THE MAPPING OF HYDROGRAPHIC DATA IN ATLASES

A PLEA FOR MORPHOLOGICAL MAPS

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The representation of features of the sea bed on atlas maps has followed conventional lines closely comparable with the techniques evolved for topographic maps. In the recently published Atlas of Britain, for example, the bathymetric map of the British Seas and the corresponding bottom deposit map represent no radical departure from previous practice [1]. With the ever-increasing interest in oceanography and the gradual accumulation of more and varied data, the question arises whether existing methods of cartographic representation are adequate and, if not, what possible new lines of approach are available. This is the dual theme of the paper which follows.

First, the present method of portraying hydrographic data, particularly that relating to the form of the sea bed and the bottom deposits, may be briefly summarised. In the Atlas of Britain, with which the author was closely associated, the bathymetric map was compiled from published Admiralty charts, the contours being interpolated from the soundings shown on the chart. Although the number of soundings on the chart represents only a small proportion of the total on the original hydrographic survey fair sheet, the scale reduction from the chart to the atlas map is such that little would be gained by going back to the original fuller survey instead of the published chart. If the chart is accepted as the basic document for the compilation of the atlas map, it is as well to realise its limitations. It does not, for example, give a synoptic picture of the form of the sea bed at any one time, for, being compiled from a number of surveys of different dates, scales and varying degrees of thoroughness, this lack of uniformity is inevitable and must be accepted. Again, however, the large scale reduction from chart to atlas map means that any error is at least minimised if not eliminated. Some idea of the effect of scale reduction can be gained from the following example. For areas close inshore, where the initial hydrographic survey was carried out on a scale of 1/50 000, the soundings are plotted on the fair sheet with a linear distribution of ten to the inch. On this basis an error of about 400 feet could arise in the insertion of the contours by interpolation. To anyone accustomed to the standards of accuracy achieved in topographic mapping this might seem a large margin of error. When, however, this survey is incorporated in the compilation of an atlas map on a scale of 1/2 500 000, the error in the positioning of the contour line is equivalent to a little over 1/500th of an inch and therefore of no significance in plotting. For smaller scale surveys, such as those which are normally taken offshore, the accuracy of representation will be correspondingly less. Many of these deeper water surveys are old and were based on sounding with a hand lead, with the result that the amount of detail shown and their general positioning is not comparable with modern surveys. Until the invention of the Decca system, fixing out of sight of land presented a real problem and it is not surprising that numerous methods were tried out without any achieving a high standard of accuracy [2]. Even today the positions of some of the shoal banks in a frequented area like the North Sea are not accurate to within about 1/8th of a mile. In time errors like these will be eliminated but it seems unlikely that these offshore areas will ever be surveyed on a large scale like the more coastal areas. This fact is of importance in deciding the best way to represent hydrographic information on the small scale map normally found in atlases.

In addition to these limitations imposed by scale, date, and lack of a synoptic picture of the basic survey data, there is also no common datum plane used by all countries which border the seas of the continental shelf. Although this is of little consequence in relation to mapping sea bed contours on the scale normally employed on atlas maps, it is perhaps surprising that until the recent connection across the Strait of Dover, very little has been done to establish a scientific basis for comparison of the surveys undertaken in different countries.

After the initial compilation, hydrographic maps stand in need of constant revision, particularly for the shallow water areas where the banks and channels are subject to change. For an area like the East Anglian coast, or the Thames Estuary, tidal streams can effect considerable changes over a relatively short period of time so that a map on a scale as small as 1/500 000 would require some revision about every five years [3].

For many parts of the sea bed, physical processes create a highly irregular bottom topography which cannot be reproduced by contours on a medium scale chart let alone on a small scale atlas map. Major breaks of slope like submerged cliff lines or deep pits might be indicated by using occasional spot depths to supplement the information given by the contours. A complete cover of soundings superimposed on the contours such as is used in the Russian Morskoi atlas seems undesirable in that the final result is neither a navigational chart nor a hydrographic map. Even soundings of relatively high density fail to give any indication of the highly irregular bottom topography which exists in such areas as the Flemish Bight. Here echo sounding and, more recently, acoustic ranging have disclosed that the sea bed is fashioned into a complex pattern of large sand-waves with their crests at right angles to the direction of the dominant tidal streams [4]. Only in coastal areas like the Goodwin Sands, where there is a high density of soundings, does the sand-wave pattern emerge on the surveyor's fair sheet. By the time this is used for the compilation of the published chart, this distinctive feature has disappeared.

The other type of hydrographic map commonly found in atlases, namely that which shows bottom sediments, also follows accepted cartographic practice in that it records the areal distribution of the various sea bed deposits in much the same way as superficial deposits are shown on the drift editions of a geological map. No indication is given of the thickness of the sediments which can vary, in the British Seas, from a few inches in the English Channel to hundreds of feet in the North Sea. At present accurate section lines similar to those on geological maps are not feasible in view of the limited data available but this will not always be the case as new methods of measuring sediment thickness are developed.

The method of compilation of a bottom sediment chart such as appears in the Atlas of Britain is relatively simple. The information on which it is based is derived largely from official Admiralty hydrographic surveys. During the course of a survey the type of bottom sediment is examined periodically by "arming" the old-fashioned sounding lead with tallow set in the base. The tallow either brings up a sample for identification or is moulded by the pebbles or rock on the sea bed. This method might appear crude in theory but in practice it gives a reasonable indication of the quality of the bottom. As a method it has been in use for centuries, and in the period before the invention of the sounding-machine and echo-sounder, when all depths were measured with a hand-lead, a vast amount of information was acquired, each depth having a corresponding indication of the type of bottom sediment. Today only an occasional bottom sample is recorded as it means a special operation entirely divorced from sonic sounding. In consequence, the survey fair sheets of the last century are a far more valuable source of information than contemporary surveys if it is accepted that the accuracy of position fixing is less, especially out of sight of land.

One major difficulty in using the Admiralty survey as a source of data for the compilation of a bottom sediment map is that the designation of the type of sediment is vague and lacks a scientific basis. The distinction between fine, medium and coarse sand is often only a visual one and is not based on accepted scale of grain size values. The latter system is impossible unless actual samples are obtained, and it is only in the North Sea that the work of JARKE [5], PRATJE [6], VAN VEEN [7], BAAK [8] and BORLEY [9] enables this to be done. Thus on the bottom chart in the Atlas of Britain more detailed information is shown for the North Sea than for other parts of the continental shelf. Throughout there has been the generalisation which inevitably follows from the small scale of the final compilation. Some idea of the complexity of sediment distribution in the coastal zone down to 10 fathoms can be seen from the bottom deposit map of Start Bay (fig. 1). When this is reduced to the scale of the normal atlas map the degree of generalisation makes it of very limited value. In the example given the whole of Start Bay on the relevant map in the Atlas of Britain is shown as sand with a small patch of gravel.

From the foregoing it will be seen that the hydrographic maps in the Atlas of Britain are a straightforward record of the available data, with the amount of detail shown being conditioned by their relatively small scale. The same is true of other general atlases which contain a small number of

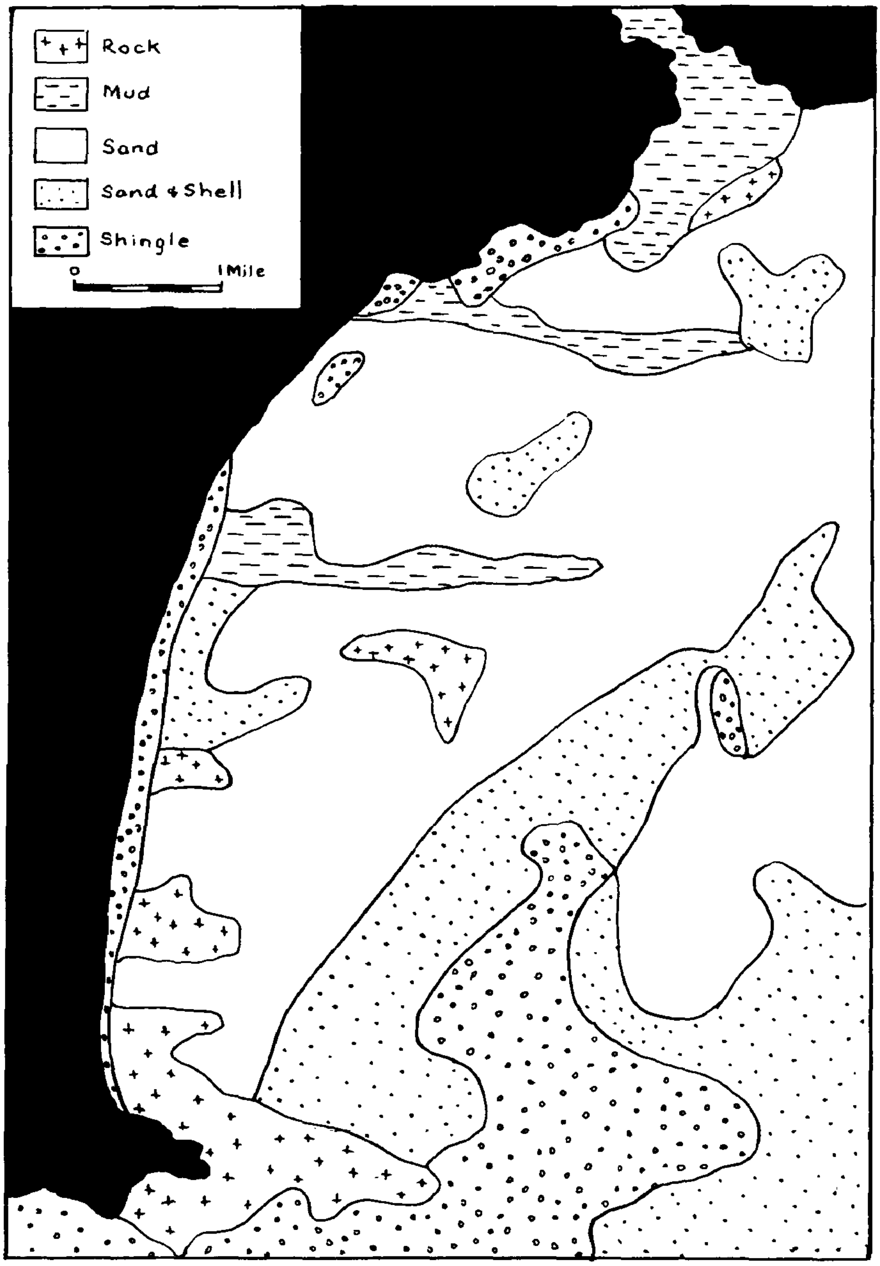

Fig. 1. — A bottom-sediment map of Start Bay, off the south-east coast of Devon, showing the complexity of the sediment distribution.

hydrographic or oceanographic maps. In many instances lack of data imposes a serious limitation on their usefulness. More information will undoubtedly become available in the next decade due partly to the extension of present work and partly as a result of the development of new techniques. It is unlikely, however, that a full scale hydrographic survey will ever be undertaken of the deeper water areas away from the main navigable channels, and so for large parts of the continental shelf information regarding bottom form will remain scanty. What is more likely is that limited areas of the sea bed will be examined from a morphological and geological viewpoint using such techniques as acoustic ranging as well as the conventional echo sounding [10]. The data acquired from such surveys would probably add little to the existing conventional maps but could be of great value in the compilation of maps which seek to express cartographically the geomorphological features of the sea bed. The semipictorial morphological map with all its imperfections represents a step in this direction. Morphological maps have been produced for land areas and there is no reason why similar hydrographic maps should not be compiled. Already a start might be made for those shallow water areas within the continental shelf where a considerable amount of morphological and geological information has been acquired in recent years. For limited areas like the North Sea Basin it is feasible to construct a preliminary map incorporating information about the form, bottom deposits, geology and underlying structure of the sea bed. In this way the really significant facts about the sea bed can be presented, the relatively small scale of the atlas map counteracting any impression that the compilation is based on detailed information.

Such an interpretative map represents a further stage of development of the physiographic map much favoured in the United States. Both RAISZ and LOBECK have drawn landform maps of this type, and more recently Bruce HEEZEN and others have produced similar physiographic maps of the Atlantic Ocean [11]. These oceanographic maps are on a very small scale but even then the paucity of data is such that there are many gaps. Although such physiographic maps are of value in emphasizing the main features of the sea bed by combining the skill of the artist with the accuracy of the cartographer, they give little or no guide to the origin of the features they represent. A morphological map would, in contrast, use the results of geomorphological research and seek to portray cartographically our present knowledge of the form of the sea bed in terms of its origin. In its compilation it would make use of the conventional bottom contour and bottom deposit map and this relationship could be shown by printing the morphological map on plastic and using it as an overlay on either of these basic maps.

In its present form the morphological map would require an accompanying explanatory text to bring out the full significance of the data it attempts to record. In a sense this is an admission of partial failure on the part of the cartographer but, until such morphological maps become commonplace and develop their own system of convention, it would seem that an explanatory text is desirable. This has already been done for land areas, for example in the Atlas of Denmark, edited by Professor Axel SCHOU. For an area like the North Sea Basin for which a preliminary morphological map has been prepared (fig. 2), the accompanying text would emphasize the great contrast between the northern and southern parts, with the dividing line drawn roughly between the Humber and Zuider Zee [12]. To the north of this line, the sea bed features are almost wholly attributable to the effects of the Pleistocene Ice Age. The end moraines which link up

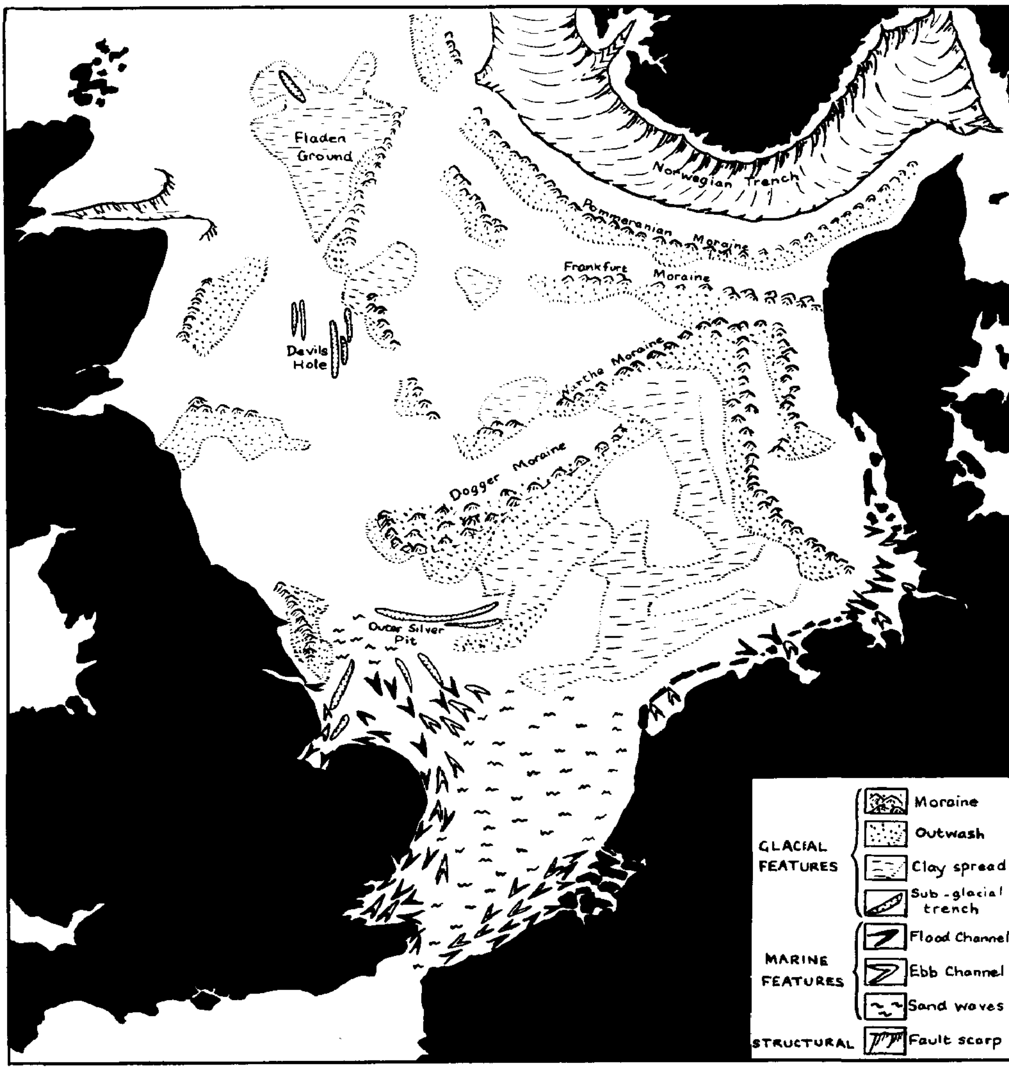

FIG. 2. — A tentative morphological map of the North Sea Basin distinguishing features which are of glacial, marine or structural origin.

with those of Denmark and the North German Plain are based on the researches of PRATJE published over a decade ago. Although not forming the same positive relief features as they do on land, they nevertheless often coincide with shallow banks. PRATJE drew his moraines largely on the evidence of gravel deposits which he interpreted as outwash fans fronting the moraines. This method of approach is interesting in that it shows the importance of the bottom deposits in any attempt at an analysis of the sea floor morphology. More recently EWING and STRIDE have produced seismic evidence which suggests that the Dogger Bank is a huge morainic dump left behind by an ice advance earlier than that which formed the moraines further north [13]. Equally significant as features of the sea bed directly attributable to the Pleistocene Ice Age are the deep clefts like the Devils Hole and Outer Silver Pit. For long these were regarded as the remnants of a former valley system associated with the combined Thames and Rhine drainage but, in view of the recent estimates of the thickness of glacial deposits in this part of the North Sea, this explanation seems unlikely. Their form suggests a close parallel with the sub-glacial overdeepening of channels on land. In the case of the Devils Hole, the channel has been cut to a depth of about 70 fathoms below the general level of the surrounding sea bed which here has an average depth of about 50 fathoms. This represents localised erosion on an enormous scale but comparable figures are available for land areas. In the Furness district of Lancashire, for example, a drift-filled valley 537 feet deep has been located near Dalton [14].

In contrast to these northern parts of the North Sea, the Flemish Bight in the south has features more directly attributable to marine agencies.

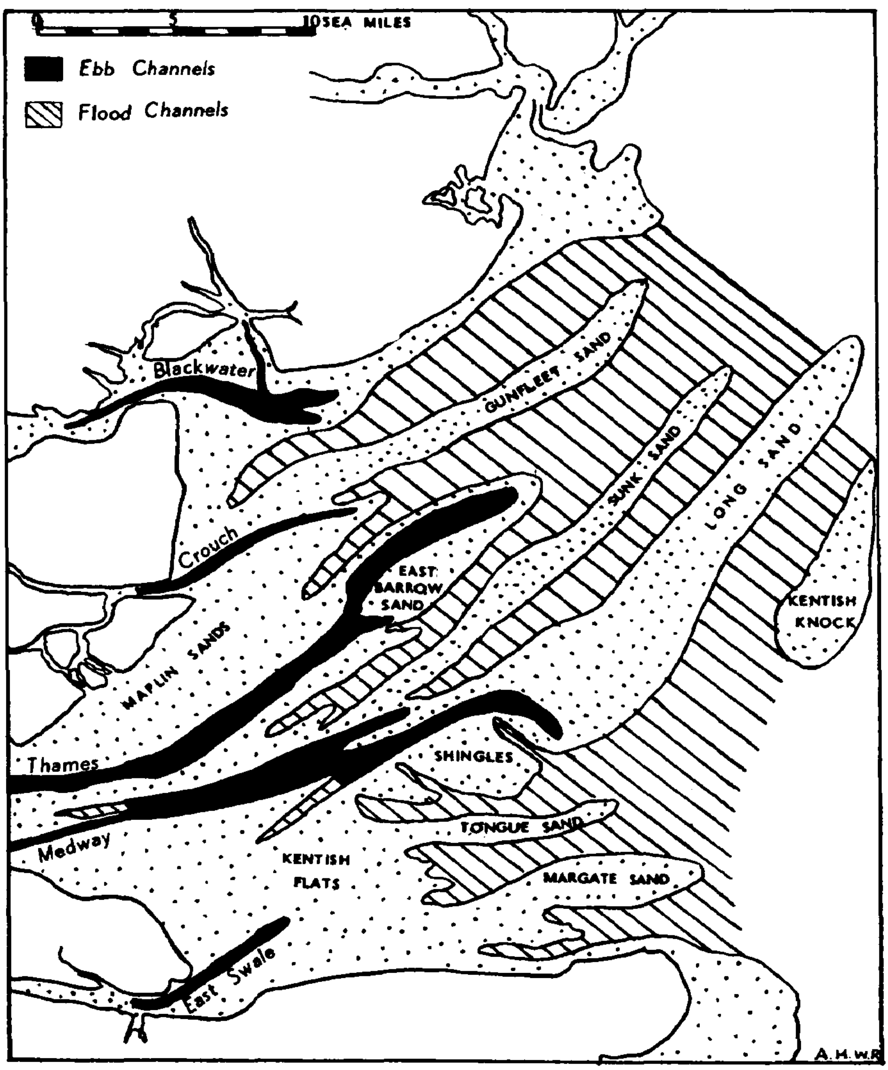

FIG. 3. — A larger scale morphological map of the Outer Thames Estuary showing the ebb-flood channel pattern and the submerged plain of marine denudation of the Kentish Flats.

This area was not subject to glaciation during the later stages of the Ice Age and in consequence the original glacial topography has been destroyed by subsequent marine and possibly sub-aerial erosion. The marine agencies, particularly tidal streams, have re-worked and re-sorted the glacial deposits and created distinctive elements in the form of the sea bed. Where the deposit is thick and tidal streams are linear in character and of sufficient strength to transport the sediment, an ebb-flood pattern of banks and channels has come into being, as off the East Anglian coast and Flanders coast [15]. In these areas, and elsewhere where tidal streams are operative on a sea bed composed of sand, the surface has been fashioned into a number of corrugations with the development of sand waves. These are most numerous in the central part of the Flemish Bight. None of these glacial or marine features, which would form the subject of an accompanying descriptive text, is clearly discernible on the bottom contour or bottom sediment maps alone and yet they are of fundamental importance in any understanding of the hydrography of the North Sea Basin. It would seem, therefore, that there is a need for a morphological map representing a synthesis of all relevant hydrographic data.

The relatively small scale of such a map in an atlas will necessarily involve generalisation and compression of detail. While this has its advantages where information is scarce or rudimentary, it can be a disadvantage in some areas where significant details cannot be portrayed. In these cases an inset map can help. In the Outer Thames Estuary, for example, there is a marked contrast between the ebb-flood channel system extending outwards from the Essex coast and the plain of marine denudation existing off the north coast of Kent (fig. 3). The latter, varying in depth from between 0 and 3 fathoms has developed as the London clay cliffs have retreated steadily under the combined attack of marine and sub-aerial erosion. Such a morphological contrast is not at all apparent on the small scale general North Sea map : only a large scale inset map could emphasize it to advantage.

To complete the morphological picture, a series of maps illustrating the changing bottom form could be used. Estuary regions and shallow water embayments like Liverpool Bay are particularly prone to rapid changes in the configuration of the banks and channels [16]. Although these changes do not appear to be cyclic, the presentation of a series of period pictures based on surveys of different dates will serve to express cartographically the nature and extent of the changing submarine morphology.

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