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Effect of Overburden Pressure on Clay Fabric

by Stanislas WARTEL and Parvinder Sing SETHI

Abstract

The effect of overburden pressure up to 8 Kg/cm^2 on the clay-fabric of a recent marine clay sample (North Sea) has stepwise been tested. SEM-analyses showed that the original clay-fabric was maintained even for the highest overburden pressures applied. The only changes observed were a reduction in pore size and a flattening of pore shape. It seems thus that older sediments will reflect their original clay-fabric, at least as far as they have not been covered by a sediment layer exceeding 15 m in thickness.

Key-words: sedimentology, gas in sediments, clay fabric, Pleistocene.

Samenvatting

De invloed van een overdruk tot 8 kg/cm^2 op de klei-textuur van een sedimentstaal (Noordzee) werd stapsgewijze nagegaan. SEM-analysen tonen aan dat het oorspronkelijke patroon behouden blijft, zelfs voor de hoogste toegepaste druk. de enige waargenomen veranderingen zijn een verkleining en afplatting van de poriën. Het is dus waarschijnlijk dat in oudere sedimenten de oorspronkelijke klei-textuur herkenbaar blijft, tenminste voor zover het sediment niet bedolven werd onder een sedimentlaag van meer dan 15 m dikte.

Trefwoorden: sedimentologie, gas in sedimenten, klei-textuur, Pleistoceen.

Introduction

The SEM-analyses of modern deposits revealed that the clay-fabric of sediments deposited in fresh water is distinctly different from the clay fabric of sediments deposited in brackish or salt water. In fresh water clay particles are deposited separately leading to a Face-to-Face fabric. whereas in brackish or salt water clay particles settles out as aggregates or flocs causing to a Edge-to-Face fabric. It follows that clay-fabric is related to the environment of deposition (WARTEL, SETHI & FAAS, 1989) and thus can be a useful tool for palaeoenvironmental interpretation. However, clay-fabric is also affected by compaction and the possible effects of increasing overburden pressure (e.g. particle reorientation) have to be taken into account. Therefore a study of the "nature" and the "extend of variation" for a specific value of overburden pressure will furnish important guidelines in the possible use of clay-fabric analyses in stratigraphic work.

Methodology

In a laboratory simulation the possible variations in clay-fabric in response to overburden pressures of 0.5 Kg/cm^2, 4 Kg/cm^2, and 8 Kg/cm^2 were studied. Each of these pressures was applied for 24 hours using an oedometer apparatus (BOWLES, BRYANT & WALLIN, 1969). Three subsamples were obtained from within the same mud horizon of box core sample 88A27, sampled off the Belgian coast (51°16,27'N and 2°55.63'E) at a depth of approximately 10 m, during a research campaing on board of the Belgian oceanographic vessel BELGICA. A radiograph of this box core sample was taken using an X-ray beam of 80Kev and 10mA. Since the subsamples were taken next to each other it can be reasonably assumed that they possess essentially similar grain-size, mineralogical and compressibility characteristics. Each of the subsamples was analysed with a Scanning Electron Microscope. The SEM samples were prepared using standard "cleaning", "peeling" and critical-point drying methods (SETHI, 1989). Unfortunately it is impossible to show photographs having the same scale factor because of the large differences in scale. Neither was it possible to rephotograph the same sample because complete drying out of the sample and subsequent disturbance of the original fabric could not be avoided.

Sample description

The radiograph of the box-core sample (Fig.1) shows alternating mud and sand layers (Fig. 2). The layers range from 1 mm or less to 4 cm in thickness. The uppermost layer (2 cm thick, not shown on the radiograph) consists of sand. From 2 to 6 cm a mud layer (layer 1), laminated at its base, occurs. From 6 to 9 cm (layer 2) the sediment structure is more complex: bioturbated muddy sediments occur on top of a sand layer

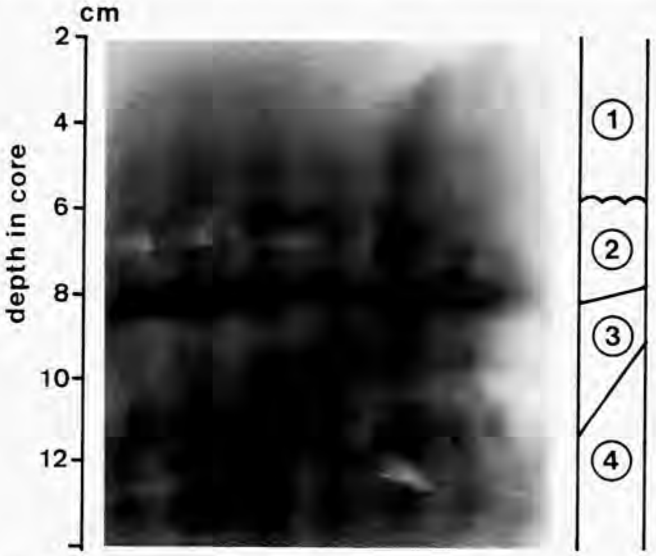

Fig. 1. – Radiograph of sample 88A27. The uppermost 2 cm of the core are not represented. A detailed description is given in the text.

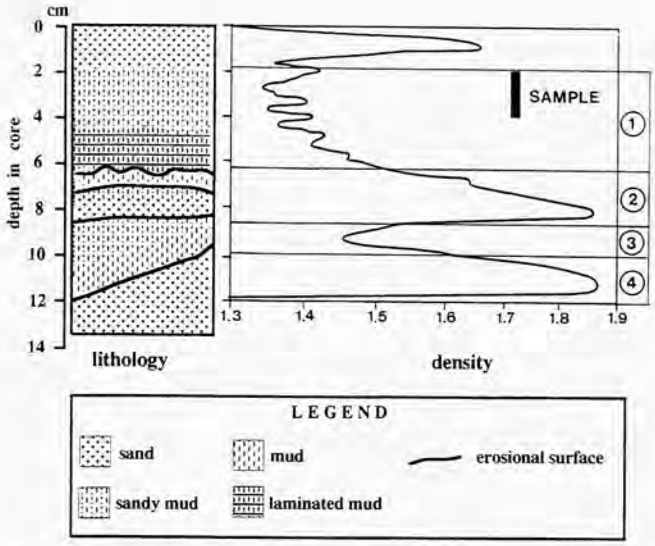

Fig. 2. – Lithology and bulk density distribution in sample 88A27. The subsample for the compaction tests was taken between 2 and 4 cm below the top (bar on record).

(below 8 cm) with numerous shells and shell fragments, oriented parallel to the stratification. Below it another mud layer (layer 3, from 9 to 12 cm), wedge shaped and showing a sharp boundary at its top and at its base as well, overlies a sand and shell layer (layer 4, from 12 cm to base of photograph).

Three subsamples were selected from mud layer 1 and used for the SEM and the compression analyses. The density distribution in these sediments is shown in Fig. 2. Densities are lowest in the mud layers (average values are 1.37 g/cm^3 in layer 1 and 1.45 g/cm^3 in layer 3) and increase toward the base of these layers. Densities are relatively high in the sand layers (approximately 1.66 g/cm^3 in the uppermost layer and 1.86 g/cm^3 in the lower sand layers). The grain-size distribution of layer 1 (mud) shows 28% sand, 45% silt and 27% clay. The grain-size distribution of the sand in layer 2 is 89% sand, 6% silt and 5% clay. The molluscs found in these sediments belong to species still living on the Belgian continental shelf: *Cerastoderma edule* (LINNAEUS), *Donax vittatus* (DA COSTA), *Abra alba* (W. WOOD) and *Spisula subtruncata* (DA COSTA) were identified.

Observations

The original sediment sample, obtained from the North Sea bottom, reveals a clay fabric typical of the marine environment. It shows dominantly "single particle" edge to face (SPEF) and edge to edge (SPEE) contacts with abundant "floc"-formation and only few domains (i.e. group of particles with a Face-to-Face fabric). No preferred orientation of the clay particles is seen. The sample subjected during 24 hours to an overburden pressure of 0.5 Kg/cm^2 exhibits essentially the same clay fabric as the original sample discussed above. Dominant flocs along with SPEF and SPEE configuration are observed with a high degree of voids. No preferred orientation could be seen (Fig. 3). The diameters of the pore spaces observed with the SEM are at maximum 1.5 to 2 µm.

During the following step an overburden pressure of 4 Kg/cm^2 was applied for 24 hours, resulting in a slight compressional effect. As the individual particles are forced into a smaller volume, the pore spaces are slightly reduced, their maximum observed diameters becoming smaller than 1 µm. However, the nature of the clay fabric in terms of particle-to-particle contact (Fig. 4) remained essentially the same as in the original sample.

Fig. 3. – SEM-photograph of subsample 88A27 after a 24 hours compaction test at 0.5 kg/cm^2 (White bar on photograph is 10 µm; pore space is indicated by arrow).

Fig. 4. – SEM-photograph of subsample 88A27 after a 24 hours compaction test at 4 kg/cm^2 (White bar on photograph is 1 µm; pore space is indicated by arrow).

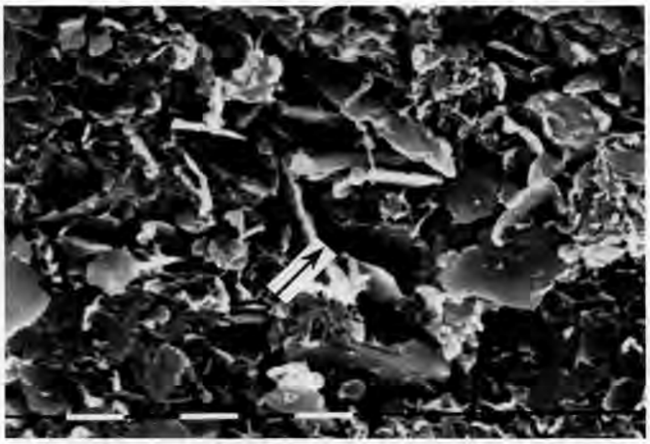

Fig. 5. – SEM-photograph of subsample 88A27 after a 24 hours compaction test at 8 kg/cm^2 (White bar on photograph is 1 µm; pore space is indicated by arrow).

Dominantly SPEF and SPEE contacts with a random orientation are seen.

Finally, during the last step the sample was subjected to an overburden pressure of 8 Kg/cm^2 (Fig. 5) for 24 hours. After this test a greater degree of compressional effect is seen in the sample. The pore spaces become more flattened and their maximum diameters are now smaller than 0.6 µm. Nevertheless the chief observation was that the original clay-fabric in terms of particle-to-particle contact remained unaffected. Even though the individual particles are seen to occur in closer proximities, the original SPEF and SPEE arrangements along with individual flocs are still observable and no signs of any preferred orientation are seen.

Discussion

The observed response of a freshly deposited mud to increasing overburden pressure demonstrates that the original clay-fabric can still be recognized even if the sediment has been buried under a sediment cover upto at least 15 m (corresponding to an overburden pressure of 8 Kg/cm^2). Indeed, although a compaction effect in terms of a decreased pore space is observed, the original clay-fabric nature of the freshly deposited sediment will be retained. As in the case of the sediment studied here, the dominance of the SPEF and SPEE contacts along with flocs could be seen in all the samples. It follows that at least with the restriction given above, clay-fabric is indeed a useful tool for identifying the depositional environment of older deposits.

An example for such an interpretation can be found in the lower part of the Rijkevorsel Clay Member of the Campine Sand and Clay Formation (Pleistocene). The SEM-analyses of this macroscopically homogeneous clay layer, outcropping (2 m thick) in the NOVA pit (Beerse, Belgium), reveal a vertical cyclicity of 2 major clay-fabric types: (a) Face to Face domains resulting from particle deposition in fresh water and (b) Edge to Face domains resulting from flocculated-particle deposition in brackish or salt water (SETHI, 1989).

Conclusion

The above observations point out that an accurate clay-fabric analysis is a useful palaeoclay-fabricenvironmental tool for clay horizons in a stratigraphic profile, as far as these horizons have not been covered in the geologic past by more than 10 to 15 m of sediments. Even though compressional effects are observed, they apparently do not seem to affect the genetic particle-to-particle contact of the clay minerals. However, more work must be done to quantify the different physical parameters of the overlying sediments like water content, specific gravity, compressibility, etc. with the clay-fabric observed at different depths in a profile. This would enable to point out more specifically up to what depth in the profile the clay-fabric can retain its original character.

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Stanislas WARTEL
Afdeling Mineralogie en Petrografie
Koninklijk Belgisch Instituut voor
Natuurwetenschappen,
Vautierstraat 29, B-1040 Brussel

Parvinder Sing SETHI
International Postgraduate training Course on
Fundamental and Applied Quaternary Geology,
Vrije Universiteit Brussel,
Pleinlaan 2, B-1050 Brussel

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