

EXPLORATION OF SEABED RESOURCES USING BATHYMETRY AND GEOLOGY

Seabed Resources and Hydrography

The seabed of the Dutch sector of the North Sea is one of most densely sampled marine areas in the world. Sampling started in the mid-1960s with the exploration of fill sand in the coastal zone. Since that time, a reconnaissance mapping programme of the entire territory has been carried out in close co-operation with the North Sea Directorate of the Dutch Ministry of Public Works and Water Management, and the Hydrographic Office (HO) of the Royal Netherlands Navy.

The sample spacing varies much from north to south and from east to west, reflecting the differing relevance of various areas to policy makers and industry. In the northern part, the mean sample density is 1 per 25 km², and in the southern part the interval in the coastal zone west of the port of Rotterdam increases to 1 per km². To establish the boundaries between the different sedimentological grain-size classes, bathymetric and side-scan sonar data collected by the HO have been used. The interpretations have led to a better understanding of bedforms and sedimentation-and-erosion patterns, and allow continuous improvement of the seabed-sediments maps. All information will become available from the TNO website <http://dinoloket.nitg.tno.nl/>

One of the tasks of TNO Netherlands Institute for Applied Geosciences, business unit Geology, is applied research and geo-advice with respect to geomarine data acquisition, mapping and coastal research. The activities focus on the sustainable management and use of the seabed and its shallow natural resources, as well as process-response relationships governing coastal systems in low-lying coastal areas. As part of the activities, a reconnaissance mapping programme at a scale of 1:250,000 is carried out in the Dutch North Sea sector. One of the products is a map with seabed deposits.

The HO has been surveying the bathymetry of the Dutch part of the North Sea every 10 years for up-to-date navigation charts, and uses only the data important for safe navigation. TNO has compiled all measured points into a very detailed, full-coverage bathymetric map revealing seabed features that were previously unknown.

With a bird's-eye view of the map, the Dutch sector can be divided into several areas with different seabed features. One of the most striking is the extensive sand-wave field. In the south, sand waves with amplitudes between 4 and 6 metres cover the entire area. All the way in the south-west, the sand waves have amplitudes up to 13 metres. The sand-wave field extends to about 53° 10' N and bends from there to the north-east where it becomes patchy.

Calculating Seabed Dynamics

In the past year, a new method has been developed for automated analysis of sand waves from both single-beam and multi-beam echosounding data. The method comprises the following steps:

1. Gridding the raw data: for this, a Java application was written especially to deal with the large data files; the grid program comprises three algorithms for different grids: average, median and kriged grids. The application also provides an error analysis, by comparing the re-sampled grids to the original data, in order to assess the accuracy of the grids.
2. Calculating the general migration direction and distance, using cross-correlation analyses in Matlab.
3. Analysing the signal (currently one-dimensional), using an attuned Fourier analysis in Matlab. By separating and filtering out the megaripple signal from the sand-wave signal, the crest, trough and inflection points can be determined uniformly and consistently.
4. Calculating the morphological and morphodynamic parameters based on the crest and trough points; for example, the length, height and asymmetry of the sand waves, and their change in length, height, asymmetry and migration speed, respectively.

Preliminary results suggest that sand waves do not always migrate in a direction normal to the sand-wave crest, which, until now, was the assumption of marine geologists and modellers. In addition, sand-wave migration rates in the North Sea are highly variable. Presently, the method is being extended to a two-dimensional analysis. The detailed results of the sand-wave morphology will be useful in guiding sand-mining activities in the North Sea and may be used for an updated morphological map of the North Sea bed. The new migration data also makes the assessment of the stability of different areas in the North Sea possible. Separation of the signals representing bedforms of different scales allows investigation of the behaviour of these different bedforms separately, which will give better insight in the relation between bedform evolution and hydrodynamic conditions [1].

Some Striking Seabed Features

Apart from the well-known Zeeland Ridges such as Schouwenbank, between 52° 20' N and 53° 20' N, a large number of linear ridges with north-south to north-north-east running crests occur. The Brown Bank, in the west, is the most striking of these ridges. This bank has an amplitude of more than 20 metres, and on both sides the seabed is deeply scoured by tidal currents. Little is known about the

smaller banks east of the Brown Bank. The detailed bathymetry, however, reveals similar depressions, but less deep, alongside those ridges. This consistent pattern points to stability of the ridges for a certain time. Borehole and seismic data indicate that the Brown Bank has been stable for a very long period. Its core consists of clay deposited during the last glaciation, and is eroded on both sides of the ridge.

At the median line between the UK and Dutch sectors, two elongated depressions occur at 54° N. The Botney Cut is a 20-metre-deep south-east running depression, and an unnamed one extends in a north-easterly direction. Both valleys are partly filled with fine muddy sand and mud. The depressions form the continuation of the east-west running Outer Silver Pit in the UK sector. Both valleys were formed during the last glaciation when British land ice reached as far east as about the 4° E meridian in the Dutch sector. Below the eastward moving ice mass, melt-water rivers eroded channels into the underlying land. From seismic surveys it is known that, locally, the base of the valleys occurs at a depth of more than 80 metres below sea level. After the land ice had receded, the scoured channels were kept partly open by tidal currents.

Between the valleys, south of the Cleaver Bank, a large gravelly area is present. This gravel field was discovered by studying side-scan sonar images. The tidal current in this area ranges between 0.25 and 0.4 metres per second, with a north-west/south-east direction (80°–120° and 260°–295°). The gravelly subsurface in this region is covered with “sand ribbons”™. These are elongated sand bodies, several decimetres high and ranging in width from 30 to 150 metres. Their axes run approximately north-west to south-east, in the direction of the current. The sections between the sand ribbons contain gravelly current ripples measuring about 15 centimetres in height. These ripples run more or less along a north-easterly to south-westerly axis and have a wavelength of about 1 metre.

The gravel was deposited by the land ice as an end moraine. The ice mass initially covered the entire area; underneath the ice, gravel, sand and clay were crushed into a mixture called boulder clay. Later, the ice receded before advancing once again, thus pushing up the boulder clay into up to 12-metre-high knobs. During a subsequent standstill in the advance of the ice, the melt water deposited a mixture of coarse sand and gravel on top of and in between the ice-pushed knobs.

In the northernmost part of the Dutch sector, pockmarks were recently discovered. During the reconnaissance mapping of the northernmost part of the Dutch sector, evidence of the presence of pockmarks was initially discovered on side-scan sonar images of the HO and on 3.5-kHz seismic records. Similar features were first reported by King and MacLean in 1970 [2], and by McQuillin and Fannin in 1979 [3].

These crater-like features in the seabed are marked by a rimmed circular depression with a diameter between 10 and 300 metres, and are formed in this area by the sudden release of gas that migrates upwards along faults from the deep gas fields in the subsurface. During a detailed study of the pockmarks, gas plumes were observed in the water column.

Final Remark

All features described were found and explained by combining a vast and improving hydrographic database with steadily increasing geological knowledge, leading to a better understanding of both seabed behaviour and composition.

References

[1] For more information contact thaienne.vandijk@tno.nl.

[2] King, L.H., MacLean, B., 1970. Pockmarks on the Scotian Shelf. Geological Society of America Bulletin 81, 3141-3148.

[3] McQuillin, R., Fannin, N.T.G., 1979. Explaining the North Sea floor. New Scientist 1163, 90-92.