8. WATER CONTENT, BULK DENSITY AND ORGANIC CARBON

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METHODS

The readily oxidizable matter (organic carbon) was determined by the Walkley-Black method (Walkley and Black 1934), adopted and modified from Jackson (1962). To account for the organic carbon not readily oxidizable, the 1/0.76 factor was applied to the sediment analysis. The method excludes (up to 90–95 %) the elementary carbon present as graphite and charcoal (Walkley 1947). Proteins may also remain unoxidized (Olausson 1975). $CaCO_3$ has no influence on the method (Walkley 1947). The coefficient of variation for replicate analyses was determined as 3.8 % (Cato 1977).

The water content was determined as the difference in weight between a fixed quantity of wet sediment and the corresponding dry sediment which was obtained after drying at 105°C to constant weight. The content was expressed as a percentage of the weight of wet sediment. The coefficient of variation for replicate analyses was determined as 1.3 %.

The bulk density was determined by Niels Abrahamsen in connection with the magnetic sampling. Polystyrene beakers of constant volume were filled with sediment by pressing them into the undisturbed core. The samples were sealed and weighed immediately afterwards. The coefficient of variation for replicate analyses was determined as 1.2 %.

RESULTS

The results are plotted *versus* depth in the summary diagrams (see Chapter 20, Figs. 20:1a, 20:2a and 20:3a).

SOLBERGA

Organic carbon – The organic carbon content decreases progressively from about 1.7 % at the top of the core to about 0.8 % at about 4 m depth. Downwards the organic carbon content remains fairly constant to a depth of about 18.4 m where a slight increase can be observed, reaching a maximum at 19.3 m. Further down the organic carbon content varies around 0.8 % with a slight decrease at the bottom of the core. A minimum of 0.3 % occurs at 21.4 m depth, where the clay content reaches a maximum (see Chapter 7).

Bulk density and water content – The bulk density varies around 1.56 g/cc (water content 43.7 %) in the gyttja silty-clay, but decreases progressively downwards in the silty clay to a minimum of 1.45 g/cc (maximum of water content 52 %). At greater depth this change is followed by a short increase to about 1.52 g/cc (water content 47 %) at the transition to the homogeneous clay around 7 m. The bulk density and the water content then remain rather constant down to the sand peak at 17.5 m, where bulk density increases and water content decreases as the clay content sharply declines (cf. Chapter 7, Fig. 7:1). A maximum for bulk density (1.62 g/cc) and a slight minimum for water content (39 %) occur at the level (18.4 m) at which the clay content stops its downward decrease. The bulk density progressively increases downwards to about 1.7 g/cc while the water content decreases to about 30 % at the base of the core.

BRASTAD

Organic carbon – The organic carbon content is low (0.1–1 %) throughout the core and shows a very close relationship to the clay fraction. From the top of the core there is a continuous decrease downwards from 0.8 % to about 0.2 % at the bottom. A distinct minimum of 0.1 % appears in the silty layer at a depth of 2.20–2.31 m.

Bulk density and water content – The bulk density decreases from 1.9 g/cc to 1.57 g/cc while the water content increases from 20 % to 33 % from the top of the core down to a depth just above the silty layer (2.20–2.31 m).

In the silty layer, the bulk density shows a maximum peak (1.8 g/cc) and the water content a minimum peak (25 %). Below the peaks the parameters remain fairly constant (1.55 g/cc and 40 % respectively). From a depth of about 9.5 m the bulk density shows a continuous increase to 1.9 g/cc and the water content a gentle decrease to 25 % at the bottom of the core.

MOLTEMYR

Organic carbon – The organic carbon content is about 2.3 % at 2.5 m depth but drops suddenly to 0.8 % at 3 m. Another distinct decrease occurs at 3.5 m where the content falls from about 1 % to 0.5 %. Downwards the organic carbon content shows a gentle and continuous decrease to about 0.25 % at the base of the core.

Bulk density and water content – There is a more or less gradual increase of the bulk density (from 1.2 g/cc to 1.5 g/cc) with a corresponding decrease of the water content (from 88 % to 44 %) from the peat at the top of the core, down through the detritus gyttja into the gyttja silty-clay. Downwards the parameters remain fairly constant to about 3.3 to 3.5 m depth where a slight minimum and maximum occur for the bulk density and water content, respectively. At about 3.8 m depth the bulk density decreases sharply from 1.5 g/cc to 1.4 g/cc and hovers around this value down to about 4.5 m depth. The water content increases slowly to about 62 % at 4.5 m depth. At this level the water content decreases by about 20 % and the bulk density increases by 0.3 g/cc within less than 20 cm. Further down the parameters remain rather constant with a slow increase of the water content at the bottom of the core.

INTERPRETATION AND DISCUSSION

BULK DENSITY AND WATER CONTENT

The dense measurement of bulk density was used partly to differentiate lithology in considerable detail (cf. the less dense analyses of the grain-size distribution) partly to demonstrate broader variations in composition and consolidation of the sediments. The main features of the vertical distribution pattern in the cores for bulk density reflect the water content, affected by compaction, by grain-size distribution and to a smaller extent by the organic matter content.

As illustrated in Fig. 8:1, the bulk density varies inversely with the water and organic matter content of the sediment (cf. Cato 1977, p. 23). Organic matter has a density close to that of water (Revelle and Shepard 1939:265). As the diagram shows there is a wider dispersion of the data from the Brastad and Moltemyr cores compared with those from the Solberga core. Despite differences in the grain-size distribution the Brastad core shows a higher degree of consolidation.

In general, the bulk density of the cores increases and the water content decreases with increasing depth of burial. This is mainly due to the compaction of the sediment. However, variations occur as is to be expected, since the lithology is not consistent with depth. In the Solberga core the

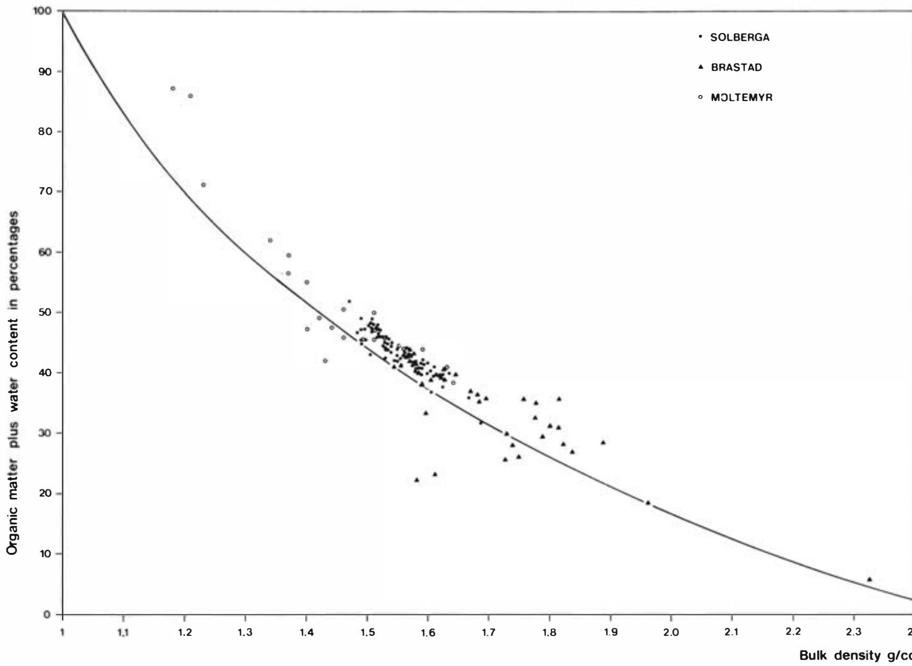

Fig. 8:1. Relationship between organic matter (organic carbon × 1.724) plus water content and bulk density in the Solberga, Brastad and Moltmyr cores.

elevated bulk-density values and lowered water content in the upper 7 m of the core are directly related to the upwards gradually decreasing clay content. The low density values and higher water content between about 7 and 18 m reflects the very clay-rich sequence of the core (cf. Chapter 7, Fig. 7:1), with its higher porosity. The rapid downwards decrease of the clay content between 17.7 and 18.4 m depth is strongly reflected in an increase of the bulk density and a decrease of the water content. The interesting feature, however, is that the bulk density and the water content show decreased and increased values, respectively, at about 19 to 20 m depth, despite the absence of changes in the grain-size distribution. This can only result from the extremely high incidence of Foraminifera and Diatom specimens in the sediment at this level (see Chapters 14 and 16). These fossils have a spongy nature and consequently a strong water-retaining capacity, which is reflected by the bulk density and water content of the sediment. At greater depth the bulk density and water content are mainly a function of compaction.

The high bulk-density values and the upwards decreasing water content at the top of the Brastad core can not be due solely to the grain-size distribution. They also indicate exogeneous disturbances. The silty layer between 2.20 and 2.31 m depth is clearly reflected by maximum and minimum peaks of the bulk density and water content, respectively. Further down the variations of these parameters are related partly to the grain-size distribution, partly to the increased compaction.

At about 13.3 m depth both the bulk density and water content indicate the occurrence of a silt layer, overlooked in the analyses of the grain-size distribution but seen in the visual examination of the core (see Chapter 6). This layer together with the variation of the bulk density in the clayey silt sequence (10.2–15 m depth) suggest that the bottom of the core may be varved – however, with a diffuse graded bedding not really visible during the examination of the core (Chapter 6).

The low bulk density and high water content in the upper part of the Moltemyr core reflect the uppermost high organic sediment, gyttja. At greater depth the parameters mainly reflect variations in the grain-size distribution. For example, the clay peak between 3.3 and 3.5 m and the 30 % clay decrease between 4.4 and 4.7 m (see Chapter 7) are clearly discernible from the distribution of these parameters *versus* depth. Further down the bulk density and water content weakly indicate the increased clay content, since they are mainly affected by the increased consolidation.

ORGANIC CARBON

The organic carbon content of the Solberga core is low (<1 %) and shows no variations *versus* depth, if the upper 4 m (1–2 % organic carbon) and the sequence between about 18 and 21 m (>1 % organic carbon) are excluded. The increased values within this lower zone may be due to a low sedimentation rate, *i.e.* the organic matter is less diluted with clastic particles than elsewhere in the core. The elevated values in the upper part of the core is a well-known phenomenon, due to the wave-washing and transportation of sediments from higher, emergent areas to areas still below the surface of the sea, *i.e.* postglacial sedimentation.

As a consequence of the amelioration of the climate during the Preboreal times the organic production increased (cf. *inter alios* Digerfeldt 1972, p. 87, Berglund and Malmer 1971). It is interesting that the organic carbon content does not increase in the clay-rich sequence between 7 and 17.7 m, which is here assumed to be of the Preboreal age. This indicates an increased dilution of organic matter in this sequence of the Solberga core, due to an accelerated sedimentation rate of clastic sediments poor in organic matter. The latter in turn may point to a sediment sequence of mainly allochthonous origin.

At Brastad the organic carbon content is less than 1 %. Below about 3 m it shows a close relationship to the grain-size distribution. Above this level stronger variations occur with a sharp minimum in the silt layer between 2.20 and 2.31 m. The elevated values in the upper 2 m can be related to postglacial sedimentation (see above).

In the Moltemyr core, too, organic carbon content is less than 1 %, if the upper 3 m is excluded (peat and gyttja). It shows a close relationship to the grain-size distribution below, but not above 3 m depth. The gradual increase of the organic carbon above this level is probably caused by the progressively increased protection of the site from the sea just before its isolation. The increased organic carbon content between 3.2 and 3.5 m depth is related to the increased clay content (see Chapter 7). This implies that the sedimentation rate did not change as much as at Solberga during this phase of deposition.

SUMMARY AND CONCLUSION

The measurement of bulk density and water content *versus* depth was partly used to differentiate the lithology in considerable detail. With the exceptions given below, the results could be related to changes in grain-size distribution and to the natural consolidation of the sediments.

In general, the bulk density increased and the water content decreased with increasing depth of burial. The clay-rich sequences between 7 and 18.4 m at Solberga, between 3.3 and 3.5 m, 3.8 and 4.5 m at Moltemyr, and the silt layer at 2.2–2.3 m depth at Brastad are clearly reflected by these parameters. On the other hand the bulk density and the water-content values between 19 and 20 m in Solberga and around 1.5 m depth in Brastad show anomalies. The former is assumed to reflect the high incidence of foraminifers and diatoms at this level (see Chapters 14 and 16), while the latter is probably an effect of exogenous disturbances of the sediment.

The organic carbon content in general falls below 1 %, but in the uppermost part of the Solberga and Moltemyr cores rises to about 2 %. At Solberga this can be related to postglacial sedimentation, while at Moltemyr the gradual isolation from the sea may be of greater importance. The low organic carbon content between 7 and 17.7 m at Solberga is presumably a consequence of an increased sedimentation rate of clastic sediments of allochthonous origin.

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