeontologic activities on Gotland, although later studies, primarily by micropalaeontologists, have clearly shown most of Hede's units to be diachronous. The degree of divergence, still far from settled, has been discussed by, e.g., Martinsson (1967), Laufeld & Jeppsson (1976), and Bassett *et al.* (1981). The various opinions stem from different views on which parameters actually reflect "true" time-planes. The matter is complicated because of the scarcity of continuous outcrops and the rapid lateral shifts of litho- and biofacies. If, in some way, time-planes could be unequivocally defined and established, this would have a tremendous impact on all future geologic work on Gotland, and many of today's "facts" would probably be challenged.

During a national Project Ecostratigraphy meeting, held at Allekvia geological field station in August 1979, a decision was made to initiate a new subproject that would focus on the time-plane problem. Like the Vattenfallet subproject (Jaanusson *et al.* 1979), this new one should aim at an integration of an optimum of palaeontological information. In addition, small scale petrographic and sedimentologic studies should be carried out, and the rocks analysed for their pertinent geochemical aspects. Also, whenever possible, new techniques, methods of analysis, and instruments should be employed in order to find new ways of approaching the problems. By broadening the scope of investigation, as compared to the Vattenfallet project, and by examining, bed-by-bed, several short outcrop sections (situated some distance apart) that embody a similar lithologic succession within the same defined stratigraphic interval, the resultant new insights would widen the understanding of the depositional mechanisms of the rocks and unveil their detailed history of origin. This in turn, it was argued, might well provide a basis for a definition of time-planes founded on composite data.

Because of the holistic approach of the new subproject it was pretentiously entitled "The Whole Environment – Silurian Slite Beds, Gotland". A brief introduction of the project is given by Laufeld (1981).

Three localities in the upper Slite Beds were chosen as a suitable test sequence. Detailed data on this unit can be found in the general references given above. It would suffice here to say that the Slite Beds is one of Hede's most complex units, both in terms of lithology and stratigraphy, and the most extensive with regard to its outcrop area. It is middle Wenlock in age and its thickness estimated at about 100 m. As seen in Fig. 1, the Slite Beds can be broadly divided into one area with predominantly limestones, and one with predominantly marlstones. In the northeastern region of Gotland and on Fårö, this lithologic transition was defined by Hede as the boundary between the Slite Marl and the lowermost part (the Ryssnäs Limestone) of his

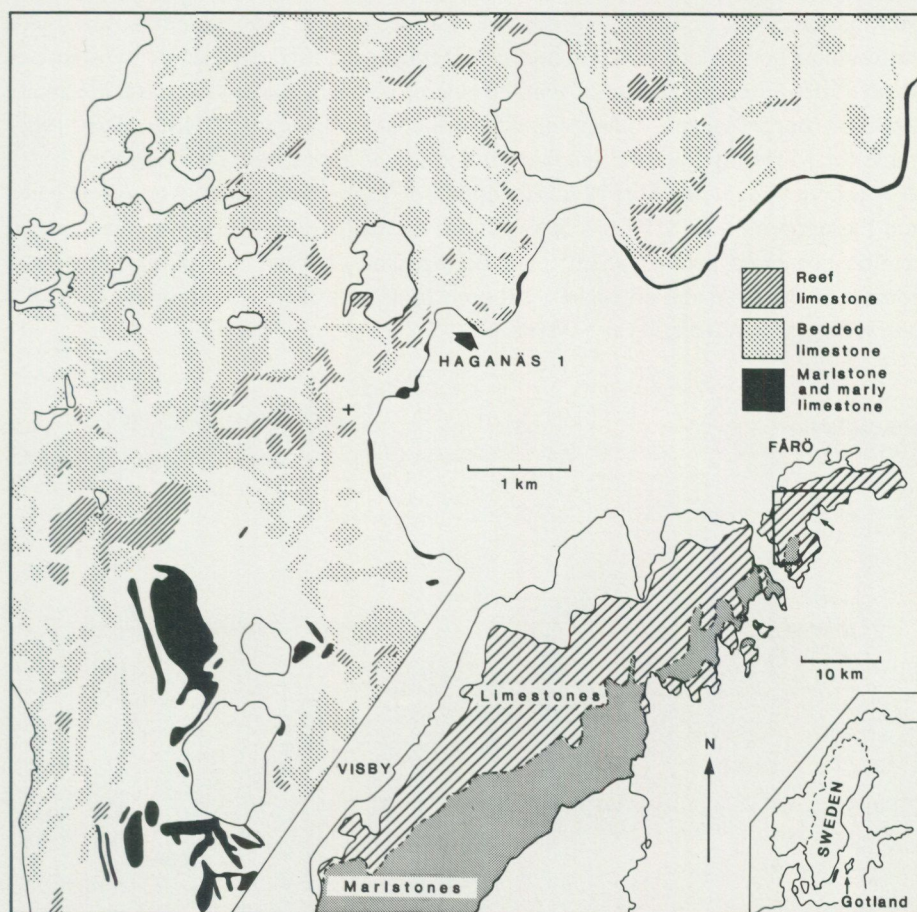


Fig. 1. Map of northern part of Gotland (right), showing the areal distribution of the Slite Beds, their main lithologies, and the location of Haganäs 1 on Fårö, and (left) a close-up map of the locality and surroundings (based on Hede 1936).

limestone unit *g*. Obviously Hede regarded this boundary as what is now called a chronohorizon (Hedberg 1976:67). The Slite Marl is thus not a lateral facies of unit *g*, but is older and clearly overlain by the Ryssnäs Limestone.

In the three localities to be studied in this subproject, the transition between the Slite Marl and unit *g* is well exposed and easily accessible. In this paper the petrographic and sedimentologic aspects of the transition at the locality Haganäs 1 on Färö are described and their environmental significance discussed.

LOCALITY AND SAMPLING

Haganäs 1 (Laufeld 1974a) is briefly described by Hede (1936:32; 1960:71 Loc. 25) in terms of lithology and palaeontology. It is also included in the studies by Hede (1942), Martinsson (1962), Laufeld (1974b), and Larsson (1979). The locality is the south-easternmost portion of a c. 3.5 m high SW facing beach cliff, exposed for a distance of about 250 m (Figs. 1, 2). For most of the outcrop distance, the sequence is horizontally stratified, but at Haganäs 1 the strata dip a few degrees to the south. Hede (1936, 1960) made the following topostratigraphic subdivision of the section: the lowermost c. 1.0 m+ as belonging to the Slite Marl, the middle c. 1.0 m as constituting transition beds, and the uppermost c. 1.5 m as belonging to the Ryssnäs Limestone. In the sampled section presented herein, which totals 2.73 m and does not include the uppermost portion of the cliff, the boundaries between Hede's three units correspond to level 0 (the reference level) and level +90 cm.

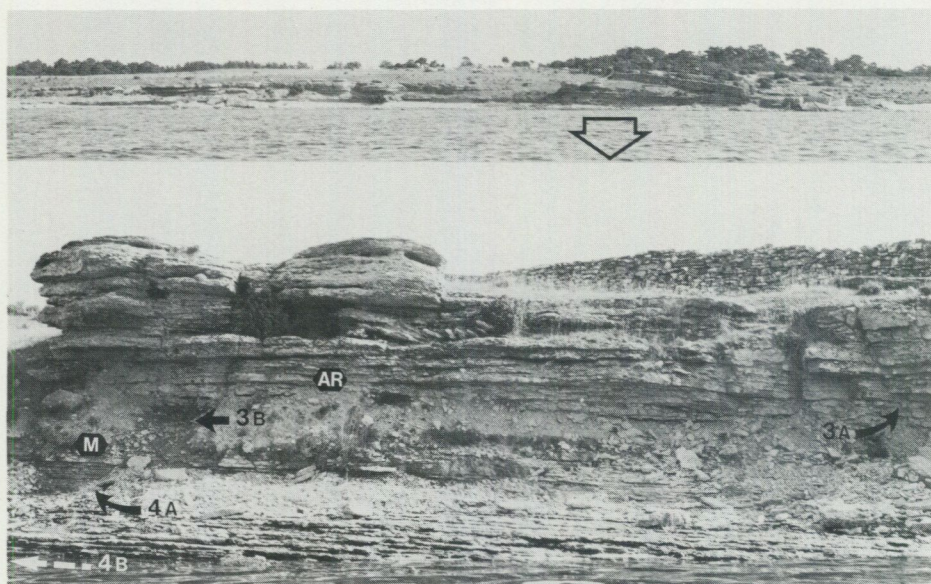


Fig. 2. Photograph of the southwestern shore of Haganäs peninsula and (below) closer view of the main part of the locality with the two marker-beds indicated. The arrows give positions of the close-up photographs in Figs. 3 and 4. (Photographer Arne Philip 1981-08-04.)

To avoid confusion, it should be noted here that Laufeld (1974a) suggested a reference level at "The boundary between the Slite Marl and Ryssnäs Limestone". In so doing, Laufeld (pers. comm.) inferred, from the overall lithologic similarities, that Hede's 'transition beds' might be regarded as the uppermost part of the Slite Marl. It follows that the reference level recommended by Laufeld is not the one used in this paper. His reference level corresponds herein to the +90 cm level. I concur with Laufeld's opinion, but regard the 'transition beds' as a unit possessing characteristics that are both similar and dissimilar to the underlying as well as to the overlying units. The lithologic characteristics will be described in a subsequent section. It should, however, be stated here that the +90 cm level is used in this paper as the boundary between the Ryssnäs Limestone and the Slite Marl, and that the Slite Marl is divided into three informal subunits, viz., Slite Marl *z*, coinciding with Hede's 'transition beds', Slite Marl *y*, comprising the portion between 0 and c. -70 cm, and Slite Marl *x*, constituting the lowermost portion of the sampled sequence. A formal stratigraphic subdivision of the Slite Marl must be deferred until sufficient palaeontologic, sedimentologic, and geochemical data are available from all three sections included in the subproject.

The field-work was carried out in cooperation with Sven Laufeld between September 23 and October 5, 1979. The locality was revisited by us on May 15, 1981, for some additional sampling. Four sets of samples were taken almost continuously through the section. Two sets were collected for micropalaeontological studies, and one set for geochemical analyses. Samples for this study were taken from all beds that were regarded as being coherent enough to withstand the laboratory treatment described below. This kind of selective sampling resulted of course in slightly biased samples with regard to the entire outcrop sequence. For a petrographic study of this sort and with the available equipment, however, this slight bias was unavoidable. Under the circumstances I feel that the material collected adequately reproduces the actual outcrop situation.

The section was sampled from just above sea level upwards until the lithologic transition was considered sufficiently covered. Two marker-beds were painted in the section, viz. bed M (broad red strokes) and bed AR (red dots), see Fig. 2. At the southeastern end of the exposure, a stone fence reaches the shore. The southernmost boulder in the fence was chosen as the reference point for the locality (the boulder is marked RP in red paint). The sample collection and outcrop description were made in three separate parts of the locality, and with use of the reference point these can be given as follows: samples AZ-AT (+162 cm to +111 cm) were taken 14.5-17.0 m N20°W from RP, samples AS-AB (+111 cm to -66 cm) were taken 24.0-25.0 m N22°W from RP, and samples AC-AQ (-66 cm to -111 cm) were taken in line from a point 29.2 m N26°W (AC) to a point 31.7 m N30°W (AQ) from RP (Figs 2, 3, 4).

When collecting samples, we checked every bed for possible silicification by dissolving chips in HCl. The test-result was negative. No silicification was found in the cut slices or in the thin sections either.



Fig. 3. A. Upper part of the cliff (Ryssnäs Limestone) with the uppermost sampled bed AZ and the marker-bed AR specially indicated. Note channel-like scour in center of photograph. B. Uppermost part of Slite Marl (below bed AR), herein called Slite Marl z. Ruler in A and B is 17 cm long.

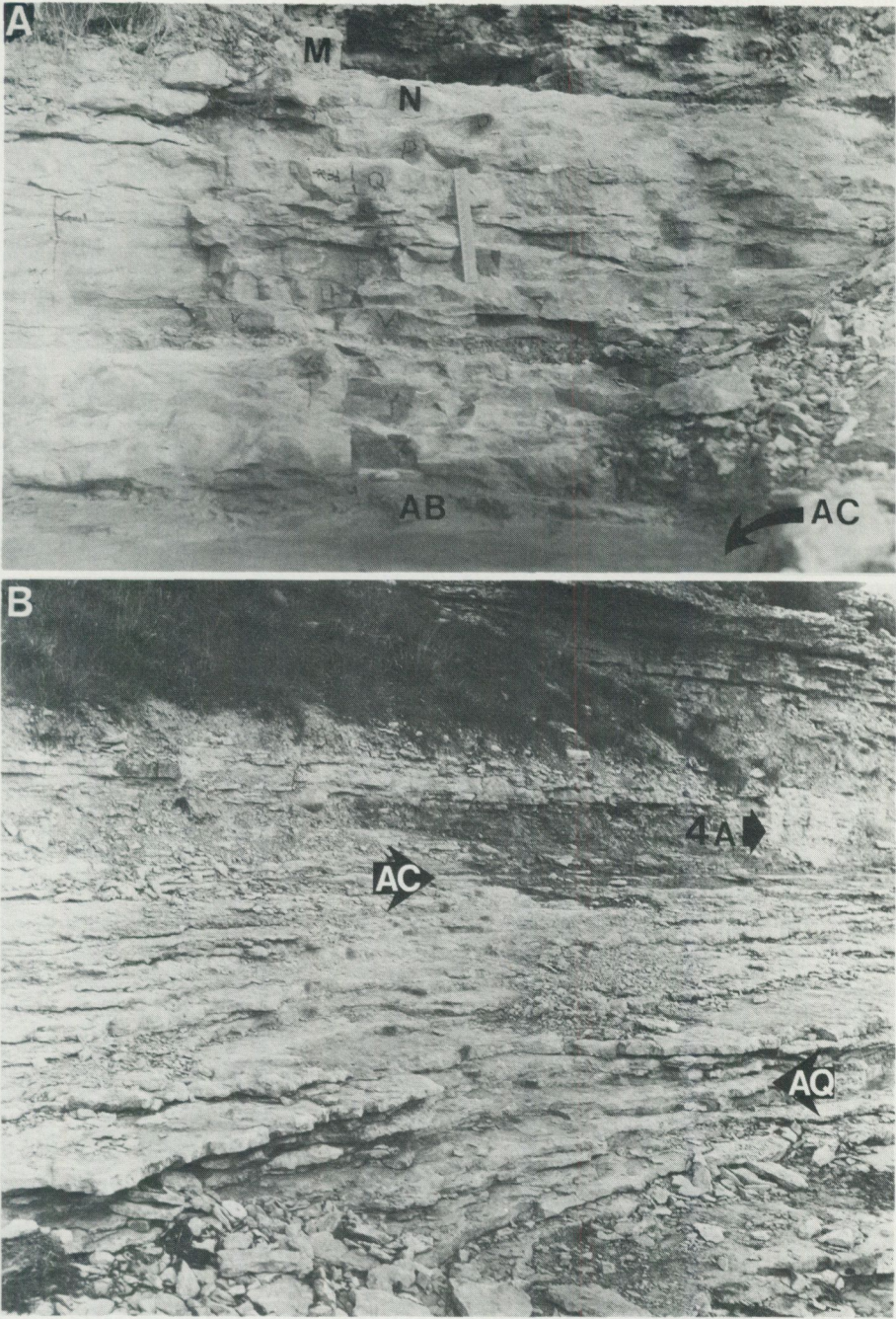


Fig. 4. A. Part of Slite Marl between marker-bed M and bed AC, herein called Slite Marl y. Ruler is 17 cm long. B. Part of Slite Marl between bed AC and bed AQ, herein called Slite Marl x. Position of A is indicated to the right in photograph.

For this study, a total of 56 samples were collected, most of which represent a stratum and a few represent a part of a stratum in the section. From bed C only, two samples were taken. All samples were top-oriented, and the average sample size was about 15 cm in length, 10 cm in width, and 5 cm in thickness. The rock and thin section material is deposited at the Museum Dept., Geological Survey of Sweden, Box 670, S-751 28 Uppsala, under the serial numbers: SGU R(ock) O(riginal) 14-69, and SGU T(hin) S(ection) 333-78-334-88.

STUDY METHODS

LABORATORY TREATMENT

Approximately three to four slices, each about 10 mm thick, were cut in series from each sample perpendicular to bedding. The obvious advantage of cutting many slices is the larger, total exposed surface of a sample, thus greatly increasing the amount of information. The top-orientation of the sample was transferred to every slice. All slices from a sample were thoroughly cleaned in running water (no brush) and checked with the naked eye for a general estimate of variability. The most representative slice from each sample was ground on both sides, using the following procedure: 1, carborundum abrasive No. 120 was used for quick removal of cutting marks, 2, careful cleaning with the finger-tips (no brush) under gently running water, 3, grinding with carborundum abrasive No. 280 to get a smooth, even surface, and 4, cleaning as above. Further grinding with finer abrasives was found unnecessary. The ground slices were then etched with 5% HCl (135 ml of commercial HCl + 865 ml of distilled water) at room temperature in the following way: 1, held in the hand, the slice was first thoroughly wetted in gently running water to facilitate a quick and uniform spread of the dilute acid, 2, with the slice held horizontally, the acid was dispensed from a wash-bottle uniformly over the surface, 3, to maintain the reaction, fresh acid was added continuously and the slice was carefully tilted back and forth to keep an even coating of acid, and 4, after about 15-30 seconds, depending on the reaction speed, the slice was rinsed for about a minute in very gently running water (no finger-tips, no brush).

The grinding and etching procedure yielded a set of sample slices in which all essential properties with respect to average grain-fabric and internal structures were easily examined. Under a low-power binocular microscope, the presence and position of terrigenous quartz and mud, silicification, less soluble carbonate minerals etc., could be rapidly estimated and the plane-parallel surfaces reduced tedious focus adjustments to a minimum.

Many of the slices were stained with Alizarin Red S for an overall measure of the amount and position of dolomite in the rocks. The stain, which was prepared by dissolving 0.1 g of Alizarin Red S in 100 ml of 0.07% HCl (2 ml of commercial HCl + 998 ml of distilled water), gives calcite a deep red colour after about two minutes

whereas dolomite remains unstained. Different stains and staining methods for the discrimination of carbonate minerals have been reviewed by Friedman (1959), Warne (1962), Dickson (1966), Lindholm & Finkelman (1972), and others. The staining procedure used by me follows that of Warne, except for the time of reaction which I reduced to 2–3 minutes.

One of the excess slices from each sample was used for the preparation of thin sections. The exact positions of the thin sections in the slices were carefully registered and the top-orientation was marked on every thin section. The thin sections were made with standard automatic grinding and polishing equipment except for those from very fine-grained rocks with high amounts of terrigenous mud, which normally had to be prepared by hand. All thin sections were cut to an average size of about 23×28 mm, and ground to a thickness of 30–35 μm .

THIN SECTION POINT-COUNTING

The modal analysis was carried out by means of point-counting, using a Leitz attachable mechanical stage. Routinely the thin sections were examined at a magnification of 63x, and the distance between points was set at 1 mm. All grain measurements were made with a calibrated graticule inserted in one of the oculars. In the analysis, the grain solid definition of Dunham (1962:111) was applied and each point was recognized as belonging to one of 81 defined categories, listed on specially designed recording sheets (see further below). From 55 samples a total of 110 thin sections were prepared. 100 of these, representing 86 stratigraphic levels, were point-counted. The number of points recorded in each thin section varied somewhat due to variation in size (see Appendix 1 for original figures). The grand total of points incorporated in the analysis amounts to 62,069. The mean of 621 points per thin section indicates that the estimated percentage of any particular constituent has an absolute error of less than 4% at the 0.95 confidence level. This is graphically shown by van der Plas & Tobi (1965). For percentages lower than 17 and higher than 83 the error is less than 3%, for percentages lower than 7 and higher than 93 the error is less than 2%, and for values lower than 2 and higher than 98 the error is less than 1%. These per cent standard deviations refer to the average number of points recorded. In some rocks with a high variability, two thin sections from the same stratigraphic level were analysed and the number of points amounted to c. 1,300, thus decreasing the overall absolute error for those levels. For theoretical and practical aspects of petrographic modal analysis reference can be given to, e.g., Chayes (1954, 1956), Purdy (1963), Jaanusson (1972), and Flügel (1978:150–166).

DEFINED CONSTITUENTS AND TERMINOLOGY

A petrographic study based on thin section point-counting of a large number of samples, with the intention to be of some stratigraphic significance and application in a regional context, must be based on uniformity in analytic method. This is essential because the resultant mode of every thin section must be comparable to the mode of any other thin section. Ideally, prior to any systematic modal analysis, a set of thin sections should be scrutinized and all relevant components and micro-structures carefully noted, so that the full spectrum of constituents are known as to kind, and the point-counting process thus becomes a matter of identification and categorization only. Usually such a formalized process is achieved by establishing a number of conventions that clearly define constituents and terminology, and by the use of standard recording forms a uniform examination is guaranteed. Such forms, originally designed by me for petrographic modal analysis of rocks from other parts of Gotland, proved to be useful for this study as well. A brief description of items and their arrangement in these forms will be given below (see also Appendices for a summary).

Basically, all constituents (both clastic and authigenic) are classified according to their largest diameter into three size categories, viz., smaller than 0.1 mm (mud), between 0.1 and 2 mm (sand), and larger than 2 mm (gravel). Then follows identification of the object (point) as belonging to one of 38 alternative constituents and, for some of these, indication of relative position. In total the recording forms distinguish between 81 variables. These are listed with numbers in annotated form below, and the 38 alternative constituents are given in italics. Variables 1–50 deal with clastic biogenic constituents, 51–59 with clastic biogenic or abiogenic constituents, 60–65 with clastic abiogenic constituents, 66–71 with clastic abiogenic or authigenic constituents, and 72–80 deal with authigenic constituents. The 81st variable is biogenic dimensionless and additional in character, because it refers to a specific quality of skeletal particles. The suffixes M(=mud), S(=sand), and G(=gravel) indicate each constituent's size category; in cases size is part of its definition. The variables are listed in 28 groups, and occasionally a group is supplemented with references of particular relevance. When no reference is given, some modern well illustrated texts have been of great value. These include, for carbonate petrography in general, Bathurst (1971), Wilson (1975), and Flügel (1978), and, for the discrimination of skeletal particles, Majewske (1969), Johnson (1971), Horowitz & Potter (1971), and Scholle (1978). The recent review of biomineralization products by Lowenstam (1981) has been most useful, as have Wilkinson (1979) and Freeman & Wilkinson (1980).

The 81 variables are:

1. *Skeletal particles <0.1 mm* M. Several studies have suggested that a lower size limit of 0.1 mm is both practical and reasonable for identification purposes (see, e.g., Jaanusson 1972).

- 2–9. *Cyanophyta* S,G.

Rhodophyta S,G.

Chlorophyta S,G.

Algae indeterminate S,G. Rothpletz (1908, 1913), Johnson *et al.* (1959), Johnson (1960, 1961), Wray (1977), Danielli (1981). The blue-green algae are measured according to the size of an aggregate. Many of the green algae are completely converted to sparry calcite. Their identification is then based on preserved internal morphology.

10–19. *Pelecypoda* S,G.

Gastropod S,G.

Cephalopoda S,G.

Tentaculitoidea S,G.

Mollusca indeterminate S,G. Lindström (1884), Larsson (1979).

Identification is mainly based on relative size, external morphology, and occasionally relict shell structures. The Tentaculitoidea are placed among the molluscs according to tradition.

20–21. *Echinodermata* S,G.

22–27. *Trilobita* S,G.

Ostracoda S,G.

Arthropoda indeterminate S,G. Martinsson (1962).

28–29. *Brachiopoda* S,G.

30–35. *Bryozoa erect* S,G.

Bryozoa encrusting S,G.

Bryozoa indeterminate S,G. Brood (1975, 1976). Coenitids are included in this group.

36–37. *Foraminifera* S,G. Conkin & Conkin (1977, 1979). This group is rarely present in any number, but occasionally agglutinated forms with strong reddish or brownish colours occur.

38–39. *Tabulata* S,G. Lindström (1899); Stel (1978).

40–41. *Rugosa* S,G. Wedekind (1927), Minato (1961).

42–43. *Stromatoporoidea* S,G. Stearn (1966), Mori (1969, 1970).

44–45. *Vertebrata* S,G. Gross (1966, 1968a, 1968b).

46–47. *Unidentifiable skeletal particles* S,G.

48–50. *Micritized skeletal particles* M,S,G. Fragments of any size that have been bored or macerated to such an extent that identification as to fossil group is not possible.

51–52. *Phosphate indeterminate* M,S.

53–54. *Brown organic matter* M,S. Thin threads and sheets or small shapeless bodies of a semi-translucent material present along crystal interfaces or floating in mud.

55–57. *Coated grains* M,S,G. A general term for any encrusted particle, including ooids.

58–59. *Peloids* M,S. A general term for particles formed of cryptocrystalline or microcrystalline material irrespective of size or origin (McKee & Gutschick 1969:

101). The term (including pellets) as used here refers to micritic semi- to non-translucent circular to oval particles of mud- and fine sand-size.

60–61. *Intraclasts* S,G. A term proposed by Folk (1959) for fragments of lithified or unlithified sediment of local origin.

62–63. *Terrigenous quartz* M,S.

64–65. *Mica* M,S.

66–67. *Glauconite* M,S. The *sensu lato* morphologic use is applied (McRae 1972).

68–69. *Micrite* M.

Micrite, intraparticle M. A term proposed by Folk (1959). Used here for non-translucent extra- and intraparticle cryptocrystalline material, which implies that very fine-grained terrigenous matter may be included. This definition differs from Folk's.

70–71. *Microspar* M.

Microspar, intraparticle M. A term proposed by Folk (1965). Used here for calcite or dolomite crystals with a maximum diameter smaller than 0.1 mm. The term does not *per se* indicate that the crystals are neomorphic as originally defined by Folk. Also the size range differs from Folk's definition.

72–73. *Authigenic opaque minerals* M,>M.

74–75. *Authigenic silica* M,>M.

76–80. *Sparry cement* >M.

Sparry cement, fissure >M.

Sparry cement, shelter >M.

Sparry cement, vug/fenestral >M.

Sparry cement, intraparticle >M. Calcite or dolomite crystals that are larger than 0.1 mm, irrespective of origin. Synonymous to macrospar (Sundquist 1982a).

81. Micrite envelopes. Nontranslucent rind on skeletal particles. Their origin and environmental significance have been discussed by, e.g., Bathurst (1964, 1966, 1971, 1974), Friedman *et al.* (1971), Alexandersson (1972), Kobluk & Risk (1977a, 1977b), and Fabricius (1977). Although it has become evident that Recent formation of micrite envelopes, as well as the process of micritization of skeletal grains in general, is not solely a result of the boring activity of blue-green and green algae (endolithic sponges, bacteria, and fungi have also been recorded), the algae seem nevertheless to be the most common borer where micritized biogenic particles are found in abundance, which is down to 40–50 m depth. Thus heavy micritization of large numbers of skeletal particles might well be a palaeobathymetric indicator.

The list of variables could have included many more items. The spectrum given, however, has proved to be practical for point-counting of large numbers of thin sections, and it includes all important aspects with regard to particle composition of those rocks from Gotland I have seen. Textural, non-numerical properties, i.e. microstructures like lamination, bioturbation, grading etc. and cement characteristics like

pendent, meniscus, relict isopachous rinds etc., were noted, if present, contemporaneously with the counting. Detailed study of sedimentary structures, however, was accomplished by scanning the set of etched slices under a low-power binocular microscope. The terminology used in the sedimentologic description is to be found in most standard texts on the subject; a comprehensive treatment is given in Reineck & Singh (1980). For terminology of stratification, I have followed that of McKee & Weir (1953) and for trace fossils that of Martinsson (1970). The term 'primary' dolomite refers to the presence, in some quantity, of dolomite rhombs with an average size of about 50–60 μm , floating in micritic/microsparitic matrix and that show no evidence of growth at the expense of adjacent skeletal debris (Fig. 9A). The environmental significance of 'primary' dolomite will be discussed in the section on "Depositional environments", as will other sedimentary structures and characteristics found in the section. Regarding lithologic classification, I have chosen not to arrange the data presented here according to either the scheme of Folk (1959) or Dunham (1962), the two most widely adopted today. There are several reasons for this, one being that terms like "intramicrudite" or "pelsparite" (Folk's) say very little, if anything, to the non-sedimentologist and are, in my experience, usually more confusing than informative. Another reason is that no one classification is applicable to a detailed analysis because many of their rock types are so often present in the same thin section that classification usually becomes capricious. A third reason is that although Dunham's terms are useful for superficial characterization of rock types, they are intuitively descriptive, Dunham's basis for classification (presence or absence of mud as indicating rate of water turbulence in the area of deposition) is hardly sound. As pointed out by Bathurst (1974:269), and others, much of the "mud" can in fact be a microcrystalline cement, and much of the sparite can be neomorphic in origin. To use Dunham's classification properly, careful and detailed studies have to be made in order to establish the origin of the "mud" and sparite present. This is not always an easy task, but if not considered (which is too often the case), Dunham's terms can only be used in a descriptive sense. I have used the easily understood adjectives calcilitic, calcarenitic, and calciruditic for the general description of the lithologies present in the Haganäs 1 section. As used here the terms refer to the overall impression of a stratum, and not to any precise percentage values. In a future summary of the lithologic data from all three sections incorporated in Project "The Whole Environment", some pertinent discriminating classification will be employed. For the time being I think the terms used sufficiently characterize the lithologic succession.

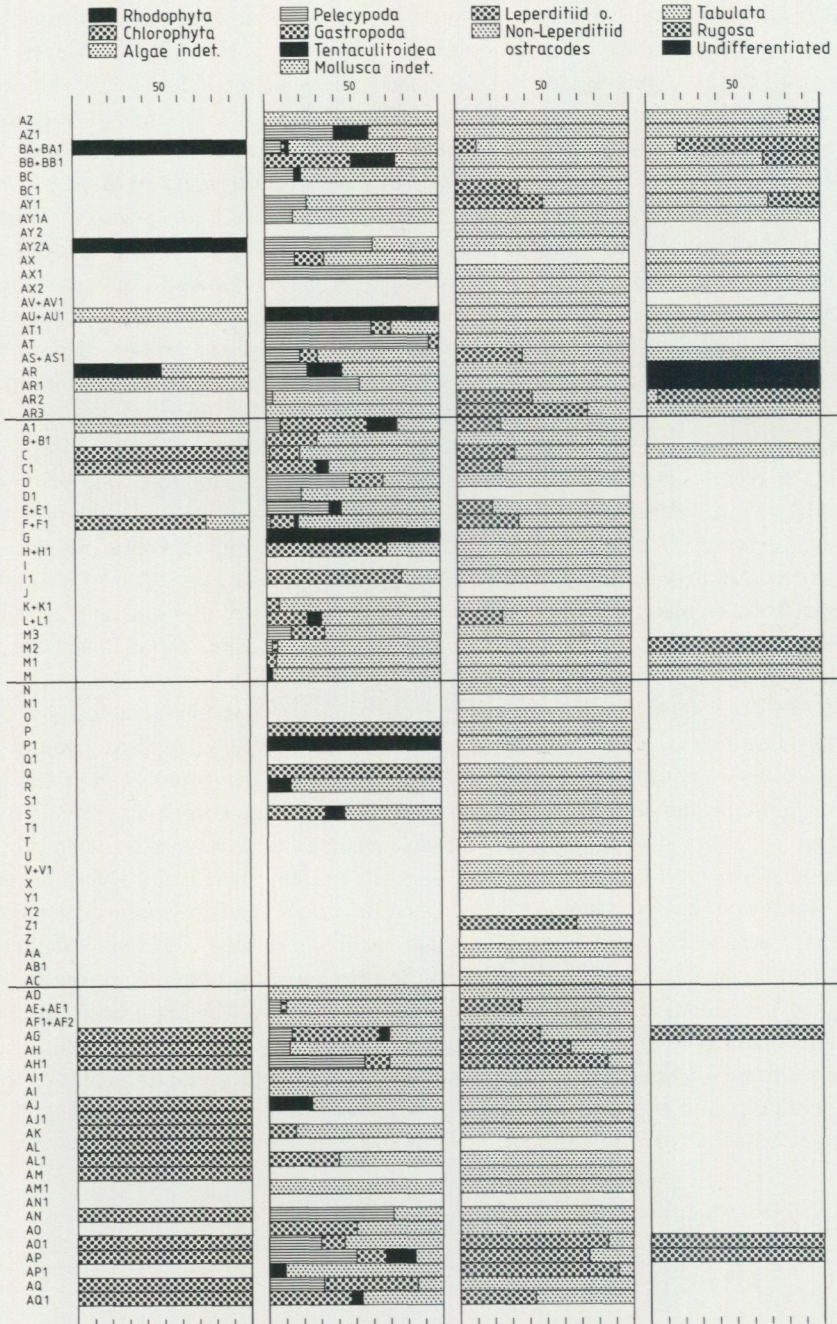


Fig. 5. Special account of kinds and percentage frequencies of algae, molluscs, ostracodes, and tabulates & rugose corals. Thin section designations and levels are given to the left. Note that for each level, each group is given as 100% regardless of variation in absolute numbers. The three horizontal lines mark the boundaries between the major lithostratigraphic units.

DESCRIPTION OF THE SECTION

SUMMARY OF PETROGRAPHIC MODAL ANALYSIS

A summary of the modal analysis is presented in the fold-out diagram (back cover), supplemented with a special account in Fig. 5, and in simplified and slightly modified form in Figs. 6 and 7 (for these see further below). Normalized raw data are given in Appendix 1. To the right of the lithologic column in the fold-out are given the percentage frequencies of the major constituents, assembled under three main headings. The data represent 86 stratigraphic levels, 72 based on one thin section and 14 based on two. Black bars denote values in per cent of all points counted, and (regarding the skeletal debris) black and white bars together denote values in per cent of all points identified as skeletal debris of sand and gravel size, the total amount of which is given in one column. In order to facilitate the reading of the fold-out, some short remarks will follow. Under the heading *Gross composition* all points are included (except for authigenic opaque minerals, the amounts of which are negligible here; see Appendix 1). These four columns give an immediate conception of rock composition according to particle size and amount of sparry cement. Under the heading *Composition of mud and peloids* are shown the 'mud' constituents and the size variation of peloids. Hence micrite, microspar, detrital quartz (all of which is of mud size), and peloids smaller than 0.1 mm, together make up the constituent termed 'mud'. Because of repeated difficulties in the complete separation of microspar and skeletal grains of mud size, the latter are incorporated in the microspar. When clearly distinguished, however, these skeletal grains amount to some per cent only. Under the heading *Composition of skeletal debris* are shown the majority of the 'sand' and 'gravel' constituents, and the original detailed data have, for practical reasons, been lumped into major taxa. 'Others' in the last column include, in addition to some scattered foraminifers and phosphatic fragments, micritized skeletal particles. The amounts of these are given separately in Appendix 1, as are micrite envelopes, intraclasts, and size distribution of each taxon. With regard to arthropods, the distinction between trilobites and ostracodes was not complete in six of the thin sections. The points recorded as indeterminate were then distributed to trilobites and ostracodes respectively, proportional to the frequencies of these taxa. The purpose of this arrangement is only to simplify the graphic presentation of the data. It does not, in my opinion, result in any strong bias because the number of indeterminate arthropods never amounts to more than about 1/4 of the total trilobites plus ostracodes.

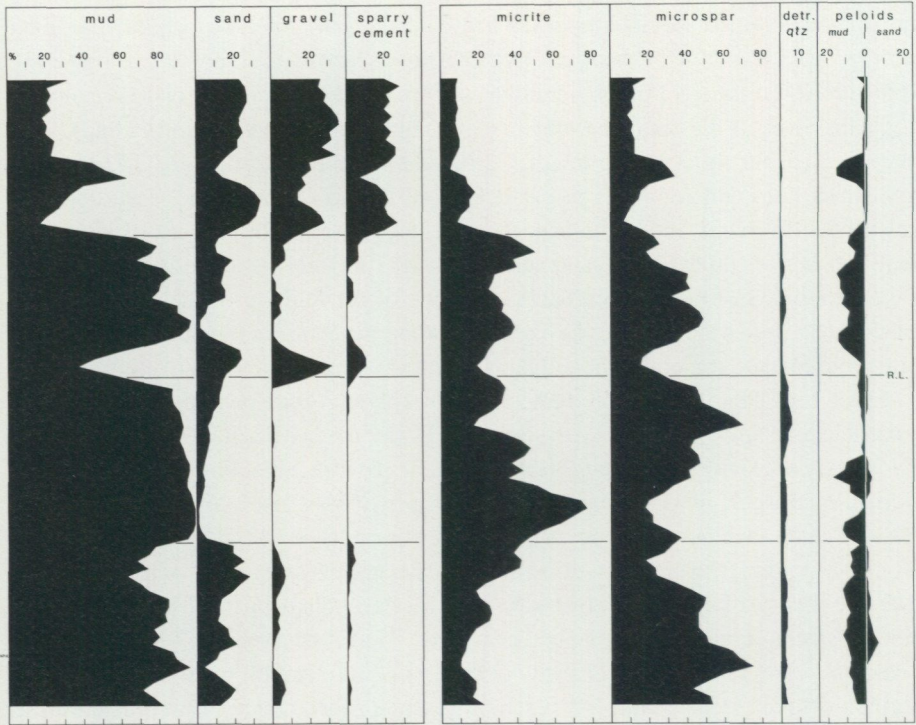


Fig. 6. Time-trend analysis of percentages of the gross-components, mud-components, and peloids, shown in the fold-out diagram. Black areas give percentage of whole samples. The 84 levels (thin section levels AZ and AQ1 had to be excluded) are plotted at equal vertical distance. Horizontal lines indicate boundaries between major lithostratigraphic units.

TIME-TREND ANALYSIS

To generalize the picture and identify stratigraphic trends, the modal analysis data were slightly smoothed by the use of a moving average. The techniques of smoothing numerical data have been described and discussed by, e.g., Harbaugh & Merriam (1968:53–59) and Davis (1973:222–231). The process, commonly called time-trend analysis, was accomplished here by the aid of a Texas Instruments Programmable

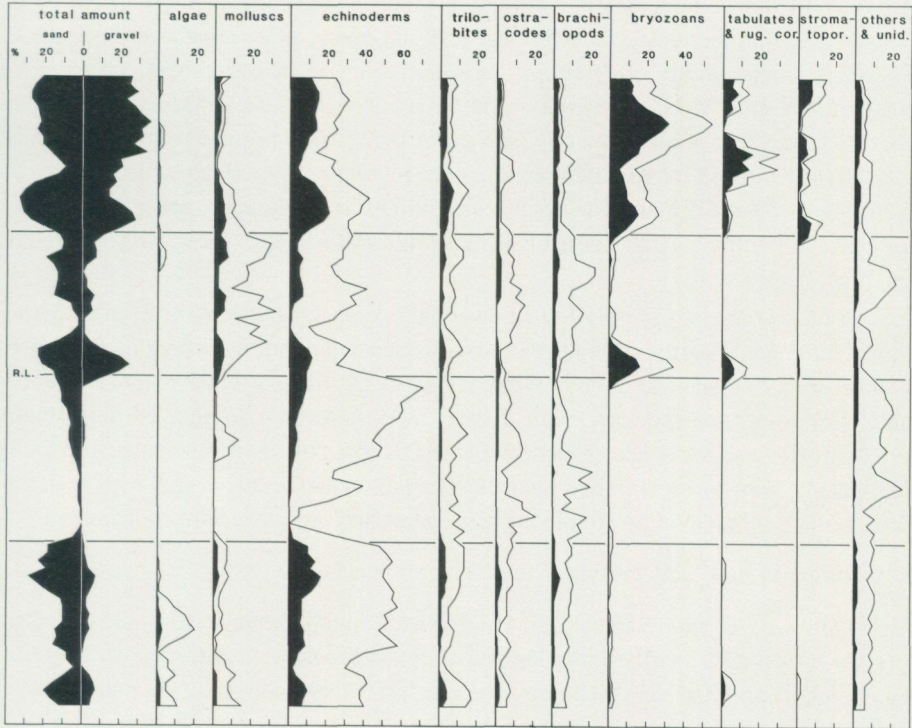


Fig. 7. Time-trend analysis of percentages of the skeletal debris, shown in the fold-out diagram. Black areas give percentage of whole samples, black and white areas give percentage of skeletal debris. Cf. Fig. 6.

Calculator TI-59 and program ML-17. The minimum moving average interval of 3 was used to preserve part of the dynamics of the original data. The smoothed data are shown in Figs. 6 and 7, where they are arranged in precisely the same way as in the fold-out diagram, but are plotted at equal vertical distance (thus ignoring the actual sample distances). Note that due to the three-term interval, the data from the top-most and bottom-most thin sections cannot be smoothed and are consequently excluded in Figs. 6 and 7.

CONTINUOUS LITHOLOGIC ANALYSIS

The lithologic description that follows is based on the set of cut and etched slices and supplemented with field observations. Although the vertical lithologic succession as depicted in the column on the fold-out diagram is basically correct, it should be emphasized that the nature of individual beds can show rather rapid lateral variation. Therefore some of the observations recorded, such as bed thickness, presence of hardgrounds etc., have a somewhat limited application. Sedimentary structures and characteristics that occur frequently, and are of significance for the recognition of most beds in the field and for the interpretation of depositional environments, are summarized in the fold-out diagram. The description follows in stratigraphic order from base to top, and is complemented occasionally with illustrations (for overview photographs see Figs. 2, 3, and 4).

–111 to –108 cm. (Sample AQ.) Lower half: compacted grey to olive-green, partly thinly laminated, partly strongly bioturbated mudstone with endichnia and scattered non-ordered fine skeletal debris. Weakly developed irregular erosive contact. Upper half: fining-upward sequence with a basal c. 5 mm thick stratum of horizontally oriented, fine and some coarse skeletal debris, overlain by nearly uncompact, thinly laminated, grey to brown-grey mudstone rare in skeletal debris and with scattered endichnia, grading into grey to olive-green compacted mudstone with endichnia.

Grey-green shaly clay parting, 1 to several mm thick.

–108 to –105 cm. (Sample AP.) Lower half: slightly compacted to uncompact grey to brown-grey, partly thinly laminated, partly bioturbated mudstone with scattered endichnia and fine skeletal debris. Distinct flat but irregular, erosive contact. Upper half: coarse- to very coarse-grained stratum with non-ordered skeletal debris and rounded intraclasts of a lithology identical to that of the lower half, in a grey to brown-grey mud matrix. No apparent grading. Fig. 8A.

Grey-green shaly clay parting, 1 to 10 mm thick.

–105 to –102 cm. (Sample AO.) Lowermost part fine and coarse, non-ordered skeletal debris in a grey mud matrix grading upward into grey to brown-grey partly thinly laminated, partly strongly bioturbated, almost uncompact mudstone with scattered skeletal debris and endichnia, succeeded by compacted, strongly bioturbated brown-grey mudstone with some fine skeletal debris.

Grey-green shaly clay parting, 1 to 10 mm thick.

–102 to –98 cm. (Sample AN.) A basal, about 5 mm thick stratum of horizontally oriented fine skeletal debris grading upward into greyish thinly laminated uncompact mudstone with few skeletal fragments and endichnia, succeeded gradually by distinctly thinly laminated, slightly bioturbated compacted brown-grey mudstone with rare skeletal debris. Fig. 8B.

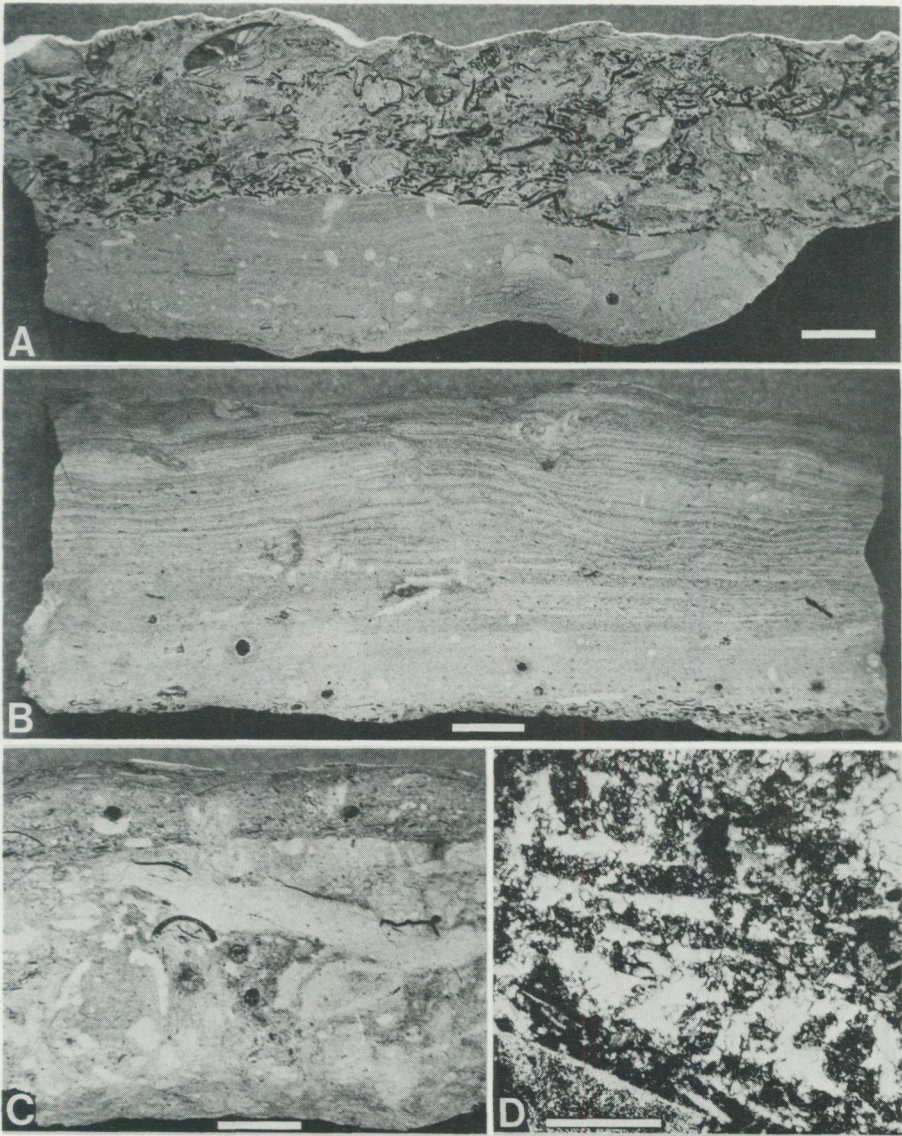


Fig. 8. A-C. Photographs of individual beds (etched slices, bar is 1 cm). A. Bed AP. Note erosive contact between thinly laminated lower part and very coarse upper part. B. Bed AN. Note sparse skeletal debris and thin, slightly wavy lamination and virtual lack of bioturbation. C. Bed AJ. Note erosive contact in the upper part, and some "black dots" (those in center of photograph with geopetal fill) present also in the lower part of A and B. D. Micrograph from thin section AJ showing the well preserved internal structure of a "black dot". It is interpreted as the calcified remains of a dasycladacean algal thallus, here in slightly oblique section with mud filled sporangia and central stem. Bar is 0.5 mm. Plane light.

Green-grey shaly clay parting, 1 to 15 mm thick.

–98 to –95 cm. (Sample AM.) Grey to brown-grey, laminated and thinly laminated, almost uncompact mudstone with sparse fossil debris and endichnia, succeeded gradually by a c. 5 mm thick stratum with fine skeletal debris in a brown-grey mud matrix. In the lower part of the bed there are a few, mm-wide vertical cracks filled by sparry calcite and/or mud.

Green-grey shaly clay, 5 to 30 mm thick.

–95 to –92 cm. (Sample AL.) Lower part strongly bioturbated greyish uncompact mudstone with much fine and some coarse non-ordered skeletal debris overlain gradually by grey to brown-grey strongly bioturbated, partly compacted mudstone with scattered fossil debris and endichnia.

Green-grey silty, shaly clay, 1 to 15 mm thick.

–92 to –90 cm. (Sample AK.) Lower half fine and some coarse horizontally oriented skeletal debris in a brown-grey mud matrix, grading upward into laminated and thinly laminated brown-grey, slightly compacted mudstone with scattered fossil fragments and endichnia. Some, mm-wide internal cracks filled by sparry calcite in the lower and upper part.

Green-grey silty, shaly clay parting, 1 to several mm thick.

–90 to –87 cm. (Sample AJ.) Lower 3/4: strongly bioturbated, almost uncompact greyish mudstone with some fine and coarse skeletal debris and many endichnia, some of which have a considerable size. Flat erosive contact. Upper part constitutes a fining-upward sequence with horizontally oriented fine and some coarse fossil debris in a grey mud matrix grading into brown-grey mudstone with few endichnia. Figs. 8C and 8D.

Green-grey silty, shaly clay, 1 to 20 mm thick.

–87 to –82 cm. (Sample AI.) Grey to brown-grey slightly compacted mudstone with a c. 8 mm thick basal accumulation of fine and some coarse, horizontally oriented skeletal debris, and with a decreasing amount of fine and coarse fossil fragments upwards. The bed contains many endichnia and is intensively bioturbated in its upper part. Some, mm-wide vertical cracks in the upper and lower part. Fig. 9A.

Green-grey silty, shaly clay, 1 to 10 mm thick.

–82 to –79 cm. (Sample AH.) Abundant medium- and coarse-grained skeletal debris, most of which are horizontally oriented, with no apparent grading, in a grey to brown-grey fine-grained to muddy matrix. The bed is partly bioturbated and only slightly compacted, and contains cm-sized intraclasts with slightly irregular outlines in its upper part. The lithology of the intraclasts is identical to that of the upper part of the underlying bed. Fig. 9B.



Fig. 9. A. Micrograph in plane light from thin section AI illustrating the highly dolomitic, finely crystalline hypidiotopic fabric characteristic of many microsparitic calcilitites in the section. The virtually unaffected calcitic trilobite carapace indicates an early dolomite nucleation ('primary' dolomite). Bar is 0.2 mm. B. Micrograph in plane light from thin section AH1 illustrating poor sorting and patchy accumulations of micrite indicating bioturbation. Bar is 1 mm.

Grey clay parting, 1 to several mm thick.

—79 to —77 cm. (Sample AG.) Medium- and coarse-grained non-ordered skeletal debris in a greyish fine-grained and muddy matrix, eroded irregularly into grooves and ridges of one to several cm in amplitude. The erosion surface is rather smooth and occasionally has a mm-thick dark rind. The grooves are filled partly with non-ordered

fine and coarse skeletal debris, partly with brown-grey mud, partly with mm- and cm-sized intraclasts of a lithology similar to that of the eroded bed. The presence of bryozoan holdfasts encrusting the pitted surface and the dark rind indicate a submarine hardground. Rare vertical cracks filled by sparry calcite and mud in the lower part of the bed.

Grey clay parting, 1 to several mm thick.

–77 to –75 cm. (Sample AF.) Brown-grey homogeneous bioturbated slightly compacted mudstone with very few fine skeletal debris, and abundant endichnia. At the base are cm-sized, well rounded darkened intraclasts of a fine-grained muddy lithology. In places the bed is developed as a hardground similar to the underlying bed.

Grey clay parting, 1 to several mm thick.

–75 to –72.5 cm. (Sample AE.) Dark grey, partly strongly bioturbated bed made up of non-ordered medium- and some coarse-grained skeletal debris, partly in a light grey mud matrix, partly in a sparry calcite matrix, with muddy intercalations. In its lower part, the bed contains cm-sized rounded and elongated intraclasts of greyish mudstone. In places the bed is developed as a hardground with an irregular, pitted and mineralized surface and bryozoan holdfasts.

Grey clay parting, 1 to several mm thick.

–72.5 to –70.5 cm. (Sample AD.) Light to dark grey, very strongly bioturbated, somewhat compacted mudstone with patchy accumulations of non-ordered fine and some coarse skeletal debris.

Grey clay parting, 1 to several mm thick.

–70.5 to –68.5 cm. As sample AC, *q.v.*

Grey clay parting, 1 to several mm thick.

–68.5 to –66 cm. (Sample AC.) Greenish grey, strongly bioturbated and compacted mudstone, enclosing elongated diffusely defined uncompact nodular bodies with scattered fine skeletal debris and endichnia.

–66 to –64.5 cm. Green-grey shaly clay.

–64.5 to –62 cm. (Sample AB.) Grey to brown-grey partly thinly laminated, partly bioturbated mudstone with very few fossil fragments and abundant endichnia, most of which are vertical. The bed is apparently uncompact except for its lowermost and uppermost part, which show strong compaction. Fig. 10A.

Green-grey clay parting, 1 to several mm thick.

–62 to –60 cm. (Sample AA.) Grey to brown-grey partly massive, partly thinly laminated, partly bioturbated mudstone, apparently barren of skeletal debris, and with many endichnia, most of which are vertical. Mainly uncompact but strongly com-

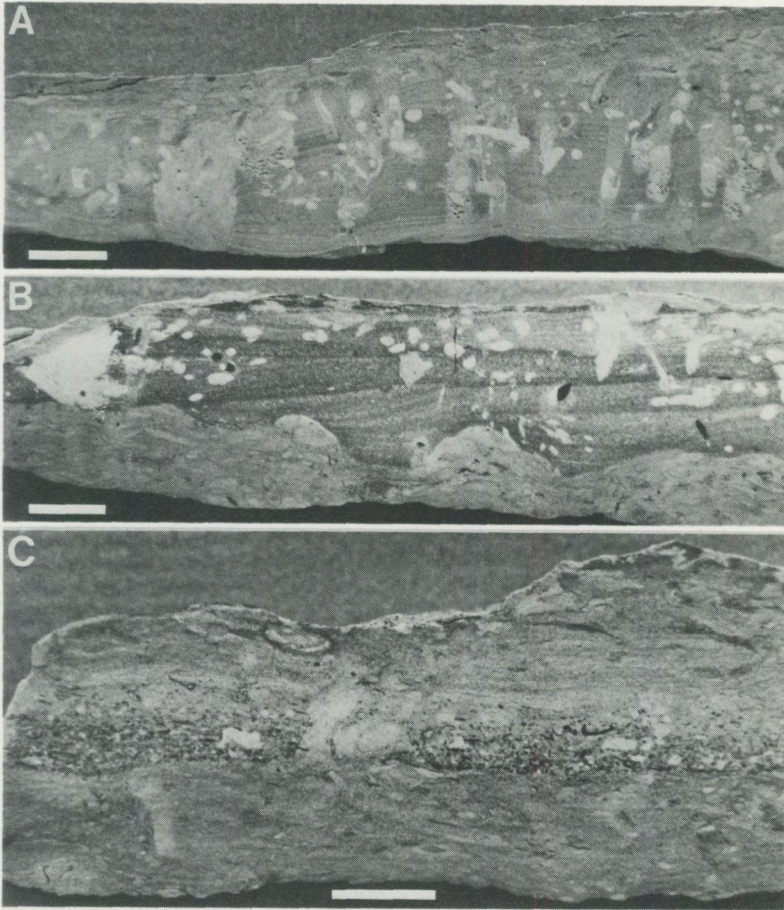


Fig. 10. Photographs of individual beds (etched slices, bar is 1 cm). A. Bed AB. Note thin lamination and abundant vertical burrows. B. Bed X. Note irregular erosive contact between lower strongly bioturbated part and upper cross-laminated, slightly bioturbated part. C. Bed R. Note thin fining-upward sequence in the middle of the bed.

pacted in its uppermost and lowermost part. Some very thin to mm-wide internal vertical cracks filled by sparry calcite and mud.

–60 to –59 cm. Grey-green shaly clay.

–59 to –54 cm. (Sample Z.) Grey to green-grey, strongly bioturbated and much to slightly compacted mudstone with very few skeletal debris of sand size.

Green-grey clay parting, 1 to several mm thick.

–54 to –49 cm. (Sample Y2.) Grey to green-grey, strongly bioturbated and compacted mudstone with irregular silty intercalations and rare fine and coarse fossil debris in the lower part. (Sample Y1.) Grey to green-grey, strongly bioturbated and compacted mudstone with scattered fine fossil debris.

Green-grey clay parting, 1 to several mm thick.

–49 to –46 cm. (Sample X.) Lower part: green-grey, strongly bioturbated and compacted mudstone with scattered fine skeletal debris. Irregular erosive contact. Upper part: brown-grey, cross-laminated to thinly cross-laminated, in the uppermost part thinly laminated, fine-grained bed with many endichnia, and rare fine skeletal debris. Fig. 10B.

–46 to –44 cm. Green-grey shaly clay.

–44 to –41 cm. (Sample V.) Lower part: grey to brown-grey, slightly compacted to uncompact, laminated to thinly laminated fine-grained bed with many endichnia and scattered fine skeletal debris. Irregular erosive contact. Upper part: slightly bioturbated, green-grey compacted mudstone with brown-grey silty thin laminae. At the base of the upper part some intact trilobite carapaces and brachiopods of cm-size.

Green-grey clay parting, 1 to several mm thick.

–41 to –37.5 cm. (Sample U.) Lower part: grey to brown-grey, partly thinly laminated, partly massive, partly severely bioturbated, slightly compacted to uncompact mudstone with scattered skeletal debris. Upper part: green-grey strongly bioturbated and compacted mudstone with small patchy accumulations of fine skeletal debris. The transition between lower and upper part predominantly vaguely defined and highly irregular.

Green-grey clay parting, 1 to several mm thick.

–37.5 to –32 cm. (Sample T.) Green-grey strongly compacted and severely bioturbated mudstone with scattered fossil fragments as well as small patchy accumulations of fine skeletal debris, and thin silty intercalations.

Green-grey clay parting, 1 to several mm thick.

–32 to –28 cm. (Sample S.) Lowermost part: green-grey, strongly compacted and bioturbated mudstone with scattered skeletal debris. Upper part: grey to light green-grey, slightly compacted and bioturbated, partly thinly laminated mudstone with some endichnia, some scattered fine and coarse fossil fragments, and a thin basal accumulation of horizontally oriented fine skeletal debris. In the uppermost part a scour-and-fill accumulation of medium- to coarse-sized skeletal debris in a mud and sparry calcite matrix.

–28 to –25 cm. Green-grey silty clay enclosing a lenticular bed (=sample R). Lower part: green-grey strongly bioturbated and compacted mudstone with thin silty intercalations and scattered fine skeletal debris. Upper part: grey to green-grey bioturbated and compacted mudstone with thin silty laminae and a basal, partly bioturbated c. 1 cm thick accumulation of horizontally oriented medium and some coarse fossil fragments in a mud matrix, constituting a fining-upward sequence. No apparent erosion at the contact to the lower part of the bed. Fig. 10 C.

-25 to -18 cm. (Sample Q.) At the base green-grey, strongly bioturbated and compacted mudstone, succeeded by a c. 15 mm thick fining-upward sequence with a basal accumulation of horizontally oriented medium and some coarse skeletal debris in a mud matrix, grading into light green-grey slightly bioturbated mudstone, succeeded by a c. 5 mm thick accumulation of horizontally oriented medium and coarse skeletal debris in a mud matrix, succeeded gradually by c. 4 cm of light green-grey strongly bioturbated, partly strongly compacted mudstone with endichnia and small patchy accumulations of fine and medium skeletal debris.

Green-grey silty clay parting, 1 to several mm thick.

-18 to -11 cm. (Sample P.) Grey to green-grey, in places dark grey, very strongly bioturbated, partly strongly compacted, partly almost uncompact mudstone with endichnia and scattered, non-ordered medium and coarse skeletal debris, as well as irregular, patchy cm-sized accumulations of skeletal debris of fine and medium size in a mud and sparry calcite matrix.

Vaguely defined and irregular bedding plane.

-11 to -6 cm. (Sample O.) At the base green-grey strongly compacted and bioturbated mudstone with scattered skeletal debris, succeeded gradually by grey to green-grey, in places dark grey, very strongly bioturbated, partly compacted, partly almost uncompact mudstone with some endichnia and scattered medium and coarse skeletal debris, along with intact trilobite carapaces and brachiopods of cm-size, and irregular patchy cm-sized accumulations of fine to coarse skeletal debris in a mud and sparry calcite matrix.

Vaguely defined and irregular bedding plane.

-6 to 0 cm. (Sample N.) Grey to green-grey, in places dark grey, severely bioturbated, mostly strongly compacted, mottled mudstone with scattered fine to coarse skeletal debris and some diffuse patchy accumulations of fine- and medium-sized skeletal debris in a mud and sparry calcite matrix. The uppermost part grey-brown to yellow-brown and top surface highly irregular and strongly pitted. Fig. 11B.

0 to +2 cm. Reddish brown, in places greyish green, silty clay.

+2 to +11 cm. (Sample M.) Lower 2/3: thin bed composed of a completely unsorted and chaotic mixture of fine to coarse (up to several cm) slightly to strongly rounded skeletal debris and intraclasts (grey to dark grey mottled mudstone with some scattered skeletal debris; many with a dark grey to almost black mm-thick outer rind) and a grey to brown-grey mud matrix and mm-sized interstices filled by sparry calcite. The bed is rather strongly compacted with many sutured contacts between larger particles. Upper 1/3: the bed just described is rather abruptly overlain by three distinct lithologies, which are, in succeeding order: grey to brown-yellow thinly laminated silty mudstone, truncated by a somewhat irregular erosive contact of scour-and-fill

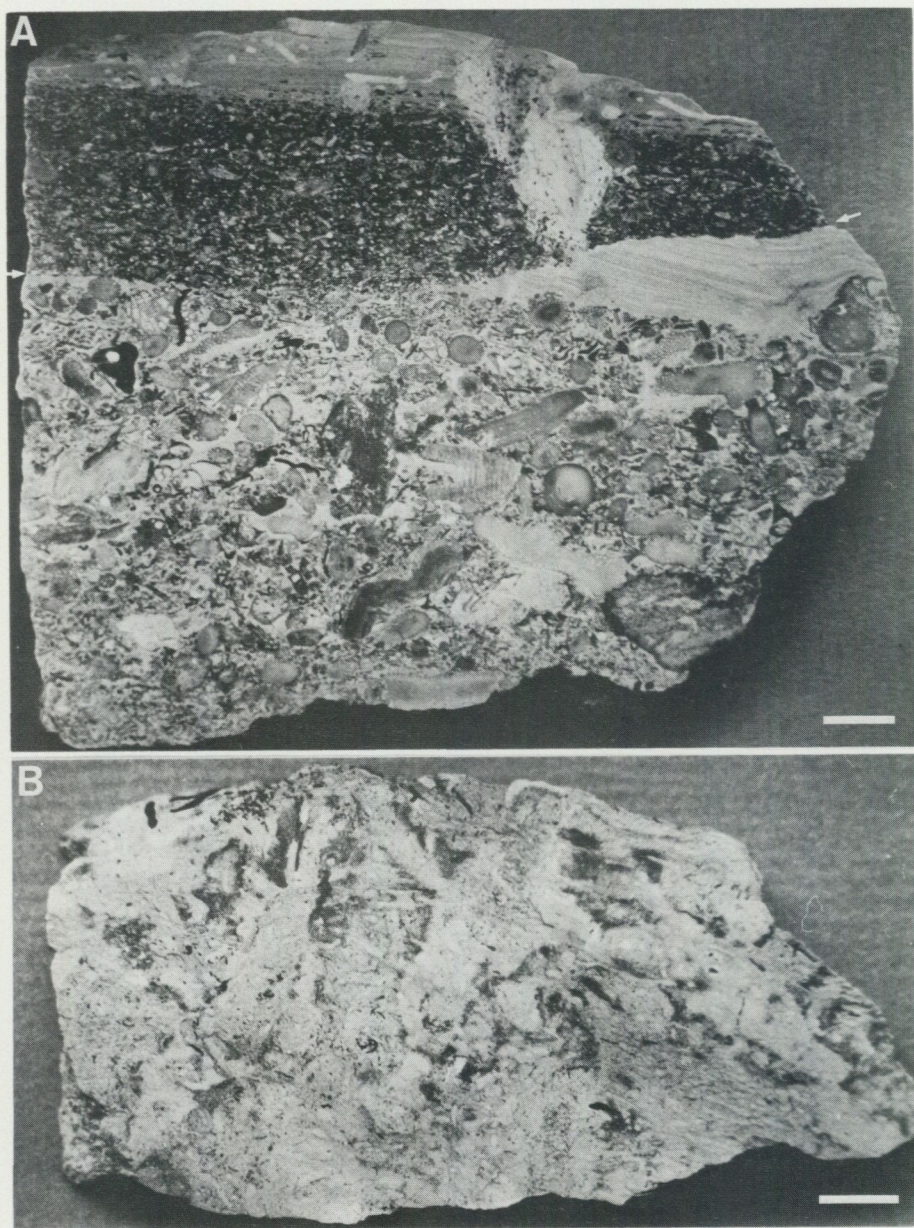


Fig. 11. Photographs of individual beds (etched slices, bar is 1 cm). A. Bed M. Note the erosive contact (arrowed) between the lower pebbly fining-upward sequence and the upper finer-grained fining-upward sequence. B. Bed N. Note large burrows and differentiated degree of early lithification.

character. Dark grey very thin, compacted bed composed of poorly sorted fine to coarse horizontally oriented, slightly to moderately rounded skeletal debris and some intraclasts (grey mudstone, up to 5 mm) in a slightly muddy and predominantly sparry calcite matrix. Rather distinct but gradual contact. Grey to brown-grey, little bioturbated and compacted, laminated to thinly laminated silty mudstone with some endichnia and a basal accumulation of horizontally oriented fine to medium skeletal debris. The uppermost two lithologies are penetrated by a funnel-shaped structure filled by homogeneous yellow-grey mud with some non-ordered fine to medium skeletal debris. Fig. 11A.

+11 to +12 cm. Reddish brown silty clay.

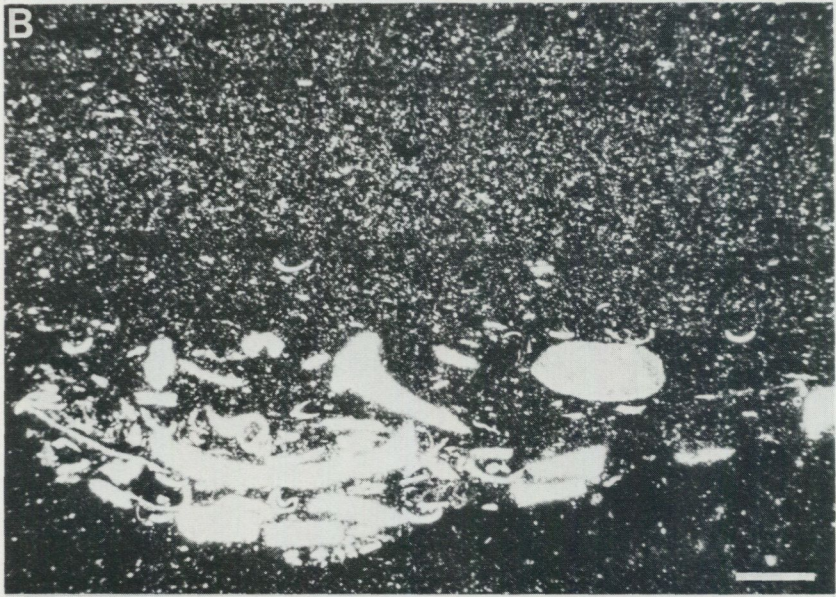
+12 to +15 cm. (Sample L.) A basal lamina of grey to light green-grey mudstone with some medium to coarse skeletal debris. Diffuse to distinct, highly irregular erosive contact. Lamina of fine to coarse, horizontally oriented skeletal debris and medium to coarse (up to several cm) angular to rounded intraclasts of a lithology identical to that of the underlying lamina, in a grey to brown-grey mud matrix. Distinct, gradual contact. Very thin bed of dark grey to brown-grey, thinly laminated, slightly compacted silty mudstone with some thin laminae of horizontally oriented, medium-sized skeletal debris, and basally situated cm-sized intraclasts (brown-grey thinly laminated mudstone with morphologically intact gastropods and endichnia). Scattered endichnia at base and top. In the middle of this upper lithology is a flat erosive contact, marked as a small scale angular unconformity.

+15 to +21 cm. Green-grey shaly claystone with thin silty laminae and thin (up to some cm) lenticular calcareous beds.

+21 to +24 cm. (Sample K.) Lower half: grey to brown-grey, slightly bioturbated, almost uncompactd thinly laminated silty mudstone with endichnia and very few scattered skeletal debris, and some internal vertical hair-line cracks filled by sparry calcite. Wavy irregular erosive contact of scour and fill character. Upper half: lithology identical to the lower half but with a basal very thin accumulation of horizontally oriented fine- to medium-sized skeletal debris, constituting a small scale fining-upward sequence, and with climbing ripple thin cross-lamination in the lower part. Fig. 12A-C.

+24 to +26 cm. Green-grey shaly claystone with thin silty laminae.

+26 to +29 cm. (Sample J.) Lowermost part green-grey, compacted claystone with thin yellow-grey silty laminae. Slightly irregular erosive contact. Very thin bed of brown-grey, somewhat compacted and bioturbated, thinly laminated silty mudstone with endichnia and rare skeletal debris. Within this bed is an irregular erosive contact, marked as a small scale angular unconformity, and some hair-line to mm-wide vertical cracks filled by sparry calcite. The cracks end abruptly against an uppermost part which is identical to the lowermost part. Fig. 13A.



+29 to +36 cm. Green-grey shaly claystone with thin silty laminae and thin (up to several cm) lenticular calcareous beds.

+36 to +40 cm. (Sample I.) At the base slightly compacted greenish grey mudstone with small patchy accumulations of non-ordered, fine- and medium-sized skeletal debris, succeeded with no sharp contact by an about 10 mm thick lamina of brown-grey uncompact mudstone with some endichnia and fine- and medium-sized skeletal debris and a basal accumulation of horizontally oriented, medium to coarse skeletal debris, grading into brown-grey thinly laminated, slightly compacted mudstone with scattered coarse skeletal debris and many endichnia, grading into light brown-grey, thinly laminated compacted silty mudstone with endichnia.

+40 to +43 cm. Reddish grey silty clay.

+43 to +51 cm. Lower half: green-grey strongly compacted clayey mudstone with silty intercalations. Transition to overlying half gradual. Upper half (sample H): very thin bed of green-grey to brown-grey, compacted, partly thinly laminated, partly homogeneous mudstone with scattered endichnia. This bed is irregularly eroded to a depth of about 3 cm and overlain by a fining-upward sequence, forming a scour-and-fill structure, of the following character: the lower part consists of an unsorted and chaotic mixture of fine to coarse skeletal debris, with abundant morphologically intact gastropods (many of which are of cm-size) in a homogeneous, light greenish grey mud matrix. This muddy shell accumulation is very slightly compacted and fills almost completely the eroded parts of the underlying bed, and has a horizontal upper surface. The lower part is succeeded gradually by brown-grey slightly compacted thinly laminated mudstone with few endichnia, some of which are of cm-size. Fig. 13B.

+51 to +52 cm. Reddish grey silty clay.

+52 to +54.5 cm. (Sample G.) Lower 2/3: in places severely bioturbated green-grey, in places brown-grey and thinly laminated mudstone with scattered non-ordered fine- and medium-sized skeletal debris and some endichnia. Distinct, irregular erosive contact. Upper 1/3: light greyish brown, thinly laminated silty mudstone with few endichnia, grading upwards into green-grey clayey silty, partly thinly laminated, partly much bioturbated mudstone. Fig. 14A.

+54.5 to +55 cm. Grey-green silty clay.

+55 to +57 cm. (Sample F.) Dark grey to grey-brown, very thin bed composed of fine to coarse, predominantly horizontally oriented skeletal debris, including some

Fig. 12. A-C. Bed K. A. Etched slice, bar is 1 cm. Note erosive contact (arrowed) between thinly laminated lower and upper parts. The sinuousoidal lamination in the upper part indicates current action as does the scour-and-fill character of the erosive contact. Some large endichnia are present. B. Micrograph in plane light from thin section K, bar is 1 mm. Close-up of scour-and-fill structure at the erosion contact (arrowed in A), and overlying thin laminae. C. Micrograph in plane light from thin section K, bar is 0.5 mm. Closer view of thin lamination in upper part of B. Note at least five darker, finer-grained laminae (indicated by arrows to the right) separating thicker slightly coarser-grained laminae. Cf. Fig. 17B.

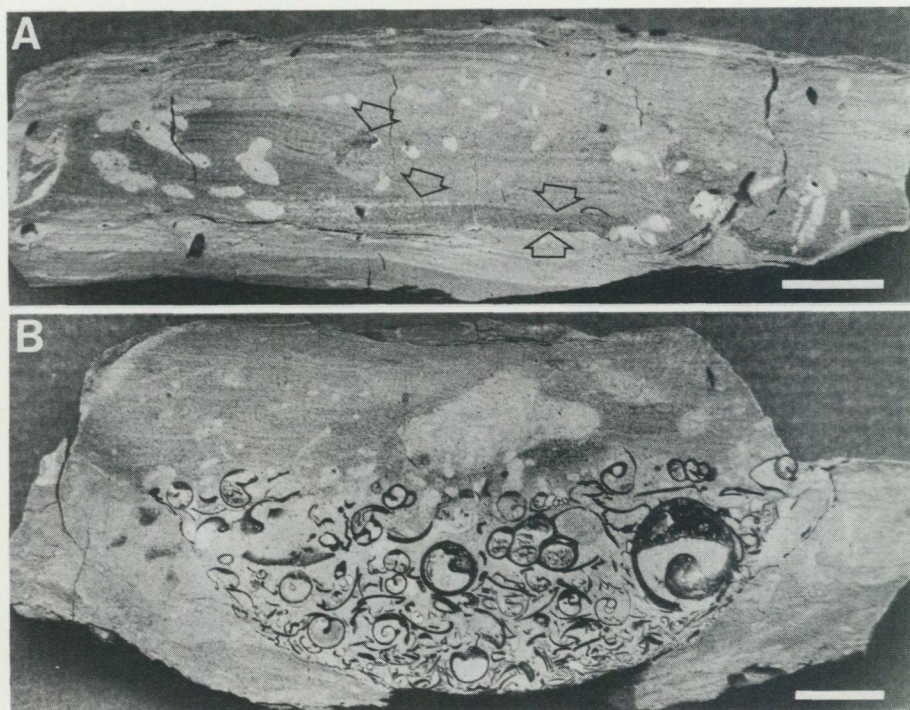


Fig. 13. Photographs of individual beds (etched slices, bar is 1 cm). A. Bed J. Note two erosive contacts, one almost horizontal marked with the lowermost arrow, and the other (with a small overhang) indicated with three arrows. Note also the vertical, spar-filled tiny cracks with abrupt upper ends, and scattered endichnia. B. Bed H. Nicely preserved small scour-and-fill structure. The fill is mainly composed of gastropods, and some fragmented trilobite carapaces. Note intact shell morphology, body chambers infill, and apparent lack of compaction.

intact cm-sized trilobite carapaces and brachiopods, with a primarily greyish brown, laminated mud matrix in the lower part and with a primarily sparry calcite matrix in the upper part.

+57 to +57.5 cm. Grey-green silty clay.

+57.5 to +59 cm. Brown-grey silty mudstone.

+59 to +59.5 cm. Grey-green silty clay.

+59.5 to +62 cm. (Sample E.) Lowermost part: green-grey clayey bioturbated mudstone with non-ordered fine to coarse skeletal debris and some endichnia. Distinct, flat erosive contact. Middle part: greyish brown, thinly laminated, uncompacted mudstone with several thin accumulations of fine to coarse horizontally oriented skeletal debris at the base. Scattered endichnia, some of which are of cm-size, and vertical hair-line cracks filled by sparry calcite. Uppermost part: much compacted brown-grey silty mudstone with some endichnia. Fig. 14B.

+62 to +63 cm. Grey-green silty clay.

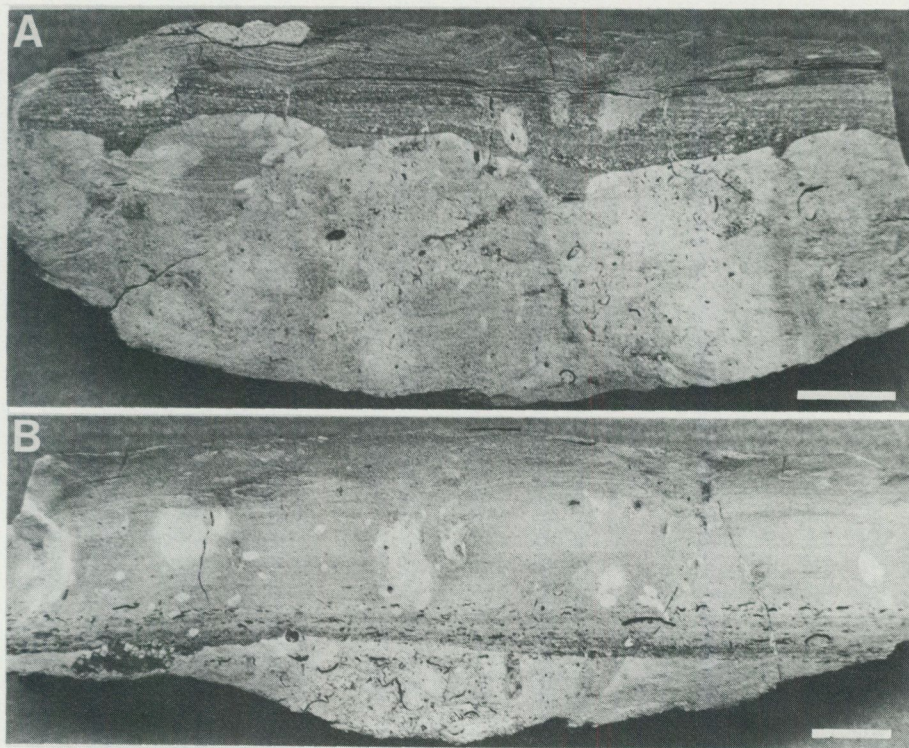
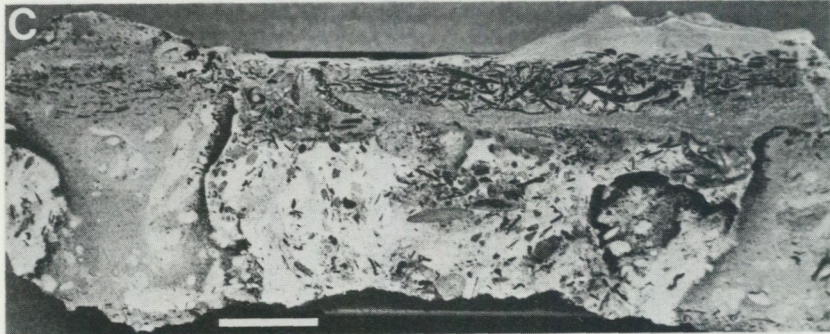


Fig. 14. Photographs of individual beds (etched slices, bar is 1 cm). A. Bed G. Note irregular erosive contact between laminated upper part and patchily bioturbated lower part with some remains of the original thin lamination. B. Bed E. Note flat erosive contact, several horizontal shell accumulations, the thinly laminated upper part with well preserved endichnia, and spar-filled tiny crack (left) with an abrupt upper end.

+63 to +67 cm. Very thin bed, at places disrupted into discrete flags, with grey-green silty clay filling the joints. (Sample D.) Lower 2/3: brown-grey, very slightly compacted, strongly bioturbated, mottled mudstone with endichnia and scattered fine- to medium-sized skeletal debris and some aggregates of pyrite crystals, one to several mm in size. Distinct flat erosive contact. Upper 1/3 consists of two laminae, separated by a flat erosive contact. The lower lamina is about 1 cm thick and made up of partly thinly laminated, dark brown-grey mudstone with abundant horizontally oriented fine and some coarse skeletal debris, partly thinly cross-laminated, light brown-grey mudstone devoid of skeletal debris. This latter lithology is partly overlying, partly laterally replacing the fossiliferous lithology, thus partially constituting a fining-upward sequence. Also in this lower lamina are scattered small aggregates of pyrite crystals. Some vertical hair-line to mm-wide cracks are present in the lower 2/3 through lower 1/3, and are filled by sparry calcite. The upper lamina is up to about 0.5 cm thick and made up of almost uncompacted grey-brown, thinly laminated mudstone with some, fine to coarse skeletal debris and endichnia. The lamina contains a large hypichnion, filled partly by pyrite.



+67 to +70 cm. Grey-green silty clay.

+70 to +72 cm. Reddish brown silty clay.

+72 to +78 cm. A complex bed exhibiting strong variation. Two samples were taken, about 0.5 m apart, and designated C and Ca. It was not possible to investigate in any detail the nature of the bed between these samples. C was modally analyzed. (Sample C.) Lowermost c. 1 cm: light brownish grey, bioturbated mudstone with endichnia and scattered fine- to medium-sized skeletal debris. Slightly irregular erosive contact, partly developed as a scour-and-fill structure. Middle c. 2.5 cm: very thin bed composed of fine to very coarse (up to several cm) skeletal debris, including intact brachiopods and tabulates, in a partly dark bluish grey to grey-brown, partly (with patchy distribution) in a light brownish grey mud matrix. This lithology is succeeded gradually by grey-brown to bluish grey, thinly laminated mudstone almost devoid of skeletal debris. The uppermost part of this mudstone is in places slightly mineralized and developed as a hardground (well exposed in sample Ca, *q.v.*). Uppermost c. 2.5 cm: very thin bed composed of fine to very coarse (up to about 1 cm) skeletal debris, with abundant gastropods and many bryozoans, in a light brownish, muddy to silty matrix. The bed contains many spar-filled cavities (up to about 2 cm), most of which obviously are recrystallized molluscan fragments and spar-filled molluscan body chambers. Fig. 15A.

Sample Ca is shown in Fig. 15B–D, and the description that follows refer to the slice shown in C. The primary bed is a dark grey to grey-brown partly thinly laminated, partly bioturbated, almost uncompact mudstone with endichnia and two laminae (up to about 5 mm thick) with concentrations of fine to coarse (up to c. 3 mm) horizontally oriented skeletal debris, one present at the base, and the other in the upper part. The preserved thickness of the primary bed is 3.5 cm maximum. This bed has then been eroded to a depth about equal to its preserved thickness and into a complex pattern of galleries and a convoluted and bossed sculpture. There seems to be no clear evidence indicating bioerosion of the lithified primary bed, although it seems highly probable that its present gross sculpture is a result of borrows in its pre-lithified state, followed by differential erosion and corrosion. The surface of the primary bed has a dark brown to black mineralized crust with a thickness up to some mm. The eroded parts of the primary bed are filled by a distinct succession of lithologies in the following order: the lower half is composed of light grey to brownish grey, in places strongly bioturbated mudstone with fine to coarse (up to about 1 cm) rounded skeletal debris and well rounded intraclasts (up to about 2 cm) of a lithology identical to the primary bed and with mineralized mm-thick crusts. This lower mudstone is overlain rather abruptly by a brown silty mudstone partly poor in skeletal debris and thinly

Fig. 15. Photographs of bed C, samples C and Ca (A, C, D are etched slices, bar is 1 cm). A. Sample C. Note lower erosive contact (black arrow), and the upper erosive contact (white arrows) developed as a vaguely defined hardground. B–D. Sample Ca. B. The top surface of the bed with the pitted hardground surface protruding the enclosing sediment. C and D. Sections illustrating the bossed sculpture of the hardground and galleries. Note mineralized crusts.

laminated, partly with abundant fine- to medium-sized skeletal debris, overlain in turn rather abruptly by a lamina composed of fine to coarse (up to about 1 cm), mainly horizontally oriented skeletal debris in a light grey to brownish grey mud matrix, succeeded gradually by a light grey, homogeneous mudstone with scattered skeletal debris. This last mentioned lamina makes up most of the top-surface of sample Ca, almost completely draping the hardground.

+78 to +78.5 cm. Grey-green silty clay.

+78.5 to +80.5 cm. Greyish brown, thinly laminated silty mudstone, much similar to sample A (*q.v.*).

+80.5 to +81.5 cm. Grey-green silty clay.

+81.5 to +85 cm. (Sample B.) Lower c. 2.5 cm consist of a partly homogeneous, partly thinly laminated, almost uncompacted light brownish grey mudstone with scattered endichnia and very sparse fine to coarse skeletal debris. In its lower and upper parts, the bed contains some vertical, and some slightly inclined hair-line cracks filled by sparry calcite. The bed is also penetrated by a vertical burrow, almost one cm wide, filled by brownish grey mud. Distinct but gradual contact. Upper c. 1 cm consists of dark greenish-grey, much compacted silty mudstone with much fine skeletal debris and endichnia, most of which are strongly flattened.

Grey-green clay parting, 1 to several mm thick.

+85 to +88 cm. (Sample A.) Lowermost c. 1 cm consists of dark grey to brownish grey uncompacted, in places thinly laminated, mainly homogeneous strongly bioturbated mudstone with abundant endichnia (up to about 1 cm in size) and sparse fine- to medium-sized skeletal debris. This mudstone is overlain, with a flat erosive contact of scour-and-fill character, by an up to 5 mm thick greyish brown homogeneous mudstone (constituting a small scale fining-upward sequence) with a basal accumulation of fine to coarse (up to about 6 mm), horizontally oriented skeletal debris. This lamina is succeeded, with a sharp contact, by a greyish brown, almost uncompacted, in places thinly laminated, mainly homogeneous strongly bioturbated (especially in its upper part) mudstone with a basal, 2–3 mm thick, accumulation of mainly fine- to medium-sized, horizontally oriented skeletal debris. This upper bed also contains scattered endichnia and some minor patchy accumulations of non-ordered fine- to medium-sized skeletal debris. All three strata now described are penetrated by two large endichnia, and vertical and inclined hair-line to mm-sized spar-filled cracks. Fig. 16B–C.

+88 to +88.5 cm. Grey-green silty clay.

+88.5 to +89.5 cm. Greyish brown, thinly laminated silty mudstone, much similar to sample A (*q.v.*).

+89.5 to +90 cm. Grey-green silty clay.

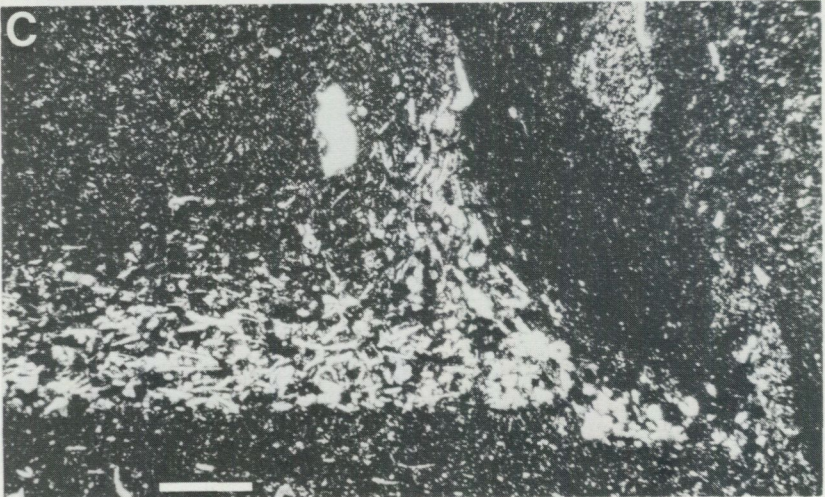
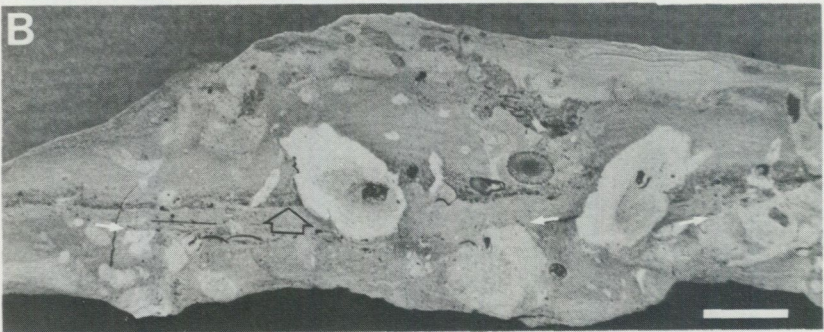
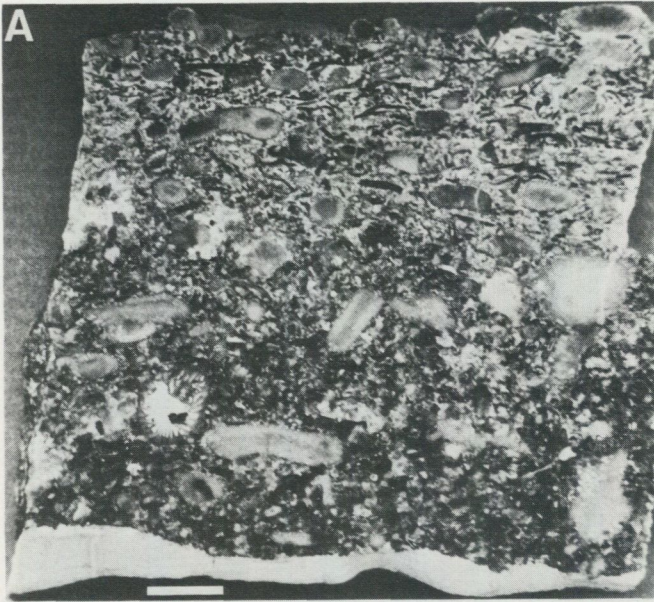
+90 to +97 cm. (Sample AR.) Lowermost up to c. 7 mm consists of light brownish grey thinly laminated silty mudstone almost devoid of skeletal debris. Slightly irregular erosive contact. The whole remaining part of the bed constitutes a well developed fining-upward sequence, with a marked increase in the amount of mud matrix from about the middle of the bed upwards. The lower half consists of poorly sorted medium to very coarse (up to several cm), slightly to strongly rounded skeletal debris, including abundant bryozoans and, less abundant tabulates, compound and solitary rugose corals, and stromatoporoids, in a predominantly dark grey sparry calcite matrix and in the upper part with a slight influx of light brownish mud matrix. Also present are cm-sized, spar-filled cavities with highly irregular and weakly defined outlines, the three dimensional geometry of which are not known. The upper half consists of very poorly sorted, fine to coarse (up to about 1 cm) skeletal debris (some slightly rounded) including abundant bryozoans, and sparse muddy intraclasts of sand size, in a predominantly greyish brown silty mud matrix. In the lower part are present also some spar-filled cavities of similar character as described above. The entire bed shows many sutured contacts between larger grains and stylolites with an amplitude of up to c. 5 mm. Fig. 16A.

+97 to +100 cm. Rounded and worn corals and tabulates, as well as bryozoans and stromatoporoids (less common), in a greenish grey silty clay.

+100 to +104 cm. (Sample AS.) Bed composed of a completely unsorted and chaotic mixture of fine to very coarse (up to about 5 cm) skeletal debris and intraclasts, in a dark grey sparry calcite matrix and, to a lesser degree in a brownish grey mud matrix. The intraclasts are partly made up of greyish brown, rounded silty mudstone up to about 5 mm in size, partly of well rounded and worn true lithoclasts of a lithology composed of very coarse skeletal fragments in a brown-grey to green-grey mud matrix. The bed also contains greenish grey clay as patchy accumulations and very irregular seams in its lower and upper part. The seams are stylolitic and have a maximal amplitude of about 1 cm. Fig. 18A.

+104 to +111 cm. Predominantly rounded and worn corals, tabulates, and stromatoporoids (many of which are up to about 10 cm in maximal dimension), but also bryozoans and intraclasts (lithoclasts) in a greenish grey silty clay. The intraclasts are up to about 6 cm in maximal dimension, and of two different lithologies, viz., in the lower part identical to bed AS, and in the upper part greyish brown silty mudstone.

+111 to +115 cm. (Sample AT.) Lower half: very poorly sorted mixture of fine to coarse (up to some cm) skeletal debris, and occasionally large (up to about 6 cm) strongly worn compound corals, in a slightly brownish muddy but predominantly dark grey sparry calcite matrix. Distinct but gradual contact. Upper half: very poorly sorted mixture of fine to coarse (up to some cm) horizontally oriented skeletal debris, including abundant bryozoans and, less abundant corals, tabulates, and stromatoporoids as well as well rounded intraclasts (up to 2 cm, of brownish mudstone with some



fine to coarse skeletal debris), in a brown-grey to light green-grey mud matrix. Strongly sutured contacts between larger particles are common, and mm-thick clay-filled stylolitic seams with an amplitude up to about 1 cm are present. In places bed AT is terminated by an up to about 2 cm thick bed of brownish, thinly laminated silty mudstone which occasionally exhibits a pitted and slightly mineralized hardground top-surface.

+115 to +117 cm. Grey shaly clay.

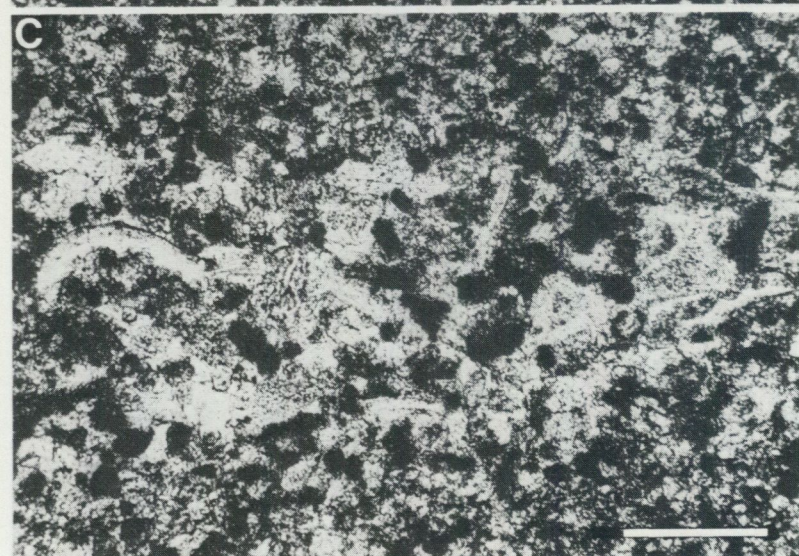
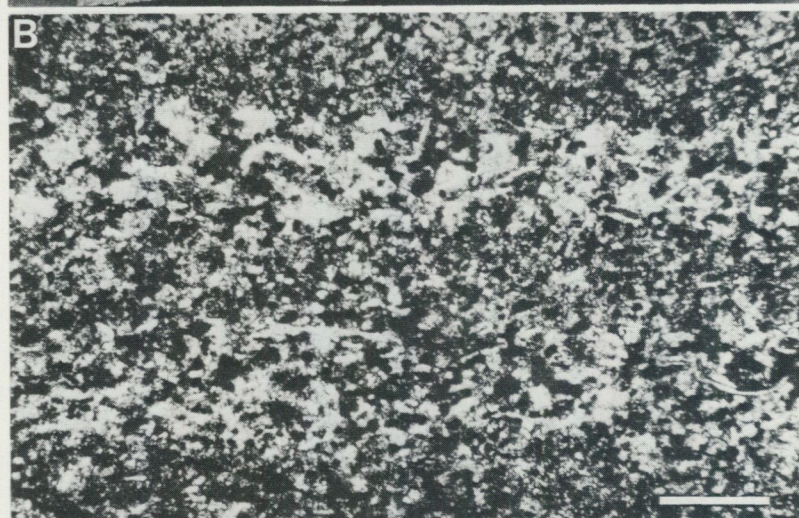
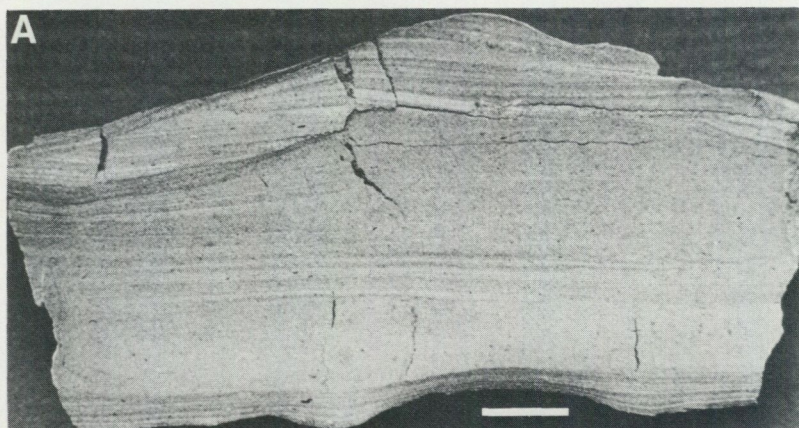
+117 to +121 cm. (Sample AU.) Lower 1–2 cm consist of brown to brown-grey almost uncompact silty mudstone with fine, and sparse medium to coarse, horizontally oriented skeletal debris. Some vertical hair-line, spar-filled cracks are present. In the upper part of this mudstone are subspherical to subconical colonies of the tabulate *Favosites*. The colonies are up to c. 6 cm in width and c. 3 cm in height, with their top 1 cm projecting above the mudstone surface. The non-worn character of the colonies, their partially buried position in the mudstone, the absence of compaction structures underneath the colonies, and geopetally settled intracorallitic mud indicate that the colonies are here preserved in life position. Upper 1–2 cm is a much compacted bed, composed of strongly worn bryozoans and tabulates (up to some cm) in a greenish grey shaly clay matrix.

+121 to +123 cm. Grey shaly clay with sporadic occurrence of worn corals and tabulates, and rounded intraclasts of brown-grey silty mudstone.

+123 to +127 cm. (Sample AV.) Light brownish grey, partly compacted, partly uncompact, thinly laminated silty mudstone with very sparse horizontally oriented fine skeletal debris. Bioturbation and endichnia are absent. The bed contains several slightly irregular erosive contacts, and several hair-line to mm-wide vertical, inclined and horizontal cracks filled by sparry calcite and/or mud. Some stylolites with an amplitude of a few mm are also present. Fig. 17A–C.

+123/+127 to +132 cm. Bed AV is replaced by this bed in places. (Sample AX.) Bed composed of a completely unsorted and chaotic mixture of fine to very coarse (up to c. 7 cm) skeletal debris, including abundant solitary and compound rugose corals, tabulates, and bryozoans, and less common stromatoporoids, partly in a brownish grey mud matrix, partly in a dark grey sparry calcite matrix. Most of the larger particles are very strongly worn and many are in stylolitic contact with ambient particles or rock mass. Hence the bed is rather strongly compacted along several irregular mud-filled stylolitic seams, up to about one mm thick, and with an amplitude of up to a few cm.

Fig. 16. Photographs of individual beds (A, B are etched slices, bar is 1 cm). A. Bed AR. Note erosive contact to thinly laminated "underbed", and decrease in grain size and continuous increase in interparticle mud upwards. B. Bed A. White arrows indicate apparent erosive contact, and black arrow indicates thin shelly base of upper mudstone (and also position of C). Note disturbances from large endichnia and lack of compaction. C. Micrograph in plane light from thin section A1, bar is 1 mm. Closer view of fine shelly accumulation (arrowed in B). Note sharp lower surface and well preserved burrow distortion.



+132 to +136 cm. Grey shaly clay with abundant worn corals and tabulates, and less abundant bryozoans. In places this bed is terminated by an up to 2 cm thick bed of light brownish grey, thinly laminated silty mudstone, similar to bed AV.

+136 to +145 cm. (Sample AY2.) An about 4 cm thick bed made up of a non-ordered mixture of predominantly medium to very coarse (up to c. 3 cm) skeletal debris, including abundant slightly worn bryozoans and tabulates, and less common stromatoporoids, in a dominantly dark grey sparry calcite matrix. The lower part of the bed contains sparse, subrounded intraclasts, that are about 1 cm in largest diameter and made up of a brownish grey mudstone with scattered skeletal debris. Several stylolites with a maximal amplitude of c. 1 cm are present. Fig. 18B. Stylolitic contact. (Sample AY1.) An about 5 cm thick bed composed of predominantly medium to coarse (up to c. 1 cm), and rarely very coarse (up to c. 4 cm) skeletal debris, including abundant bryozoans, and less common worn tabulates, solitary rugose corals and stromatoporoids, in a dominantly dark grey sparry calcite matrix with some influx of light brownish grey silty mud. Rounded intraclasts, up to c. 2 cm in largest dimension of light brownish grey mudstone with non-ordered skeletal debris, occur sporadically. Several stylolites, some of which have mm-thick mud accumulations, with amplitudes of up to c. 2 cm dissect the bed.

Highly irregular, channel-like contact (resembling a large scour-and-fill structure, c. 90 cm in width) developed at sampling spot.

+145 to +150 cm. (Sample BC.) Lower c. 2 cm consist of predominantly medium to coarse (up to c. 1 cm) skeletal debris, including abundant bryozoans in the lower part, in a dominantly dark grey sparry calcite matrix with some influx of light grey mud. Rounded intraclasts, made up of reddish brown, weathered silty mudstone with skeletal debris, occur sporadically and have a largest diameter of c. 2 cm. Stylolites with a maximal amplitude of c. 5 mm are present. Stylolitic contact. Upper c. 3 cm consist of fine to very coarse (up to c. 3 cm) skeletal debris, including worn bryozoans, tabulates and stromatoporoids, in a light grey to light greyish brown mud matrix. Several irregular stylolite seams, in places with clay enrichment, with amplitudes up to c. 1 cm, are also present.

Grey-green shaly clay parting, 1 to several mm thick.

+150 to +153 cm. (Sample BB.) Bed composed of predominantly medium to coarse (up to c. 1 cm), with scattered very coarse (up to c. 4 cm) slightly to strongly

Fig. 17. A-C. Bed AV. A. Etched slice, bar is 1 cm. Note the continuous plane thin lamination, the complete lack of larger skeletal debris and bioturbation, the cracks, the differential compaction, and erosive contacts in the upper part. B. Micrograph in plane light from thin section AV, bar is 0.5 mm. Closer view of thin lamination from the upper part of bed AV. Three darker and two lighter laminae. Note persistency in thickness and presence of shells (mainly ostracodes) and coarser average grain size in the lighter laminae. C. Close-up of upper light lamina in B, bar is 0.25 mm. Also the peloids have a larger average size in the light lamina than in the darker (top and bottom). This kind of thin lamination strikingly resembles Recent blue-green algal mat lamination, originated from daily growth pattern (light is a day lamina, dark is a night lamina).

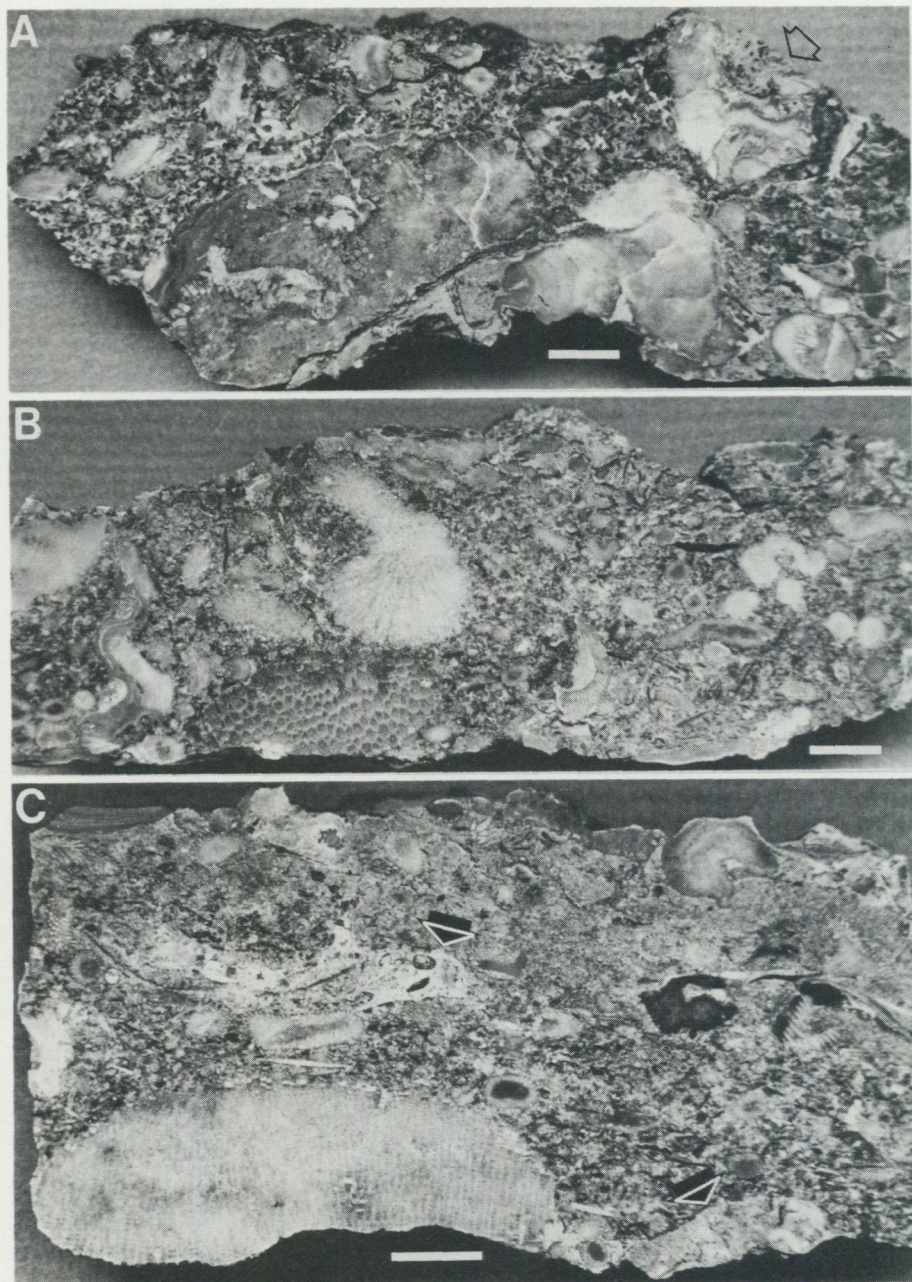


Fig. 18. Photographs of individual beds (etched slices, bar is 1 cm). A. Bed AS. Note chaotic nature of the bed, and large lithoclast (arrow). B. Bed AY2. Note poor sorting and general random orientation of elongate particles. C. Bed AZ. Note increase of silt and sand particles upwards, and two larger intraclasts (arrows).

worn skeletal debris, including bryozoans, tabulates and stromatoporoids, in a dark grey sparry calcite matrix with a minor influx of dark grey mud. The bed also contains rounded to subrounded intraclasts (up to c. 2 cm in largest dimension) of light brownish grey to yellow-brown laminated mudstone with fine skeletal debris. Stylolitic seams are present in the lower and upper part.

Grey-green shaly clay with scattered worn tabulates and bryozoans, 1 to 20 mm thick.

+153 to +156 cm. (Sample BA.) Bed made up of very poorly sorted, fine to very coarse (up to c. 4 cm) skeletal debris, including slightly to strongly worn bryozoans, tabulates, solitary rugose corals, and solenoporacean algae, and rounded to subrounded intraclasts (up to about 1 cm, of brownish silty mudstone with some skeletal debris), in a dominantly dark grey sparry calcite matrix with some influx of brownish grey mud. Stylolites in the lower and upper part, with amplitudes of c. 1 cm.

+156 to +158 cm. Lower half consists of worn tabulates, stromatoporoids and crinoid columnals, in a matrix of fine- to medium-sized skeletal debris. Distinct but gradual contact. Upper half consists of light brownish grey, thinly laminated, silty mudstone with scattered skeletal debris, including sporadic worn tabulates (up to several cm in size).

+158 to +162 cm. (Sample AZ.) Bed composed of fine to very coarse (up to c. 6 cm) skeletal debris, including slightly worn tabulates, bryozoans, stromatoporoids and molluscs (sparry calcite moulds), and rounded to subrounded intraclasts (up to c. 2 cm) of brownish grey to yellowish grey mudstone with abundant fine- to medium-sized skeletal debris, in a dominantly sparry calcite matrix with a small amount of mud in the lower half, and in a predominantly light grey-brown silty mud matrix in the upper half. Because of the marked increase of mud upwards, the bed might be described as a poorly developed fining-upward sequence. Some small depressions in the top surface of the bed are filled by thinly laminated, silty mud. Some indistinct stylolites are present in the upper part. Fig. 18C.

Bed AZ is overlain by an up to several cm thick, grey-green, shaly clay with worn tabulates, stromatoporoids and bryozoans.

It should be noted that the deficiency of information about the types of contact between individual strata stems from the fact that contacts were rarely possible to study in any detail. This shortcoming in the analysis of the section is primarily due to the abraded and weathered nature of the outcrop. The digging and hammering required to uncover the succession and expose fresh rock surfaces, in most cases resulted in an obliteration of original detailed bedding structures making correct description of bed transitions impossible. Also the sampling process, as well as cutting in the laboratory, often caused some unavoidable damage to bed surfaces.

PRINCIPAL COMPONENTS ANALYSIS

The use of computers and statistical techniques in the analysis of complex multivariate data have almost become routine in several fields of geology and palaeontology. Although, in many cases, the value of the results can rightly be questioned (e.g., Hallam 1981:12), there is little doubt that these methods of analysis can give helpful information that otherwise may have remained unnoticed. This is especially the case in multivariate quantitative data analyses where the amount of raw data is very large. The techniques most frequently used in petrologic and petrographic studies, particularly for classification and correlation purposes, seem to be cluster analysis, factor analysis, and principal components analysis. These and other methods, as well as their mathematical construction, are well reviewed in several recent books (e.g., Harbaugh & Merriam 1968; Davis 1973; Jöreskog, Klován & Reyment 1976; Loudon 1979; Gill & Merriam 1979; Merriam 1981). The three above-mentioned methods of analysis have been employed and described also in numerous articles (e.g. with special reference to carbonates, Purdy 1963; Parks 1966; Osborne 1967, 1969; McCammon 1968; Rao, Mann & Carozzi 1973; Smosna & Warshauer 1979; Warshauer & Smosna 1981).

I found it worthwhile to test the set of data from the modal analysis by means of principal components analysis (PCA). According to the literature (op. cit.) PCA can be described as a statistical method (or a mathematical manipulation, as Davis puts it) that reduces an originally large number of correlated variables to a smaller number of new, uncorrelated variables, but that contain most of the same information. The so-called principal components are the eigenvectors of the variance-covariance matrix created from the input data. The linear combination of the variables that accounts for maximum variance becomes the first principal component, the second principal component is the linear combination of the variables that accounts for maximum variance among the components that are uncorrelated with the first principal component, etc. In most cases, more than 90% of the total variance (given as sum of eigenvalues) in a data set is accounted for by the first three to four principal components. The complexity of the original data is consequently strongly reduced and PCA produces an optimal visual representation of the data in that individual sample scores can be plotted stratigraphically on the principal components and diagrammatically as scatter plots. Thus PCA can help identify stratigraphic trends and subdivisions based on major compositional characteristics. Recently, Björck (1981) made use of PCA as a complementary instrument in establishing pollen zones in Late Weichselian lake sediments.

The PCA computer run was carried out with the FORTRAN IV program PCAR-MODE written by Dr. John Birks, Cambridge, and modified by him for the Department of Quaternary Geology in Lund, for the computer Univac 1100 of *Datacentralen* at Lund University. As written, this program can handle a maximum of 40 variables and 300 individuals. This means that all 47 variables listed in the Appendices could not be included in the analysis. The following 7 were excluded: *sparry cement*, *authigenic opaque minerals*, *stromatoporoids sand*, *stromatoporoids gravel*, *others* & *unid.*

sand, others & unid. gravel, and micritized skeletal grains. The normalized raw data for all other variables from all 86 stratigraphic levels (as listed in Appendix 1) were given to the computer. In addition to information about 40 variables and 86 individuals, the control card had the following instructions (figures refer to card columns): the covariance option is taken (9), the original data will be listed (12), data are not standardized for calculation of component scores (15), data are not transformed (18), percentages are calculated (21), data cards are read in by variables (24), no additional individuals are added (27), component scores are not punched (30), no comparison of eigenvectors is made (33), stratigraphic plots of component scores are drawn (36), histograms are drawn (39).

The PCA print-out indicates that 98% of the variance in the set of data is accounted for by the first four eigenvectors. The first eigenvector (eigenvalue = 391.8), which accounts for 76.0% of the total variance, weights heavily the contributions of the variables *mud* (0.739), *micrite* (0.311), and *microspar* (0.342), giving high negative values for *skeletal debris total* (-0.311), *gravel* (-0.180), and *sand* (-0.140). Hence, the first principal component obviously measures the degree of "muddiness" of the samples, i.e. separates calcilutitic rocks from calcarenitic and calciruditic rocks. The second eigenvector (eigenvalue = 77.7), accounting for 15.1% of the total variance, weights mainly the contribution of variable *microspar* (0.639), giving a high negative value for *micrite* (-0.754). The second principal component can then be inferred to measure the degree of "microspariticness" of the samples, i.e. separates microsparitic calcilutites from micritic calcilutites. The third eigenvector (eigenvalue = 19.1) accounts for only 3.7% of the total variance, and weights heavily the contributions of the variables *sand* (0.436), *skeletal debris sand* (0.421), *echinoderms total* (0.259), and *echinoderms sand* (0.254), giving high negative values for *gravel* (-0.430), *skeletal debris gravel* (-0.388), *bryozoans total* (-0.196), and *tabulates & rugose corals total* (-0.163). The third principal component can then be said to measure the degree of "sandiness" of the samples, i.e. separates calcarenitic rocks from calciruditic rocks. The fourth eigenvector (eigenvalue = 16.8), which accounts for only 3.3% of the total variance, weights mainly the contributions of variables *peloids total* (0.635) and *peloids mud* (0.592), giving high negative values for *microspar* (-0.384), *micrite* (-0.157), and *skeletal debris total* (-0.146). What the fourth principal component actually measures, in lithologic terms, is not immediately obvious. One could possibly describe it as the degree of "peloidicness" of the samples, i.e. separates the peloid-rich calcilutites from the peloid-poor calcilutites. It is included here for the sake of completeness. Each of the remaining eigenvectors in the PCA print-out has an eigenvalue that accounts for less than 1% of the total variance. A stratigraphic plot of sample scores on principal components I-IV is shown in Fig. 19, and scatter plots of the sample scores on components I and II, and components I and III are shown in Fig. 20.

In summary, I preliminarily conclude that the PCA test-run gave no new information critically needed for interpretation of the data. It does seem to indicate that the

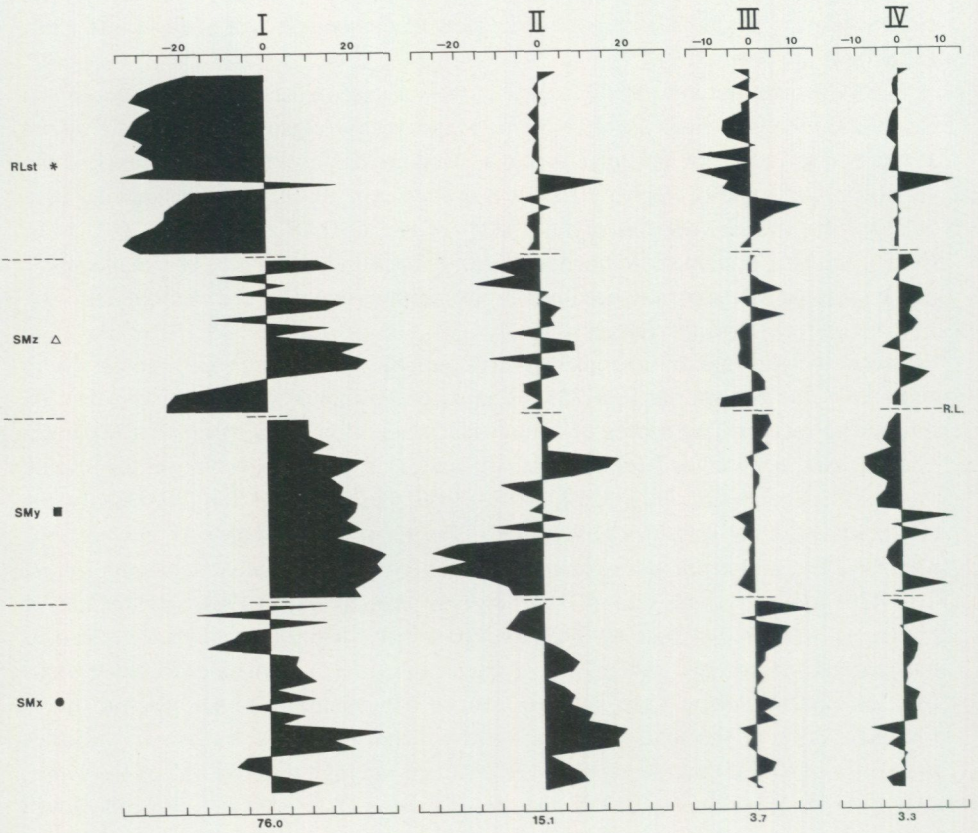


Fig. 19. Stratigraphic plots of sample scores on the first four principal components (Roman numerals). Underneath each component is given the percentage of the total variance for which the component accounts. Samples are plotted at equal vertical distance. Indicated at left are the lithostratigraphic units in abbreviated form and their symbols used in Fig. 20. R.L. stands for the reference level in the section. See text.

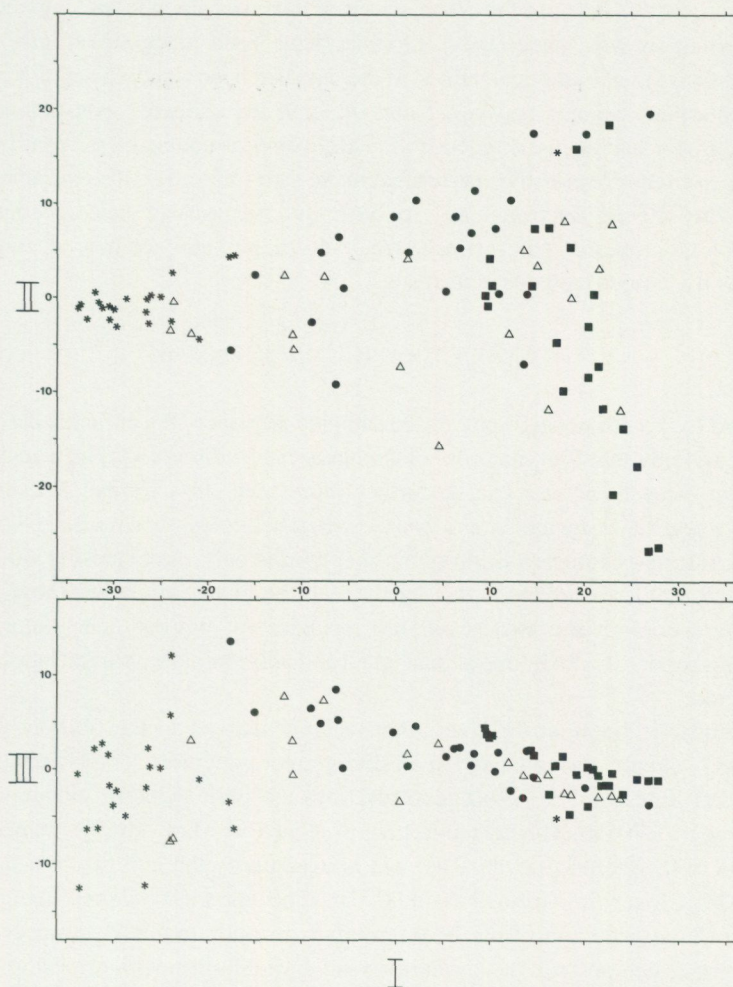


Fig. 20 Scatter plots of sample scores on principal components I and II (upper diagram) and I and III (lower diagram). The three axes (eigenvectors) are perpendicular to each other. In the triangular figure in the upper diagram the most microsparitic calcilutites occupy the upper right hand corner, the most micritic calcilutites occupy the lower right hand corner, and the most calcarenitic and calciruditic samples occupy the left hand corner. In the lower diagram the calcarenitic samples occupy the upper left hand corner and the calciruditic samples occupy the lower left hand corner. Symbols given in Fig. 19. See also text.

four-part division of the sequence is justified with regard to the overall average grain-size characteristics, especially well illustrated in the sample plot on principal component I in Fig. 19. The fact that the individual biogenic variables in this test-run are shown to be of very little importance in the gross characterization of the sequence is hardly surprising. Because the complete set of data was given to the computer, and no transformation was made, these variables have been made subordinate simply because of their small numerical values. If the data had been standardized (giving each variable an equal variance between 1 and 0), or if the collective constituents *mud*, *sand*, and *gravel* had been excluded, the result would of course have been different. Such PCA computer runs will be performed in the near future. It is also the ambition of project "The Whole Environment" to have the final set of heterogeneous data (sedimentologic, petrographic, geochemical, palaeontologic) compared and tested statistically by various methods of analysis.

LITHOSTRATIGRAPHIC SUBDIVISION

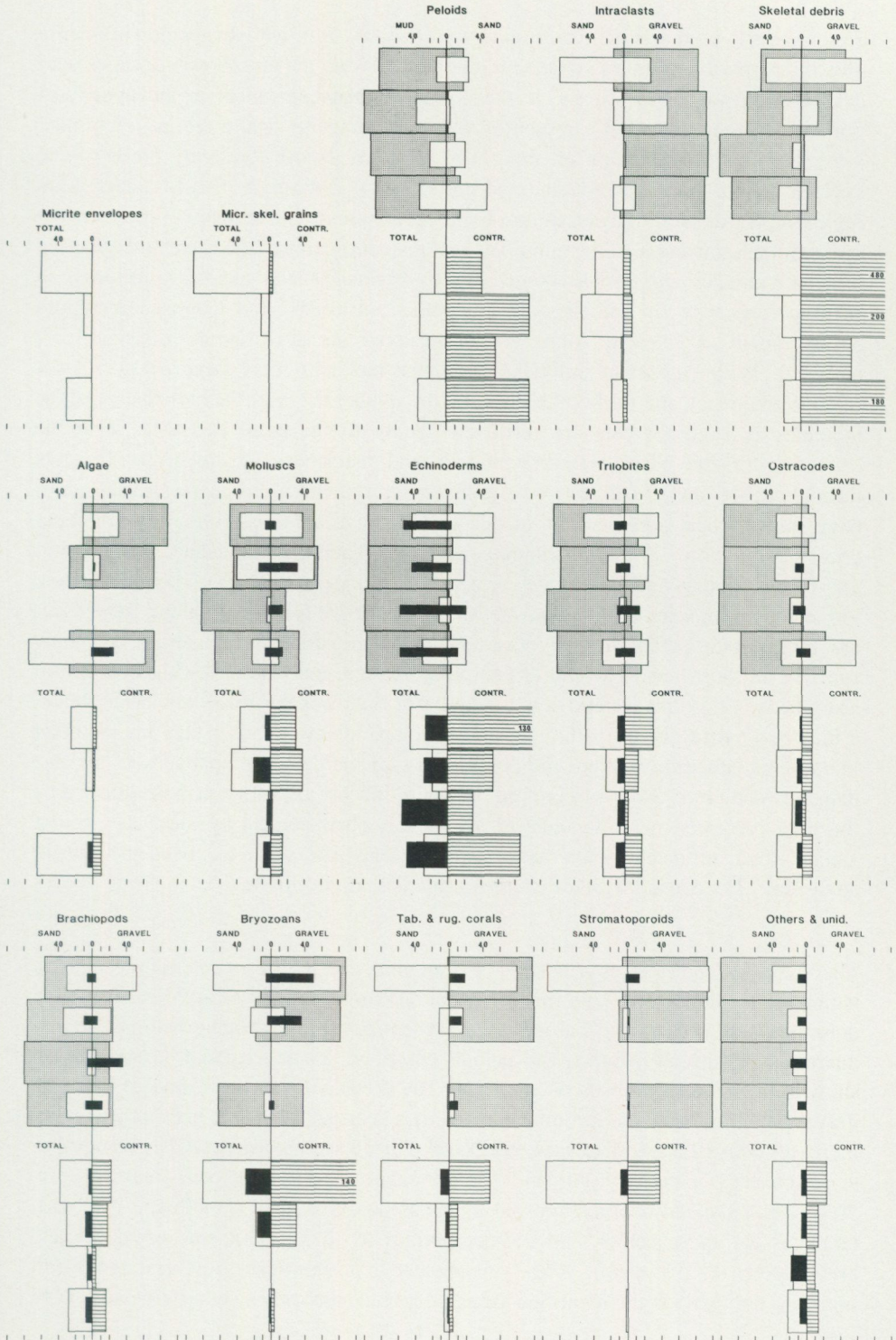
With regard to the lithostratigraphy of the sampled sequence, the previous description indicates explicitly that four major lithologic units can be discerned. The analyses also suggest that these lithozones can be further subdivided. In a formal ranking, these should be regarded as members and beds, respectively. My account here, however, will be an informal characterization of the major units only. As expressed earlier, the formal stratigraphic treatment of this locality will be given in a strictly stratigraphic context together with the two remaining localities (at present under study) in a forthcoming paper, at which time geochemical and palaeontologic parameters will also be considered.

The boundaries between the four lithozones are marked in the fold-out diagram (back cover), and are also indicated in all stratigraphic data plots. The lowermost unit, herein called Slite Marl *x* (SM_x), extends from the base (with an unknown lower boundary) to c. -70 cm. The next unit, herein called Slite Marl *y* (SM_y), extends from c. -70 cm to 0 (reference level, RL), and is overlain by the unit herein called Slite Marl *z* (SM_z) extending from 0 to +90 cm. The uppermost unit is the Ryssnäs Limestone (RLst) extending from +90 cm upwards (with an unknown upper boundary). To further demonstrate the similarities and dissimilarities with respect to composition and variation of individual constituents (also including sedimentary structures and characteristics), percentages have been calculated for each unit. Although the units are of different thickness and are sampled in different quantities, each unit has, for technical reasons, been regarded to represent 1/4 of the section. The collection of items is illustrated in Fig. 21, and the compiled, normalized raw data with means and standard deviations are given in Appendix 2.

According to the data presented in Fig. 21, and also considering those given in Figs. 5, 6, 7, 19, and 20, the following condensed characterization of the four lithozones can be made.

Slite Marl x is a slightly calciruditic, calcarenitic calcilititic unit. The dominant mud constituent is microspar, but within the unit there is a clear change from the dominance of microspar, in the lower portion to the dominance of micrite in the uppermost portion. The detrital quartz silt shows an almost constant contribution of a few per cent, and peloids contribute about 10% with no great variation. Among the skeletal debris, echinoderms dominate by far followed by trilobites and (at about equal amounts) brachiopods, molluscs, ostracodes, and algae. The contributions from bryozoans, tabulates & rugose corals, and stromatoporoids are almost nil. With regard to the dominant taxa, their frequencies show 2–3 peaks (in the upper portion and in the lowermost portion, and a less pronounced peak just below the middle). For the molluscs and ostracodes, the upper and lower peaks are also reflected in a diversity increase (Fig. 5). The algae are all green (dasycladaceans), and no tabulates have been recorded. With respect to sedimentary structures and characteristics in the unit, common features are erosive contacts, hardgrounds, intraclasts, penecontemporaneous cracks, fining-upward sequences, and lamination, while 'primary' dolomite is frequent, and bioturbation is abundant. Most of these items, however, do not occur randomly in the unit. As shown in the fold-out diagram, hardgrounds and intraclasts occur mainly in the upper portion while fining-upward sequences, lamination, and 'primary' dolomite mainly occur in the middle and lower portion. In outcrop, the unit is characterized by persistent, but slightly lenticular, calcareous beds well segregated by shaly clay partings. The contact with the overlying unit is gradational.

Slite Marl y is a slightly calcarenitic calcilititic unit. The dominant mud constituent is micrite, although there is a marked change from micrite dominance in the lower portion to microspar dominance in the upper portion. The variation in micrite/microspar ratio in this unit is the reverse of that in the underlying unit. Detrital quartz silt contributes a few per cent on the average with slightly higher mean values in the upper portion than in the lower portion and peloids contribute an average of c. 6% but are markedly more frequent in the lower portion than in the upper portion. Among the skeletal debris, the total amount of which show a steady increase from almost zero at the base to c. 10% at the top, echinoderms dominate (54%), with trilobites, ostracodes, brachiopods, and molluscs contributing about 5–10% each. Algae, bryozoans, tabulates & rugose corals, and stromatoporoids have not been recorded in this unit. With regard to respective taxa, the molluscs have a small peak just above the middle of the unit, while the other are all more frequent in absolute numbers in the upper portion than in the lower portion. Ostracodes and brachiopods, however, show a higher relative frequency in the lower portion than in the upper portion. Among sedimentary structures and characteristics, lamination is common, 'primary' dolomite is frequent, and bioturbation is abundant. All other items are either lacking or present in insignificant numbers. In outcrop, this unit is characterized by homogeneity in general appearance and irregular, vaguely defined bedding. The contact with the overlying unit is sharp.



Slite Marl z is a calciruditic, calcarenitic to calcilititic unit, with the amount of micrite plus microspar being fairly constant throughout. Within the unit, however, microspar decreases upwards and micrite is the dominant mud constituent in the uppermost portion. Detrital quartz silt is present in very small amounts, while peloids (all of mud size) contribute an average of about 10% and are almost constantly present. The skeletal debris show marked sand and gravel peaks at the base (bed M), decreasing rapidly upwards and followed in turn by a slight increase in the upper portion. In this unit echinoderms are also the dominant average contributor to the skeletal debris, but high percentages are also accounted for by bryozoans and molluscs, followed in relative frequency by trilobites, brachiopods, ostracodes, and tabulates & rugose corals, about 10% each. Algae and stromatoporoids are present in insignificant numbers. With respect to individual taxa, the molluscs show three peaks in their relative frequency and fairly high diversity throughout the unit, the bryozoans and the tabulates & rugose corals are restricted mainly to the basal bed (M). With the exception of the basal bed, brachiopods and ostracodes are relatively frequent throughout the unit. With regard to sedimentary structures and characteristics, most have their highest presence-rate in this unit. Erosive contacts, fining-upward sequences, lamination, 'primary' dolomite, and bioturbation are abundant, while scour-and-fill and penecontemporaneous cracks are frequent, and cross-lamination and intraclasts are present to common. As can be seen on the fold-out diagram, these items are rather widespread in their occurrence. The bioturbation, however, is mainly sporadic in most beds. I would like to point out here that due to the high content of shaly beds in this unit it could not be sampled as tightly as the other units. This creates a bias in all data given for the unit that is comparatively stronger than for the other units. This situation weakens the possibilities for the direct comparisons of average data between units. SMz is, therefore, as a unit, much "muddier" than is indicated by the data presented here. In outcrop, the unit is characterized by the basal, coarse "alien" bed, followed by alternating, slightly lenticular calcareous beds and beds of shaly clay. The contact with the overlying unit is sharp to erosive.

The *Ryssnäs Limestone* is a sparitic, calcarenitic, calcilititic to calciruditic unit, in which mud, sand, gravel, and sparry cement make up about 1/4 each. Microspar is the dominant mud constituent, but micrite is present as well throughout the unit. Detrital quartz silt is virtually absent, and peloids contribute a small amount on average but show a distinct peak in beds AU and AV. The skeletal debris show marked sand and gravel peaks in the lower portion, followed by a decrease, followed in turn by a steady increase, both with regard to sand and gravel. On the average, skeletal debris contribute almost half of the rock volume. The dominant taxon is bryozoans, making up c. 30% of the skeletal debris, followed by echinoderms (c. 25%), molluscs, trilobites, tabulates & rugose corals, and stromatoporoids (c. 10% each), and ostracodes and brachiopods (c. 5% each). Algae are present in insignificant numbers, but worth noting is the fact that the identified algae are all red (probably solenoporaceans). With

regard to respective taxa, the molluscs show a rather constant frequency with commonly occurring pelecypods. The echinoderms are less frequent in the middle of the unit, and the trilobites exhibit the same pattern but not as significantly. Ostracodes and brachiopods are more or less constant in their occurrence, while the bryozoans show a very strong peak in the upper portion and a less pronounced peak at the base. Interesting are the reverse frequency patterns for tabulates & rugose corals and stromatoporoids as compared to all other taxa. The rugose corals are primarily present in the uppermost portion (Fig. 5). Other things worthy of notice are that of all skeletal grains with micrite envelopes found in the section, 60% are found in this unit, and of those skeletal grains found in the section which have been completely micritized, 90% are found in this unit. With regard to sedimentary structures and characteristics, only intraclasts are abundant while most other items are present to common. The fact that no bioturbation has been noted in this unit might simply be due to a low preservation potential in the coarse-grained sediments. On the other hand, bioturbation has not been observed in the thinly laminated beds in this unit either. Although bioturbation may not be completely lacking in the unit, I am inclined to conclude that it is at least significantly less bioturbated than the Slite Marl units. Finally, as was the case with SMz, the data presented here for RLst are biased with regard to average grain-size. The clayey beds and intercalations are not included in the samples, and the factual coarseness of the unit, as seen in outcrop, is not correctly represented in the data. This is a result of the methodology used. Therefore, the portion of RLst included is, as a unit, both muddier and coarser than indicated by my data; the degree of bias is impossible to calculate at present. In outcrop, the Ryssnäs Limestone unit incorporated in the study, is characterized by slightly undulating but persistent, coarse to very coarse sparitic limestone beds, some of which are intercalated with thin beds of shaly clay (in places with stromatoporoids and tabulates), or thin beds of thinly laminated microsparitic calcilutites. Stylolites are frequent in the coarse limestone beds.

From a stratigraphic point of view, this study then gives support to Hede's (1936, 1960) concern in distinguishing a part of the sequence as "transition beds". This part is here termed the Slite Marl z. The distinction of two units in the lower portion of the sequence has not been made earlier.

INTERPRETATION OF DEPOSITIONAL ENVIRONMENTS

In recent years the literature on sedimentary environments, both modern and ancient, has grown considerably. Several larger reviews, dealing solely or partly with carbonates, which have been frequently consulted in this study include, Bathurst (1971), Rigby & Hamblin (1972), Purser (1973), Logan *et al.* (1974), Milliman (1974), Wilson (1975), Ginsburg (1975), Wantland & Pusey (1975), Multer (1977), Enos & Perkins (1977), Hardie (1977), Gebelein (1977), Friedman & Sanders (1978), Reading (1978), Zenger *et al.* (1980), and Flügel (1982). Published articles on the subject are, in fact, innumerable, and pertinent papers will be referred to in the text.

The discussion that follows is not a thorough and detailed consideration of all various aspects of the sequence that have been described above. In my opinion this would be unwarranted at present because the conclusions would probably have to be more or less revised in the near future, when geochemical (including also insoluble residue analyses) and palaeontologic data from the locality are published. Instead I will give some brief accounts on those aspects that are problematic or indicative of special environmental conditions. As a background it should be kept in mind that the traditional interpretation of the transition from Slite Marl to Ryssnäs Limestone is that the change in lithology is the natural consequence of a general shallowing in Slite time. Hence, the Slite Marl was deposited in deeper water relative to the Ryssnäs Limestone. This does not necessarily mean deep water for the marl accumulation; estimated depth figures (e.g., Hadding 1941; Gray *et al.* 1974; Laufeld 1979) have been given a range between 15 and 75 m. To a certain degree such estimations stem from the old dogma that fine-grained rocks, solely because they are fine-grained, always indicate deeper water relative to coarse-grained rocks. An important idea in this matter seems to be that most of the marly deposits in the Gotland succession are regarded as being of about the same character and therefore also of the same origin. As indicated by this paper there are differences. The importance of these, from an environmental point of view, are difficult to interpret, and so are their causes. Although the intertidal zone often has been included in environmental discussions and reconstructions, there are no published data that clearly demonstrate tidal conditions and deposits in the Silurian of the Gotland area. In my opinion, diagnostic features for intertidal processes do exist at several localities of varying age on Gotland. The succession at Haganäs 1 include many such features (see further below), and strong indications of tidal erosion and deposition have also become evident from detailed studies of the so-called Hemse Marl SE in the Lau-Hammaren-Burgen area (Sundquist, in prep.). In dealing with inferred tidal deposits in the Silurian, however, an intriguing perspective and constant problem is to try to estimate what the effects would be (both on the distribution of living and dead organisms, on sedimentation patterns and on the dimensions of sedimentary structures) of a significantly larger tidal amplitude as has been assumed for much of the Palaeozoic. That the moon had a closer orbit round the earth during that era has been suggested by, e.g., Merifield & Lamar (1968), Lamar *et al.* (1970), Kahn & Pompea (1978). The last paper has been criticized by Saunders & Ward (1979), and the whole complex of palaeotides and related geophysical and astrophysical considerations have been discussed and reviewed in Runcorn (1970), Rosenberg & Runcorn (1975), and Brosche & Sündermann (1978). Most of these studies verify a somewhat closer moon orbit than at present but that the slight difference in earth-moon distance probably did not cause a much larger average tidal amplitude than can be seen today. Obviously then, one can apply Recent diagnostic tidal sedimentary features also to Silurian rocks. The effects of tides and tidal currents should be considered in all environmental interpretations in the Gotland Silurian. Another important factor in this connection, not often considered but nevertheless of considerable concern, is water turbidity. The high

percentages of terrigenous clay and fine silt, present almost throughout the Silurian of Gotland, must indicate a nearly constant supply of such particles to the area. The influence of this mud on light penetration, sedimentation and the benthic fauna must have been great, at least at times. A third point, intimately related to the preceding ones in considering environmental interpretations, is the impact of ephemeral incidents, the results of which have been termed "tempestites". Studies on modern and inferred ancient storm erosion, sedimentary processes, and storm deposits have been published by, e.g., High (1969), Ager (1974), Kumar & Sanders (1976), Lindström (1979), Seilacher (1981), Woodley *et al.* (1981), Kreisa (1981), and highlighted in the very recent book by Einsele & Seilacher (1982). The distinction of storm deposits is essential in the interpretation of sedimentary environments as well as in the re-establishment of fossil communities because it enables one to distinguish between sedimentary processes and between displaced and endemic populations. Many storm deposits are prominent features recognizable already in the outcrop because of their obviously different nature when compared to under- and overlying deposits. Many such deposits, on the other hand, are in fact much less obvious or even indistinguishable without cutting and etching.

Returning to the sequence at Haganäs 1, some points of possible significance for the interpretation of depositional environments will be concentrated on in the following discussion. Because the environmental value of many of the biogenic constituents is difficult to estimate before their sedimentology has been considered, I will first discuss the sedimentary structures and associated characteristics that are found in the sequence.

SIGNIFICANCE OF SEDIMENTARY STRUCTURES AND CHARACTERISTICS

The many erosive contacts and related scour-and-fill structures indicate that the sediments were intermittently exposed to strong current action. Erosion occurred mainly in very fine-grained sediments and the sediments above a contact are in most cases significantly coarser (in places even pebbly) and often constitute a fining-upward sequence. Thus, conclusions can be drawn that not only were the currents strong enough to erode the muddy substrate and competent of carrying large quantities of coarse material, but also that the currents were short-lived phenomena. Hence, also much of the sediments that make up the sequence were intermittently deposited, and the excellent preservation of these structures indicates that the depositional site was not ordinarily exposed to strong wave or current action. The most prominent examples in the sequence of such "event" sedimentation are beds M and AR. The discontinuous nature of sediment accumulation is further demonstrated by the presence of hardgrounds. They are infrequent, and they are quite variable with respect to morphology and stage of development. Their environmental significance here is uncertain, but it is interesting to note that there are very few encrusters and borers present on these

surfaces. The penecontemporaneous cracks found in the sequence do not resemble desiccation cracks like those that are developed in muddy sediments exposed for long periods to the air. Because almost all are filled by sparry calcite, they are probably due to compaction fracture. Many of these cracks end abruptly against overlying sediments, a good indication of differential early lithification. Lamination and thin lamination are common to frequent in most calcilutitic beds (and also in many of the silty clayey beds and intercalations) in the sequence and occur abundantly in SMz. Their presence is usually coupled with relatively high amounts of peloids, terrigenous quartz silt and 'primary' dolomite. Planar lamination is most common, but undulating and wavy lamination is not uncommon whereas cross-lamination is rare. The fact that the carbonate laminated sediments are so well preserved, even in their details, and show little or no compaction indicate an early lithification. The fact that these sediments are primarily made up of microsparitic calcite and dolomite, and peloids, and combined with the lack or only sporadic occurrence of bioturbation structures, strongly suggest a tidal-flat depositional environment for these sediments. The origin of the lamination would then be ascribed to tidal, rhythmic sediment influx, but whether sedimentation to any larger degree was due to blue-green algal trapping, or mainly mechanical is at present impossible to estimate. There are indications for both. The presence of inferred penecontemporaneous, or 'primary' dolomite indicates a supratidal to intertidal environment, but the lack of severe desiccation structures and fenestral or birds-eye structures makes an intertidal to very shallow subtidal depositional environment more plausible.

In conclusion, with regard to sedimentary structures and associated characteristics there are indications for shallow subtidal to intertidal depositional environments throughout the sequence. SMx and especially SMz are of a more intertidal character, while SMy and RLst are of a more subtidal character.

SIGNIFICANCE OF CONSTITUENTS

Most of the peloids are obviously fecal pellets as is indicated by their usually good rounding, well defined edges, dense nature, and size range. As already discussed in the preceding section their prime occurrence is in laminated, micritic and microsparitic beds. The peloids are therefore a constituent that originated close to its place of deposition and preservation, and is (as a constituent) thus an important environmental indicator of very shallow water. Much of the microspar is evidently neomorphic, which is demonstrated by microtextural characteristics. However, an unknown quantity of the microspar is dolomite. The amounts of dolomite, and also the amounts of terrigenous clay and silt (the clay is included in the data as "micrite"), will be given in a forthcoming geochemical description of the locality by Dr. Robert E. Mosher. The intraclasts that occur are mainly of thinly laminated, peloid-rich mudstones, and discoidal in shape. In RLst there are also some very coarse-grained, severely worn

intraclasts, evidently from lithified rock. Therefore, erosion was occurring close to the area of deposition. In fact, if the interpretation of the depositional environments as indicated by sedimentary structures is correct, these intraclasts might well have been derived from the area of deposition itself. The intraclasts of fine-grained sediments are most easily interpreted as desiccation chips. The lithified rock fragments (lithoclasts) and their strongly abraded nature might indicate subaerial erosion and beach exposure. With regard to the biogenic skeletal constituents, it has become apparent from the preceding discussion that for much of their presence in the sequence, they do not represent the depositional area. To sort out in detail this situation, a much more detailed study must be made of every individual bed. The present data allow only some simple observations in this respect. For the skeletal debris in general, it can first be stated that practically all larger biogenic constituents in RLst show a more or less advanced state of abrasion and rounding. Only rarely are there stromatoporoids, bryozoans, tabulates or corals that appear to be in life position. In my set of samples, only bed AU contains a tabulate colony that is probably preserved in life position. Some of the clayey beds and intercalations within RLst contain larger colonies that might also be preserved *in situ*. It seems, therefore, safe to assume that the greater majority of the larger biogenic skeletal constituents that make up RLst do not represent a local living community. Because many of the larger fossils that are present in the Slite Marl units (although on the average much less worn) occur almost exclusively in inferred storm deposits, the same general statement can be made also with regard to those. Thus one could conclude that the larger benthic organisms that are present in the sequence tell more about living communities of adjacent areas than those that were in existence at their place of deposition. Hence, displaced or "foreign" skeletal debris of misleading nature for the environmental interpretation of the sequence, can be localized primarily to the lower and upper portion of SMx, to the base of SMz (bed M), to the base of RLst (bed AR), and to most of RLst beds. I cannot give any precise estimations about the distance of displacement or the degree of mixing of "foreign" and "local" skeletal debris in these beds. Considering first the Slite Marl, it is evident from the fold-out diagram that the stromatoporoids and the tabulates & rugose corals occur exclusively, and the bryozoans almost exclusively, in the lower and upper portions of SMx, and the lowermost portion (bed M) of SMz, all beds of which are minor or major storm deposits. These taxa can thus be regarded as not representative of the depositional environment. For all other taxa the situation is different. Although most of them have their highest frequency in storm deposited beds, they are also present in almost every analysed bed in Slite Marl. Exceptions are skeletal algae and molluscs, which are absent in certain parts. Their absence, however, might be a consequence of poor preservation only, since both taxa are mainly aragonitic. Under all circumstances, these taxa represent, to some extent, the environment of deposition at Haganäs 1. At this point one has to consider the whole complex of problems involved in discerning the number of individuals that are represented by the number of fragments encountered in the thin sections. These questions have been dealt with to some degree by, e.g.,

Ginsburg (1956, 1957), Chave (1960, 1964), Force (1969), and Seilacher (1973). I will return to these problems in a forthcoming paper, but just as an example I will compare the representativity of ostracodes and echinoderms. Because of different skeletal construction and body size, an ostracode-hit is more likely to represent about 1/2 of an individual, while an echinoderm-hit probably represents about 1/1000 to 1/2000 of an individual. These figures are very general but they should be of the right order of magnitude. For the subsequent reconstruction of depositional environments based on skeletal debris, calculations and manipulations must be made to the data generated from thin section modal analysis. For most taxa, the resultant frequency curves, based on individuals, will differ drastically from the frequency curves based on fragments. Until these calculations are made and frequency curves are plotted, and until future palaeontologic analyses of the sequence have been published, no detailed model can be developed with regard to the environmental significance of the biogenic skeletal constituents. On the other hand, I believe that it is possible to conclude that the Slite Marl in general, and for a majority of included beds in particular, not only has an average lower number of skeletal biogenic constituents but also has an average lower biogenic diversity, as compared to the Ryssnäs Limestone. At present, therefore, I cannot conclude that the kinds and amounts of biogenic debris present contradict a shallow subtidal to intertidal depositional environment as indicated by sedimentary structures and the non-skeletal constituents.

SUMMARY OF INFERRED GEOLOGIC DEVELOPMENT

In summary, the above observations and interpretations indicate that the overall lithologic characteristics in the sequence indicate an intertidal – shallow subtidal depositional environment. The frequency of erosive contacts and associated scour-and-fill structures, the frequency of lenticular bedding, the varying degree of bioturbation, the rather common occurrence of intraclasts, and the abundance of laminated to thinly laminated, pellet-rich, dolomite-rich, and fossil-poor lithologies strikingly resemble the structures and deposits from such environments of the Holocene that have been described in numerous publications (excellent and detailed recent descriptions are, e.g., Hardie & Ginsburg 1977, and Gebelein 1977), and interpreted intertidal – shallow subtidal environments from the geologic record (e.g., Roehl 1967; Laporte 1967, 1971; Matter 1967; Thompson 1970; Ashton 1981). To explain the observed vertical changes in lithologies, perhaps no substantial sea-level changes need to be inferred. With respect to the traditional opinion of a regressive phase to explain the transition from "deeper water" Slite Marl to "shallower water" Ryssnäs Limestone, there are two things (in addition to those already mentioned) in the lithostratigraphic development pattern in the sequence that add strength to the above environmental interpretations. The first one is the sudden change from Slite Marl to Ryssnäs Limestone. If this change is due to a gradual regression one would expect also a

gradual lithologic transition. The second is the effects of inferred major storm deposits seen in the sequence. If these originated in "shallow-water" and went "down-slope" it could be expected that the "deeper-water" depositional environment would return to normal after the storm deposit had settled, i.e. find the storm beds (or turbidites) interbedded with normal "deeper-water" deposits. In the sequence at Haganäs 1, the storm beds have distinctive stratigraphic positions. The most conspicuous of these beds are M and AR, also the stratigraphic turning-points for major changes in lithology. Assuming that the variation in lithology reflects variation in environment, these changes are easier to explain as effects of storms on coastal morphology in the construction and destruction of shelf barriers. The lithologic changes in the sequence could then be interpreted to reflect variation in exposure to the open sea rather than variation in water depth. Therefore, the Slite Marl units are taken to be indicative of a mainly protected depositional environment while the Ryssnäs Limestone is interpreted as having been deposited in a mainly exposed depositional environment.

If the interpretations developed in this paper are correct, a general conclusion, with regard to biostratigraphy, is that the sequence at Haganäs 1 contains (to quote Ager 1973) "more gaps than record".

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APPENDIX 1

Normalized raw data list

| Thin section | | AQ1 | AQ | AP1 | AP |
|------------------------------|--------|-----|-----|-----|-----|
| Original number of points | | 599 | 586 | 631 | 644 |
| MUD | | 511 | 550 | 469 | 410 |
| SAND | | 75 | 37 | 117 | 155 |
| GRAVEL | | 33 | 32 | 20 | 42 |
| SPARRY CEMENT | | 2 | 2 | 11 | 13 |
| AUTHIGENIC OPAQUE MINERALS | | - | - | 4 | - |
| Micrite | | 205 | 115 | 80 | 104 |
| Microspar | | 274 | 389 | 317 | 265 |
| Quartz silt | | 12 | 18 | 19 | 9 |
| Peloids | mud | 20 | 28 | 54 | 32 |
| | sand | 1 | 1 | 2 | 2 |
| | total | 21 | 29 | 56 | 34 |
| Skeletal debris | sand | 74 | 36 | 115 | 153 |
| | gravel | 33 | 32 | 17 | 42 |
| | total | 107 | 68 | 132 | 196 |
| Algae | sand | - | 1 | - | 11 |
| | gravel | 9 | 15 | - | - |
| | total | 9 | 16 | - | 11 |
| Molluscs | sand | 5 | 5 | 9 | 4 |
| | gravel | 12 | 8 | 2 | 2 |
| | total | 18 | 14 | 11 | 6 |
| Echinoderms | sand | 45 | 18 | 56 | 71 |
| | gravel | - | 3 | 4 | 4 |
| | total | 45 | 21 | 60 | 75 |
| Trilobites | sand | 6 | 5 | 25 | 25 |
| | gravel | 2 | 3 | 3 | 11 |
| | total | 8 | 8 | 28 | 36 |
| Ostracodes | sand | 5 | 1 | 5 | 14 |
| | gravel | 2 | - | 6 | 4 |
| | total | 7 | 1 | 11 | 18 |
| Brachiopods | sand | 5 | 1 | 7 | 13 |
| | gravel | 6 | 2 | 2 | 8 |
| | total | 11 | 3 | 9 | 20 |
| Bryozoans | sand | 2 | 1 | 3 | 5 |
| | gravel | 1 | - | - | 5 |
| | total | 3 | 1 | 3 | 10 |
| Tabulates & rugose corals | sand | - | - | - | - |
| | gravel | - | - | - | 10 |
| | total | - | - | - | 10 |
| Stromatoporoids | sand | - | - | - | - |
| | gravel | - | - | - | - |
| | total | - | - | - | - |
| Others & unidentified | sand | 5 | 3 | 11 | 11 |
| | gravel | - | - | - | - |
| | total | 5 | 3 | 11 | 11 |
| Intraclasts | | - | - | 3 | - |
| Micrite envelopes | | - | - | 1 | 1 |
| Micritized skeletal grains | | - | - | - | - |

| I1 | I | H+H1 | G | F+F1 | E+E1 | D1 | D |
|-----|-----|------|-----|------|------|-----|-----|
| 636 | 614 | 1226 | 645 | 1225 | 1178 | 588 | 626 |
| 580 | 610 | 491 | 580 | 352 | 566 | 594 | 432 |
| 24 | 11 | 49 | 40 | 180 | 48 | 20 | 185 |
| 16 | - | 80 | - | 32 | 5 | 1 | 3 |
| 1 | - | 2 | - | 56 | 1 | 4 | - |
| - | - | - | - | - | - | 1 | - |
| 161 | 167 | 270 | 182 | 110 | 168 | 224 | 125 |
| 380 | 363 | 139 | 282 | 188 | 306 | 253 | 194 |
| 6 | 22 | 17 | 18 | 3 | 7 | 10 | 21 |
| 33 | 58 | 65 | 98 | 51 | 86 | 108 | 92 |
| - | - | - | - | 2 | 5 | - | - |
| 33 | 58 | 65 | 98 | 53 | 91 | 108 | 92 |
| 24 | 11 | 49 | 40 | 178 | 43 | 20 | 185 |
| 16 | - | 80 | - | 32 | 5 | 1 | 3 |
| 40 | 11 | 129 | 40 | 210 | 48 | 21 | 188 |
| - | - | - | - | 1 | - | - | - |
| - | - | - | - | 2 | - | - | - |
| - | - | - | - | 2 | - | - | - |
| 2 | - | 18 | 1 | 7 | 5 | 4 | 27 |
| 11 | - | 66 | - | 16 | 3 | 1 | - |
| 13 | - | 85 | 1 | 22 | 7 | 5 | 27 |
| 6 | 6 | 13 | 15 | 101 | 17 | - | 65 |
| - | - | 1 | - | 1 | - | - | - |
| 6 | 6 | 14 | 15 | 102 | 17 | - | 65 |
| 3 | - | 6 | 3 | 12 | 2 | - | 14 |
| - | - | 7 | - | 6 | 1 | - | - |
| 3 | - | 13 | 3 | 18 | 3 | - | 14 |
| 3 | 3 | 2 | 7 | 16 | 5 | - | 32 |
| - | - | - | - | 7 | - | - | - |
| 3 | 3 | 2 | 7 | 23 | 5 | - | 32 |
| 9 | 2 | 2 | 4 | 16 | 5 | 7 | 31 |
| 1 | - | 7 | - | 2 | 1 | - | 3 |
| 10 | 2 | 9 | 4 | 18 | 6 | 7 | 34 |
| - | - | - | - | 2 | 1 | - | 8 |
| 4 | - | - | - | - | - | - | - |
| 4 | - | - | - | 2 | 1 | - | 8 |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - |
| 2 | - | 8 | 11 | 24 | 8 | 8 | 9 |
| - | - | - | - | - | - | - | - |
| 2 | - | 8 | 11 | 24 | 8 | 8 | 9 |
| - | - | - | - | - | - | - | - |
| - | - | - | - | 1 | 1 | - | - |
| - | - | - | - | 3 | - | - | - |

| AS+AS1 | AT | AT1 | AU+AU1 | AV+AV1 | AX2 | AX1 | AX |
|--------|-----|-----|--------|--------|-----|-----|-----|
| 1299 | 644 | 728 | 1347 | 1248 | 615 | 670 | 707 |
| 187 | 178 | 274 | 290 | 599 | 75 | 157 | 191 |
| 191 | 231 | 154 | 98 | 13 | 80 | 158 | 78 |
| 83 | 37 | 149 | 146 | - | 256 | 120 | 261 |
| 160 | 174 | 43 | 87 | 8 | 210 | 184 | 91 |
| - | - | - | - | - | - | - | - |
| 107 | 49 | 175 | 29 | 38 | 23 | 57 | 77 |
| 68 | 127 | 99 | 168 | 359 | 50 | 98 | 89 |
| - | - | - | 4 | 5 | - | - | - |
| 12 | 2 | - | 89 | 197 | 1 | 3 | 23 |
| 5 | 5 | 2 | 11 | 4 | - | 3 | 3 |
| 18 | 7 | 2 | 100 | 202 | 1 | 6 | 25 |
| 185 | 225 | 153 | 86 | 8 | 80 | 156 | 76 |
| 83 | 37 | 149 | 146 | - | 256 | 120 | 261 |
| 269 | 261 | 302 | 232 | 8 | 336 | 276 | 336 |
| - | - | - | - | - | - | - | - |
| - | - | - | 7 | - | - | - | - |
| - | - | - | 7 | - | - | - | - |
| 18 | 14 | 20 | 4 | - | - | 6 | 4 |
| 27 | 1 | 3 | - | - | - | 2 | 1 |
| 44 | 15 | 24 | 4 | - | - | 7 | 5 |
| 87 | 125 | 67 | 34 | 3 | 50 | 54 | 19 |
| - | 7 | 7 | - | - | - | 6 | - |
| 88 | 132 | 73 | 34 | 3 | 50 | 59 | 19 |
| 41 | 27 | 26 | 10 | - | 2 | 24 | 9 |
| 8 | 8 | 18 | - | - | - | - | 3 |
| 49 | 35 | 44 | 10 | - | 2 | 24 | 11 |
| 3 | 9 | 7 | 14 | 1 | 4 | 13 | 1 |
| - | - | - | - | - | - | - | - |
| 4 | 9 | 7 | 14 | 1 | 4 | 13 | 1 |
| 11 | 11 | 12 | 7 | 1 | 4 | 13 | 4 |
| 7 | 2 | 10 | - | - | 9 | 21 | 4 |
| 18 | 13 | 22 | 7 | 1 | 13 | 34 | 9 |
| 8 | 3 | 7 | 4 | - | 6 | 23 | 27 |
| 36 | 16 | 104 | 18 | - | 75 | 69 | 74 |
| 44 | 19 | 111 | 22 | - | 81 | 92 | 101 |
| 1 | - | 1 | - | - | - | 2 | - |
| 4 | - | 3 | 88 | - | 167 | 18 | 106 |
| 6 | - | 4 | 88 | - | 167 | 19 | 106 |
| - | - | 1 | 1 | - | 2 | 2 | - |
| - | 3 | 3 | 33 | - | 6 | 6 | 73 |
| - | 3 | 4 | 35 | - | 8 | 7 | 73 |
| 15 | 36 | 12 | 12 | 1 | 11 | 19 | 11 |
| - | - | - | - | - | - | - | - |
| 15 | 36 | 12 | 12 | 1 | 11 | 19 | 11 |
| - | 2 | - | - | - | - | - | - |
| 4 | 12 | - | - | - | - | - | - |
| - | 17 | - | - | - | - | - | - |

| AY2A | AY2 | AY1A | AY1 | BC1 | BC | BB+BB1 | BA+BA1 |
|------|-----|------|-----|-----|-----|--------|--------|
| 743 | 626 | 741 | 697 | 623 | 677 | 1251 | 1337 |
| 105 | 166 | 105 | 116 | 103 | 198 | 94 | 133 |
| 182 | 152 | 145 | 139 | 150 | 172 | 183 | 157 |
| 130 | 203 | 234 | 224 | 200 | 180 | 144 | 209 |
| 203 | 100 | 137 | 142 | 167 | 71 | 200 | 122 |
| 1 | - | - | - | - | - | - | - |
| 50 | 57 | 58 | 38 | 61 | 67 | 25 | 62 |
| 53 | 107 | 47 | 74 | 42 | 96 | 66 | 70 |
| - | - | - | - | - | - | - | - |
| 3 | 2 | - | 4 | - | 35 | 2 | - |
| 10 | 4 | - | 10 | - | 6 | 6 | 4 |
| 13 | 6 | - | 13 | - | 41 | 8 | 5 |
| 169 | 143 | 145 | 129 | 150 | 166 | 180 | 151 |
| 130 | 203 | 234 | 224 | 111 | 180 | 144 | 209 |
| 299 | 346 | 379 | 354 | 261 | 346 | 323 | 361 |
| 2 | - | - | - | - | - | - | - |
| 23 | - | - | - | - | - | - | 20 |
| 24 | - | - | - | - | - | - | 20 |
| 10 | - | 13 | 4 | - | 18 | 1 | 10 |
| 8 | - | 8 | 33 | - | 3 | 1 | 12 |
| 18 | - | 21 | 37 | - | 21 | 2 | 22 |
| 81 | 79 | 65 | 76 | 79 | 100 | 107 | 74 |
| 4 | 7 | 21 | 4 | 2 | 1 | - | - |
| 85 | 86 | 86 | 79 | 81 | 101 | 107 | 74 |
| 24 | 18 | 15 | 15 | 17 | 14 | 19 | 26 |
| - | 2 | 3 | 2 | 2 | 4 | - | - |
| 24 | 20 | 18 | 17 | 19 | 17 | 19 | 26 |
| 11 | 2 | 3 | 2 | 9 | 6 | 10 | 11 |
| - | - | - | - | 2 | - | - | 1 |
| 11 | 2 | 3 | 2 | 11 | 6 | 10 | 12 |
| 12 | 7 | 9 | 4 | 6 | 7 | 5 | 9 |
| 5 | 3 | 9 | 10 | - | 6 | 4 | 8 |
| 17 | 10 | 18 | 14 | 6 | 13 | 9 | 17 |
| 8 | 11 | 23 | 10 | 11 | 6 | 7 | 5 |
| 91 | 186 | 188 | 161 | 99 | 64 | 66 | 65 |
| 99 | 197 | 212 | 171 | 110 | 70 | 73 | 69 |
| 1 | - | - | - | - | 4 | 3 | 3 |
| - | - | 3 | 9 | 6 | 70 | - | 71 |
| 1 | - | 3 | 9 | 6 | 73 | 3 | 75 |
| 3 | - | 2 | 9 | - | 1 | - | 1 |
| - | 5 | 1 | 6 | - | 33 | 72 | 32 |
| 3 | 5 | 3 | 15 | - | 34 | 72 | 33 |
| 18 | 26 | 14 | 10 | 29 | 11 | 27 | 12 |
| - | - | - | - | - | - | - | - |
| 18 | 26 | 14 | 10 | 29 | 11 | 27 | 12 |
| 3 | 5 | - | 1 | 90 | - | - | 1 |
| 3 | - | 1 | 4 | - | - | - | 3 |
| - | 7 | - | - | 10 | - | 8 | - |

| AZ1 | AZ | GRAND TOTAL |
|-----|-----|-------------|
| 696 | 616 | 62069 |
| 162 | 298 | 36966 |
| 153 | 109 | 7826 |
| 115 | 149 | 4978 |
| 190 | 64 | 3598 |
| - | - | 16 |
| 62 | 39 | 14499 |
| 95 | 185 | 18047 |
| - | - | 925 |
| 5 | 72 | 3490 |
| 12 | 2 | 419 |
| 18 | 74 | 3909 |
| 140 | 107 | 7396 |
| 115 | 149 | 4711 |
| 255 | 256 | 12113 |
| - | - | 54 |
| - | - | 178 |
| - | - | 228 |
| 4 | 12 | 531 |
| - | 25 | 539 |
| 4 | 37 | 1070 |
| 49 | 76 | 3825 |
| 13 | - | 208 |
| 62 | 76 | 4031 |
| 34 | 2 | 816 |
| - | - | 173 |
| 34 | 2 | 988 |
| 6 | 6 | 455 |
| - | - | 72 |
| 6 | 6 | 527 |
| 11 | - | 529 |
| 7 | - | 240 |
| 18 | - | 767 |
| 14 | 2 | 310 |
| 64 | 41 | 2020 |
| 78 | 43 | 2331 |
| 2 | - | 20 |
| 19 | 11 | 786 |
| 21 | 11 | 806 |
| 6 | - | 35 |
| 12 | 72 | 503 |
| 18 | 72 | 538 |
| 13 | 11 | 818 |
| - | - | 1 |
| 13 | 11 | 819 |
| - | - | 283 |
| 2 | - | 95 |
| - | - | 45 |

Note: the original data were normalized assuming a linear relation between each constituent and the total number of points recorded in each thin section. The norm here was 620.69 (grand total number of points divided by total number of thin sections). The process was carried out by the aid of a Texas Instruments Programmable Calculator TI-59 and printer PC-100C.

The program was:

```

000 55 ÷
001 91 R/S
002 95 =
003 65 x
004 06 6
005 02 2
006 00 0
007 93 .
008 06 6
009 09 9
010 95 =
011 58 FIX
012 00 00
013 99 PRT
014 25 CLR
015 91 R/S
    
```

For each value enter original constituent data, press R/S, enter original number of points (can be inserted in program at location 001), press R/S, display = normalized data.

| APPENDIX 2 | | Slite Marl x (AQ1-AD) n = 23 (25 t.s.) | | | Slite Marl y (AC-N) n = 22 (23 t.s.) | | |
|---|--------|--|-----------|-------|--|-----------|-------|
| HAGANAS 1 normalized raw data | | x | \bar{x} | s | x | \bar{x} | s |
| $\Sigma x = 53384$ $\bar{x} = 620.7$ | | 14278 | 620.8 | | 13655 | 620.7 | |
| MUD | | 11280 | 490.4 | 79.3 | 12805 | 582.0 | 28.4 |
| SAND | | 2295 | 99.8 | 61.4 | 791 | 36.0 | 27.9 |
| GRAVEL | | 496 | 21.6 | 21.4 | 33 | 1.5 | 2.9 |
| SPARRY CEMENT | | 197 | 8.6 | 11.0 | 26 | 1.2 | 2.5 |
| AUTHIGENIC OPAQUE MINERALS | | 10 | 0.4 | 1.2 | - | - | - |
| Micrite | | 3229 | 140.4 | 70.1 | 6062 | 275.5 | 125.4 |
| Microspar | | 6562 | 285.3 | 106.2 | 5585 | 253.9 | 102.2 |
| Quartz silt | | 301 | 13.1 | 6.4 | 441 | 20.0 | 9.8 |
| Peloids | mud | 1188 | 51.7 | 26.2 | 717 | 32.6 | 47.9 |
| | sand | 211 | 9.2 | 12.1 | 88 | 4.0 | 6.7 |
| | total | 1398 | 60.8 | 33.3 | 804 | 36.5 | 52.3 |
| Skeletal debris | sand | 2085 | 90.7 | 60.6 | 703 | 32.0 | 27.4 |
| | gravel | 451 | 19.6 | 21.4 | 28 | 1.3 | 2.1 |
| | total | 2538 | 110.3 | 72.6 | 734 | 33.4 | 27.5 |
| Algae | sand | 42 | 1.8 | 3.1 | - | - | - |
| | gravel | 112 | 4.9 | 7.6 | - | - | - |
| | total | 154 | 6.7 | 8.0 | - | - | - |
| Molluscs | sand | 128 | 5.6 | 5.5 | 19 | 0.9 | 2.4 |
| | gravel | 65 | 2.8 | 4.0 | 4 | 0.2 | 0.9 |
| | total | 192 | 8.3 | 8.0 | 23 | 1.0 | 2.9 |
| Echinoderms | sand | 1174 | 51.0 | 35.7 | 396 | 18.0 | 19.0 |
| | gravel | 51 | 2.2 | 3.1 | 6 | 0.3 | 0.8 |
| | total | 1224 | 53.2 | 37.4 | 402 | 18.3 | 19.0 |
| Trilobites | sand | 222 | 9.7 | 9.4 | 58 | 2.6 | 2.6 |
| | gravel | 54 | 2.3 | 3.5 | 5 | 0.2 | 0.6 |
| | total | 276 | 12.0 | 11.7 | 64 | 2.9 | 2.8 |
| Ostracodes | sand | 123 | 5.3 | 3.9 | 64 | 2.9 | 2.8 |
| | gravel | 47 | 2.0 | 4.1 | 1 | - | 0.2 |
| | total | 170 | 7.4 | 6.9 | 65 | 3.0 | 2.9 |
| Brachiopods | sand | 170 | 7.4 | 5.5 | 38 | 1.7 | 1.7 |
| | gravel | 54 | 2.3 | 3.1 | 10 | 0.4 | 1.2 |
| | total | 223 | 9.7 | 7.4 | 48 | 2.2 | 2.0 |
| Bryozoans | sand | 28 | 1.2 | 1.5 | 1 | - | 0.2 |
| | gravel | 17 | 0.7 | 1.5 | - | - | - |
| | total | 45 | 2.0 | 2.5 | 1 | - | 0.2 |
| Tabulates & rugose corals | sand | 1 | - | 0.2 | - | - | - |
| | gravel | 44 | 1.9 | 5.7 | - | - | - |
| | total | 45 | 2.0 | 5.7 | - | - | - |
| Stromatoporoids | sand | - | - | - | - | - | - |
| | gravel | 8 | 0.3 | 1.7 | - | - | - |
| | total | 8 | 0.3 | 1.7 | - | - | - |
| Others & un- identified | sand | 199 | 8.7 | 4.7 | 124 | 5.7 | 4.9 |
| | gravel | - | - | - | 1 | - | 0.2 |
| | total | 199 | 8.7 | 4.7 | 125 | 5.7 | 4.9 |
| Intraclasts | | 46 | 2.0 | 8.5 | 5 | 0.2 | 1.1 |
| Micrite envelopes | | 31 | 1.3 | 2.6 | - | - | - |
| Micritized skeletal grains | | - | - | - | - | - | - |

| Slite Marl z (M-A1) n = 19 (25 t.s.) | | | Ryssnäs Limestone (AR3-AZ) n = 22 (27 t.s.) | | | Whole section n = 86 (100 t.s.) |
|--|-----------|-------|---|-----------|-------|------------------------------------|
| x | \bar{x} | s | x | \bar{x} | s | $\Sigma\bar{x}$ |
| 11798 | 620.9 | | 13653 | 620.6 | | 2483.0 |
| 8941 | 470.6 | 138.9 | 3940 | 179.1 | 114.1 | 1722.1 |
| 1470 | 77.4 | 61.0 | 3270 | 148.6 | 49.6 | 361.8 |
| 948 | 49.9 | 76.5 | 3501 | 159.1 | 64.7 | 232.1 |
| 438 | 23.1 | 32.1 | 2937 | 133.5 | 59.1 | 166.4 |
| 1 | 0.1 | 0.2 | 5 | 0.2 | 0.5 | 0.7 |
| 3840 | 202.1 | 88.2 | 1368 | 62.2 | 35.0 | 680.2 |
| 3796 | 199.8 | 95.4 | 2104 | 95.6 | 70.4 | 834.6 |
| 172 | 9.1 | 6.3 | 11 | 0.5 | 1.4 | 42.7 |
| 1133 | 59.6 | 34.8 | 452 | 20.5 | 46.1 | 164.4 |
| 13 | 0.7 | 1.5 | 107 | 4.9 | 3.7 | 18.8 |
| 1146 | 60.3 | 35.4 | 561 | 25.5 | 46.6 | 183.1 |
| 1455 | 76.6 | 60.8 | 3153 | 143.3 | 48.8 | 342.6 |
| 820 | 43.2 | 59.2 | 3412 | 155.1 | 64.8 | 219.2 |
| 2275 | 119.7 | 101.0 | 6566 | 298.4 | 77.6 | 561.8 |
| 5 | 0.3 | 0.7 | 7 | 0.3 | 0.8 | 2.4 |
| 13 | 0.7 | 2.5 | 53 | 2.4 | 6.4 | 8.0 |
| 17 | 0.9 | 2.6 | 58 | 2.6 | 6.6 | 10.2 |
| 194 | 10.2 | 10.1 | 190 | 8.6 | 6.8 | 25.3 |
| 257 | 13.5 | 22.2 | 213 | 9.7 | 11.8 | 26.2 |
| 453 | 23.8 | 27.2 | 402 | 18.3 | 15.7 | 51.4 |
| 607 | 31.9 | 30.5 | 1648 | 74.9 | 32.3 | 175.8 |
| 37 | 1.9 | 3.0 | 114 | 5.2 | 6.4 | 9.6 |
| 644 | 33.9 | 32.1 | 1761 | 80.0 | 35.0 | 185.4 |
| 142 | 7.4 | 6.9 | 394 | 17.9 | 10.1 | 37.6 |
| 44 | 2.3 | 2.9 | 70 | 3.2 | 4.5 | 8.0 |
| 186 | 9.8 | 8.7 | 462 | 21.0 | 12.5 | 45.7 |
| 127 | 6.7 | 7.7 | 141 | 6.4 | 3.8 | 21.3 |
| 12 | 0.6 | 1.7 | 12 | 0.5 | 1.1 | 3.1 |
| 140 | 7.4 | 8.4 | 152 | 6.9 | 4.0 | 24.7 |
| 155 | 8.2 | 7.3 | 166 | 7.5 | 3.7 | 24.8 |
| 48 | 2.5 | 3.3 | 128 | 5.8 | 5.4 | 11.0 |
| 203 | 10.7 | 8.4 | 293 | 13.3 | 7.3 | 35.9 |
| 66 | 3.4 | 5.5 | 215 | 9.8 | 7.0 | 14.4 |
| 295 | 15.5 | 33.3 | 1708 | 77.6 | 49.0 | 93.8 |
| 361 | 19.0 | 37.6 | 1924 | 87.4 | 52.9 | 108.4 |
| 1 | 0.1 | 0.2 | 18 | 0.8 | 1.2 | 0.9 |
| 109 | 5.7 | 16.1 | 633 | 28.8 | 44.1 | 36.4 |
| 110 | 5.8 | 16.1 | 651 | 29.6 | 44.2 | 37.4 |
| 1 | 0.1 | 0.2 | 34 | 1.5 | 2.3 | 1.6 |
| 9 | 0.4 | 2.1 | 486 | 22.1 | 28.9 | 22.8 |
| 10 | 0.5 | 2.1 | 520 | 23.6 | 28.4 | 24.4 |
| 156 | 8.2 | 5.5 | 339 | 15.4 | 7.9 | 38.0 |
| - | - | - | - | - | - | - |
| 156 | 8.2 | 5.5 | 339 | 15.4 | 7.9 | 38.0 |
| 129 | 6.8 | 27.0 | 103 | 4.7 | 19.1 | 13.7 |
| 8 | 0.4 | 0.7 | 56 | 2.5 | 4.8 | 4.2 |
| 3 | 0.2 | 0.7 | 42 | 1.9 | 4.5 | 2.1 |

PRISKLASS F

Distribution

Liber Kartor

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