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DIATOM ANALYSIS OF COASTAL DEPOSITS : METHODOLOGICAL ASPECTS

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SUMMARY. - In the frame of a general introduction to diatom analysis, especially of Quaternary coastal deposits, the possibilities, problems and methods of this discipline are briefly discussed.

INTRODUCTION.

Diatoms are unicellular, usually photosynthetic, algae with a box-like siliceous cell wall called a frustule. Each frustule consists of two more or less identical parts called valves. Their size ranges from less than one micrometer up to two millimeters. Most species are ten to five hundred micrometers large. The number of valid diatom taxa known at present is extremely large (more than 20,000), while the number of proposed taxonomic names is considerably higher over 80,000; S. L. VAN LANDINGHAM, 1967). Due to their small size, diatoms are very easily transported and have become distributed all over the world where they occur in a great variety of environments. Although the most prolific diatom populations are found in the marine realm, even such places as dry rocks or soils may be suitable for the growth of certain species.

As a tool in Quaternary research the study of diatoms should not be overlooked. Since the taxonomy of diatoms is based almost entirely on the morphology of the resistent siliceous test and not on its perishable contents, fossil diatoms (valves or frustules) can be identified with a high degree of accuracy. Due to the ubiquitous distribution of diatoms, sediments of very different nature contain diatom remains. Often these are present in very high concentrations, enabling a statistically valid analysis of even very small samples. The ecological requirements of many diatom taxa are narrowly limited and are already fairly well known. Diatom associations reflect their milieu and react rapidly to environmental changes by alteration of their composition. Since most Quaternary taxa are extant, our knowledge of the ecology of recent diatoms may be used directly in palaeoecological interpretations, resulting in very detailed reconstructions of past sedimentary environments. Additional positive features are that fossil diatoms are often found together with dateable material and that the techniques of diatom analysis are rather simple. Moreover diatom research is comparatively inexpensive. A high quality light microscope is the most costly piece of apparatus needed in most cases.

THE DISTRIBUTION OF DIATOMS.

If diatoms are to be used as environmental indicators, we have to know precisely what determines their distribution and the composition of their living assemblages. The most important factors in this respect are the following :

- The geographic distribution of the taxa, as some appear to occur only in restricted areas while many others are cosmopolitan.
- The type of environment (s.l.) which may be aquatic with an abundance of diatoms or purely terrestrial or of intermediate status such as periodic pools or damp rocks.
- The substrate which is of importance for the non planktonic, sessile or motile, forms.
- The water depth.
- The viscosity of the water which affects the plankton.
- The presence or abscence of tides and the period of intertidal exposure.
- The presence of currents or turbulence.
- The light conditions.
- The temperature conditions.
- The complex of factors contributing to water composition, of which salinity or osmotic pressure, hydrogen-ion

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concentration, trophic conditions, dissolved gasses, trace elements and organic substances are known to be of major importance.

- Several biological factors such as predation (including parasitism and diseases), competition and colonisation phenomena.

More detailed treatises on the distribution and ecology of diatoms are to be found in the works of e. g. B. J. CHOLNOKY (1968), N. I. HENDEY (1964), R. W. KOLBE (1932), R. PATRICK & C. W. REIMER (1966), F. E. ROUND (1971) and D. WERNER (1977).

ECOLOGICAL INTERPRETATION OF DIATOM ASSEMBLAGES.

For many of the factors mentioned above, diatoms may be grouped into categories according to their specific requirements. Therefore a number of so-called spectra, which give direct or indirect information on the environmental conditions during deposition, can be calculated on basis of the assemblage composition data. Since coastal deposits include sediments of very different origin, it will be necessary to investigate several environmental parameters and to use a large number of such spectra. Surveys of the most commonly used types of spectra are given e. g. by W. H. ABBOTT & S. L. VAN LANDINGHAM (1972), H. DE WOLF (1982) and M. B. FLORIN (1977).

Besides spectra, many other methods which all make use of the composition and structure of the assemblages may be applied to derive information on the environment : for instance the commonly used diversity indices, G. NYGAARD's (1956) pH-indices, the relative diatom temperature (T. KANAYA & I. KOIZUMI, 1966) and the ratios Centrales/Pennales and Araphidineae/ Centrales.

Although somewhat neglected, the relationships that have been noted between valve size and/or outline of certain species and factors such as salinity, nutrient availability, temperature and substrate moisture (e. g. H. BEGER, 1927; W. BOCK, 1962; N. I. HENDEY, 1951; F. HUSTEDT, 1925; R. W. KOLBE, 1927, 1954; R. MARGALEF, 1969) demand our attention.

Diatom assemblages are used primarily to determine the local sedimentary environment. However, in certain cases allochtonous valves may give some information on other biotopes in the environs of the site of deposition (e. g. D. KONIG, 1974).

The use of spectra and indices, combined with a large number of samples and taxa (often more than one hundred in a sample) involves tedious calculations. Therefore it is advisable to computerise the data processing. As each taxon can easily be given a numerical identification and environmental code this poses no problem.

PROBLEMS OF DIATOM ANALYSIS.

Several phenomena may complicate the interpretation of fossil assemblages.

First their is the problem of selective dissolution by which the more strongly silicified species will be favoured. A number of physico-chemical processes are involved and the whole mechanism is not yet fully understood. Not infrequently sediments from suitable environments are completely barren of diatoms. H. J. SCHRADER (1973) proposes the use of a "dissolution factor" which is the ratio between well-preserved and corroded valves. When weakly silicified valves, such as those of *Chaetoceros* spp., *Fragilaria striatula* or *Pleurosigma aestuarii*, are found in a well-preserved state, very little dissolution is indicated.

Selective fra mentation is the second phenomenon contributing to the preservation of fossil diatoms. Fragmentation results from mechanical stress and occurs in a variety of conditions (e. g. BEYENS & DENYS, 1982). It may enhance corrosion and generates difficulties in identification and more particularly in quantification. This may be partially overcome by using counting procedures which include some of the identifiable parts. A simple method is illustrated in fig. 1.

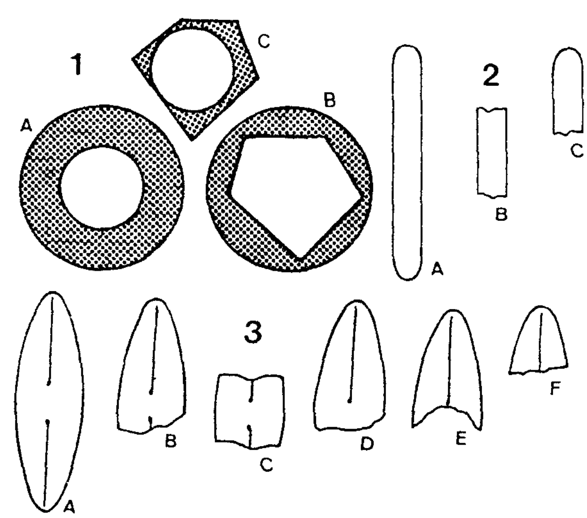

Fig. 1 - The counting of fragments.
1. Centric valves. A : complete valve, B : neglected fragment with central part missing, C : fragment counted as complete valve.
2. Pennate bipolar valves without a differentiated central structure. A : complete valve, B : neglected fragment, C : apical fragment counted as 1/2 valve.
3. Pennate bipolar valves with a differentiated central structure. A : complete valve, B-D : fragments counted as complete valves, E-F : neglected fragments with central part missing.

The problem of reworking exists for all microfossils and is cften difficult to assess. Contamination which occurs with great ease can only be avoided by extreme care in sample handling and processing. Both topics have been surveyed by K. E. LOHMAN (1960).

Transported valves often constitute an important part of fossil assemblages. With regard to the quantitative distribution of diatoms in sediments along the salinity gradient of estuaries, it is important to note that this generally follows the pattern shown in fig. 2. Fresh and brackish water species may be found far from any shore, but in this case they will mostly occur in small numbers only. Marine taxa however remain important throughout the brackish zone and even in fresh water some allochtonous marine and brackish valves may be found. Similar situations may develop in other tidal areas. Therefore the relative abundance of each group and the ecology of its members should be considered before any conclusions on the true salinity at the sedimentary site are drawn.

Due to the large number of taxa that may be encountered and their often extreme variability, the identification of diatoms is by no means always a simple matter. Much of the literature in this respect is difficult to obtain. Since correct determinations are indispensable, an unabating interest in taxonomy is required and systematic knowledge should be kept up to date. A reference collection, drawings and a photographic record amply repay the time spent on them.

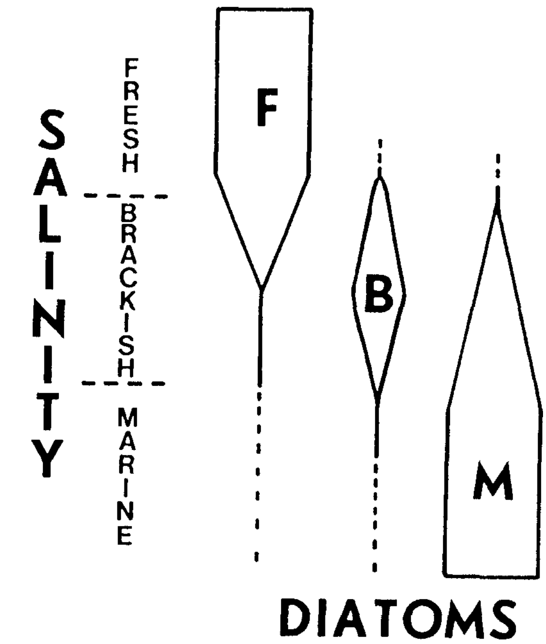

Fig. 2 - Schematic representation of the quantitative distribution of diatoms belonging to different salinity groups in the sediment along the salinity gradient of an estuary.

GENERAL METHOD OF STUDY.

There are three main types of diatom analysis of deposits. In qualitative analysis only identifications are performed, in semi-quantitative analysis the relative abundance of the taxa is estimated on sight, while in quantitative research the valves are physically counted. The relative method involves the counting of a minimum number of valves followed by the calculation of percentage abundancies. In the semi-absolute method the number of valves per traverse on the microscope slide is used as an indication of their concentration in the sediment. True concentrations are determined by absolute analysis.

The qualitative method is only suitable for stratigraphic purposes; ecologically the data have little meaning. The semi-quantitative method is subject to very large errors and the data are difficult to interpret. However it may be used in preliminary investigations. The quantitative methods, although more elaborate, are to be preferred in palaeoecology.

Absolute determinations are used in detailed studies, since the number of valves in the sediment may yield additional information on some features of the environment. The concentration of diatoms in sediments is determined by several parameters which are :

- The composition of the local assemblage; some species (especially the smaller ones) multiply rapidly to form large populations, while others do not and are only found in small numbers.

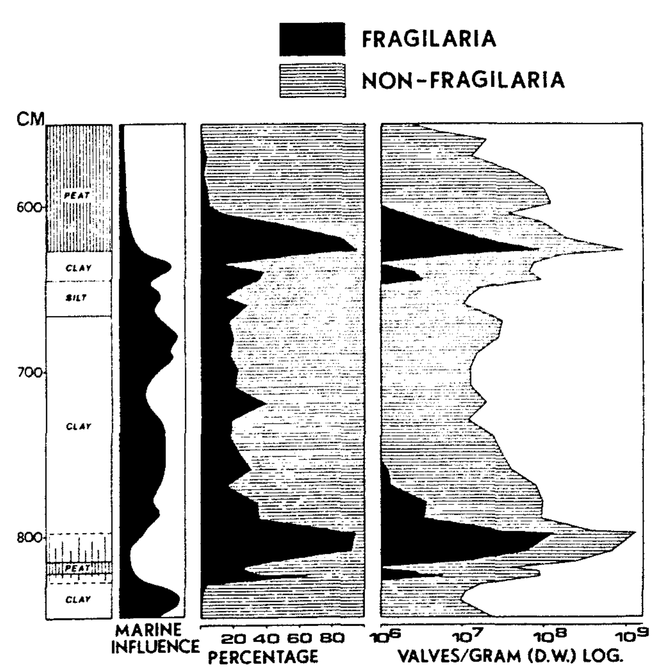

Fig. 3 - Comparison of the relative abundance of *Fragilaria* with its true concentration for part of a core containing two peat layers with clastic sediments in between. Valve concentrations determined using the method of J. STOCKMARR (1971).

- The local environmental conditions which influence the diatom productivity, such as nutrient availability, substrate stability and temperature.
- The influx of allochtonous valves.
- The sedimentary conditions for diatoms.
- The preservation before burial.
- The sedimentation rate.
- The preservation after burial.
- And finally, when working with volume units of sediment, the degree of compaction.

An additional problem may be that true concentrations are more subject to lateral variations than percentage data due to micro-environmental differences. G. W. ANDREWS (1972) has stressed the heterogeneity of the distribution of diatom assemblages in deposits and regards this as a major draw-back for quantitative studies. This can be disputed, as it is exactly this heterogeneity which enables one to recognise local paleoenvironments. In this respect mixing due to sediment transport, as encountered on a beach (M. C. AMSPOKER, 1977), can make it impossible to distinguish smaller environmental units. On the other hand it may diminish the effect of patchy growth often encountered on tidal flats.

Absolute methods also offer a better understanding of percentage fluctuations. In the example given in fig. 3, the percentage of the genus *Fragilaria* is shown for part of a core containing two fresh water peat layers intercalated in a clastic salt water deposit. *Fragilaria* shows striking maxima at the transition zones. One may ask oneself whether this is caused by an increase in *Fragilaria* or a decrease in the non-*Fragilaria*. The absolute curve clearly shows that the concentration of *Fragilaria* valves, a genus often forming water blooms in unstable brackish and fresh water environments, has increased enormously.

SAMPLE PREPARATION AND COUNTING.

Many methods have been suggested to eliminate non-diatomaceous material from sediment samples. With the exception of the destruction of organic matter and elimination of carbonates and the larger sand grains, generally no attempts should be made to clean the material any further, as this will invariably lead to changes in the fossil assemblages (K. MOLDER, 1943; H. J. SCHRADER, 1973; R. SIMONSEN, 1962). The presence of particles other than diatoms on the slides is no great problem as long as the film of material is kept sufficiently thin.

Permanent mounts using a highly refractive medium, such as phenol-pleurax (H. VON STOSCH, 1974), are necessary if accurate identifications are to be made and counts should always be carried out under high magnification using oil-immersion objectives (100x magn.).

If the quantitative analysis is accompanied by a thorough qualitative search of the slides there is no need to keep on counting until the "last" taxon is encountered. A count of 300 to 600 valves is generally sufficient. It is advisable to estimate the error or confidence limits (L. J. MAHER, 1981; J. E. MOSIMANN, 1965; R. R. REGAL & E. J. CUSHING, 1979; J. STOCKMARR, 1971) in order to obtain an idea of the statistical significance of the fluctuations observed.

FINAL REMARKS.

Diatom analysis has always played an important part in the study of former sea levels, especially in countries with a long history in this kind of research, such as the Scandinavian and North-Sea countries. The present author believes that it will continue to gain in popularity since it provides an efficient means of improving our knowledge of the genesis of particular coastal areas, especially when used in conjunction with other disciplines.

Although extensive studies have already been performed on the distribution and ecology of recent littoral marine and brackish water diatoms, several aspects still remain obscure. Further quantitative studies on the ecological behaviour of benthic taxa and communities are imperative. Also many workers have tended to focus their attention on the larger, visually more attractive, species more or less neglecting the smaller taxa which are often far more abundant. As a result taxonomic confusion and the lack of sound information increase with decreasing size.

Throughout the years diatom analysis has become a specialised discipline which may yield valuable results, yet gaps in our knowledge still require to be filled.

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