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NATURAL ENVIRONMENT RESEARCH COUNCIL

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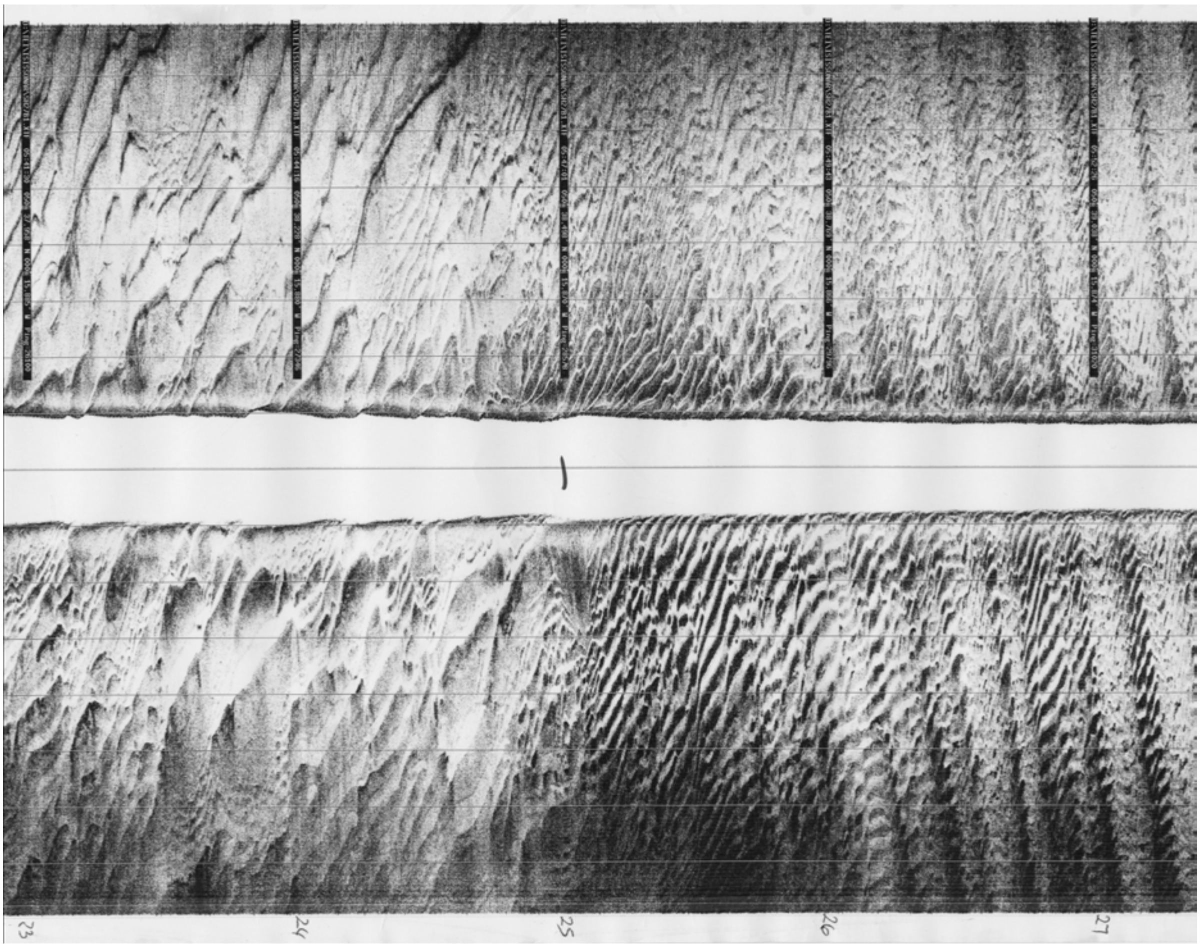
Commissioned Report CR/01/60



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Marine habitats off Shoreham, eastern English Channel: A geological perspective.

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A report prepared for the Office of the Deputy Prime Minister under Contract No. MP0675

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Cover Illustration. Sidescan sonar record of sand waves and megaripple trains.

Keyworth, Nottingham, British Geological Survey, 2002

FIGURES

1 Introduction

The mapping of marine habitats will be an important requirement in the development of UK marine environmental policy. This will demand a systematic approach to the description and identification of ecosystems based on a number of characteristics including physical, chemical and biological attributes. Such an approach is being advanced with the development of marine habitat classifications and their implementation in mapping marine habitats in the coastal, shelf and ocean environment.

A report recently completed by the British Geological Survey (James, 2002) identified and briefly described a number of marine habitat classification systems and examples of marine habitat mapping from the U.K. and overseas. The report also examined the use and application of geological data, maps and interpretation to the assessment and mapping of marine habitats. It was evident that geological and sediment data plays a very important role as a primary building block for habitat classification.

One of the conclusions of the report was that geologists, biologists and ecologists in the U.K. should undertake co-operative research into the methodologies of surveying, sampling and interpreting marine habitats, and the value and use of geological data in the mapping of marine habitats in the U.K. This current report is a small step towards meeting these aims.

CEFAS are currently completing a DEFRA funded project (AE0908) “Mapping of gravel biotopes and an examination of the factors controlling the distribution, type and diversity of their biological communities” (Brown and others, 2001). One of the objectives of the CEFAS research is to assess the utility of sea bed mapping techniques. Four areas have been surveyed between the Isle of Wight and Dungeness (Figure 1). The survey methods adopted include

- Side scan
- QTC-VIEW (Acoustic ground discrimination system)
- Video
- Grab and trawl sampling

The British Geological Survey (BGS) have seismic reflection, side scan and sample data in this part of the English Channel and have produced geological maps at 1:250,000 scale covering the area. The availability of biological and geological data at a reasonable scale in this area was an opportunity to test the value and practicality of integrating geological and biological interpretations. Because of funding and time constraints only the main survey area of the CEFAS project has been studied for this report. The main survey area is a 28 km x 12 km box to the south of Shoreham, Sussex (Figure 1).

The aims of this report are

- Produce a sea bed facies map of the main survey area off Shoreham.
- Describe the sea bed facies, bedforms and geology, and the utility of integrating biotope and geological interpretations. Also, if practicable, produce a combined biotope and sea bed facies map.
- Assess if results from this project have any implications for habitat mapping methodologies which may be adopted elsewhere in the UK.

2 Survey and data interpretation

CEFAS undertook a side scan sonar survey of the main survey area in 1999 (Figure 5). This provided almost total sidescan cover of the Shoreham Box. The survey was conducted with a Datasonics digital chirps sidescan. The analogue paper side scan records were made available to BGS and these have been used in conjunction with BGS side scan records to interpret the sea bed facies.

Six BGS boomer seismic reflection lines cross the survey area in N-S and E-W directions and these have been utilised in assessing sediment thickness and the structure of the rock and sediment underlying the sea bed. CEFAS sea bed video recordings and the results of grab and beam trawl sampling were also made available to BGS. The QTC-VIEW data was not assessed by BGS.

In order to integrate the BGS seismic reflection line data and CEFAS sidescan data the CEFAS analogue sidescan paper records were re-numbered for each line and the fix points annotated with new numbers to make them compatible with the BGS UK seismic record database. The two datasets were plotted together (Figure 5) to enable an integrated interpretation of the sea bed facies (Figure 6). The location of CEFAS sampling and video surveys were also loaded into the BGS offshore database for plotting (Figure 7) and comparison with the facies interpretation.

The method adopted by BGS to interpret the sidescan data is to examine each individual paper record and note the bedforms and physical sea bed features such as sand waves, megaripples, rock outcrops and breaks of slope, and plot and annotate these on a track map. This annotated track map forms the basis for the completed sea bed facies map (Figure 6). Sidescan mosaics were not used in the BGS interpretation because they do not show the cross profile of the sea bed, they simply show a 'picture' of the sea bed with the cross profile electronically removed. The cross profile of the sea bed is visible on the sidescan paper record (Figure 12) and enables the structure and profile of features such as sand waves and scarps to be compared with the cross profile on seismic reflection records (Figure 13). This can indicate whether there are any geological features such as bedding and folding controlling the form of morphological features at the sea bed, such as scarps and depressions.

Seismic reflection records, for example Figures 13, 14 & 17, also indicate the thickness and extent of superficial deposits and the form and depth of palaeochannels which may be major sources of marine aggregate. Palaeochannels are an important feature within the survey area and these have been mapped during investigations by marine aggregate companies (United Marine Dredging, Hanson Aggregates Marine and South Coast Shipping). Their interpretation of the extent and thickness of the infill within these palaeochannels has been made available to BGS for inclusion in this report and is shown in Figure 10.

3 Location and morphology

The Shoreham Box lies on the northern margin of the English Channel (Figure 2). It covers the relatively shallow coastal platform, which declines gently across 10 to 15 km of sea bed from a depth of just less than 10 m in the north west corner of the area to a depth of 30 to 35 m (Figure 8). At this depth there is an abrupt break of slope down to a narrow step at about 45 m, before another break of slope down to 60 m. The composite slope is <2 to 3 km wide and occurs on the northern margin of the Northern Palaeovalley, a major open depression within this sector of the English Channel (Figure 2). There is an extensive complex of filled palaeochannels and open palaeovalleys within the English Channel (Figure 3) and these have a considerable influence on sea bed morphology and the distribution of rock and sediment at the sea bed and the associated distribution of marine habitats.

The Shoreham Box can therefore be separated into three principal morphological areas

- Coastal platform
- Palaeovalley margin
- Palaeovalley floor

4 Sea bed facies

The sea bed facies interpretation from the sidescan data divided the sea bed into seven areas with distinctive primary facies (Figure 6). Six of the areas are natural occurrences with the seventh formed as a result of dredging. Three, including the dredged area, occur primarily on the coastal platform, two on the Palaeovalley margin and two within the floor of the Palaeovalley.

4.1 Gravel – Coastal Platform

This is the most extensive facies within the Shoreham Box. It dominates the western half of the coastal platform and extends across the northern limit of the area. On sidescan records its reflectivity appears as a characteristic dark monotone alleviated by intermittent sand streaks and thin sand ribbons aligned in an east-north-east to west-south-west direction parallel to direction of the peak tidal current flows (Figure 15). Breaks of slope and associated depressions commonly include areas of megaripples and megaripple trains (Figure 16). Video and grab evidence (Figure 21) indicates a predominantly gravel substrate which is poorly sorted with angular cobbles especially at the northern end of the platform.

4.2 Megaripples

An extensive field of megaripples covers much of the eastern half of the coastal platform (Figure 6 & 12). These sandy bedforms are generally <1.5 m high with a wavelength generally <10 to 30 m. Their crestlines are predominantly aligned at right angles to the direction of peak tidal current and their wavelengths are relatively uniform over wide tracts of the field. At the western margin of the megaripple field windows of gravel appear through the sand and it may thin out to sand ribbons and sand patches. The megaripple field extends beyond the eastern margin of the box.

4.3 Megaripple trains

These are extensive areas of megaripples and small sand waves that are fashioned into parallel trains or lines of waveforms, which are distinguished by abrupt changes of wavelength between each train. These trains of sandy waveforms are aligned parallel to the peak tidal currents with the crest lines at very high or right angles to the peak currents. Their steep lee slopes face predominantly towards the east-north-east indicating net sand transport in this direction. The most extensive occurrence of megaripple trains is high on the eastern end of the Palaeovalley margin between the sand wave field and the megaripple field to the north (Figure 18).

4.4 Sand waves

The slope of the Palaeovalley margin is covered in part by a field of sand waves which is about 600 m wide at the western end of the margin. The field gradually widens to over 2000 m at its eastern end (Figure 6). This eastward increase in extent is also mirrored in an increased density of sand waves to the east (Figure 18). Sand wave heights generally range from 1.5 to 3 m although some reach 6 m. Wavelengths vary from 30 m to 300 m with lee slope directions facing east-north-east.

Seismic reflection data indicates that the sand wave field not only becomes more extensive to the east, but also the thickness of sand beneath the sand waves increases eastward from around 3 m to over 15 m. This is likely to be the result of the eastward migration of sand along the Palaeovalley margin in response to the strong tidal currents within the area. The margin would also form a natural barrier to the coastward migration of sand, creating a build-up of sand against the steep slope.

There is extensive megaripple development associated with the sand wave field especially in the western half of the field where the sand waves are more isolated. Also megaripples are commonly developed on the longer, shallower stoss slopes of the larger sand waves.

4.5 Sand wave and megaripple trains with gravel windows

These trains cover an area about 4 km wide across the palaeovalley floor (Figure 6). The area runs parallel to the palaeovalley margin. The trains comprise linear, parallel-sided trains of small sand waves and megaripples. Each train distinguished by variation in wavelength, crest orientation or height from its neighbour. Individual trains vary in width from <50 m to over 250 m and may coalesce and cover areas over 700 m wide. Linear parallel windows of gravel from a few metres to over 100 wide are common and the proportion of gravel to sand is higher in the western half of the area. The trains are aligned in an east-north-east direction parallel to the peak tidal current direction.

The trains are not all parallel sided and can have feather edges of patchy sand which melt into the surrounding gravel both at the lateral margins and their ends along the tidal current stream.

4.6 Gravel – Palaeovalley

The southern margin of the Shoreham Box (Figure 6) is characterised on sidescan records by the dark monotone reflectivity of a gravel substrate alleviated by the lighter tones of an occasional isolated sand wave, narrow sand ribbons, some of which can be traced for over 1500 m, sand streaks and small sand patches. The whole area is generally flat with some minor undulations. Video evidence suggests that the gravel is relatively well sorted pebble gravel (Figure 20) compared to the more poorly sorted pebble and angular cobble gravel in some areas of the coastal platform gravel (Figure 21).

4.7 Dredged area – Coastal Platform

An area 2500 by 1300 m has been dredged on a feature that forms slightly high ground on the eastern margin of the coastal platform (Figure 6). The area lies on the northern side of a well developed depression in the platform. This depression and the high ground are associated with an underlying channel infill system (Figure 10).

The area lies within the Owers Bank licensed dredging area and the gravel has been excavated using the anchor dredging method. This method is conducted by anchoring the dredger over the sea bed and extracting the gravel in a virtually stationary position. This creates a patchwork of extraction pits at the sea bed which gives a distinctive mottled tone on sidescan records (Figure 19). The pits may be up to 6 m deep and >50 m across.

Video evidence indicates the pits are floored by fine sediment, probably reworked from the aggregate deposit during the dredging process. It is also evident that mussels (probably *Mytilus edulis*) have settled and grown within the confines of these pits, although the extent to which the dredged area is colonised by mussels is difficult to ascertain from the video footage (Figure 22 & 23). Their location within the pits suggests they are probably a post-dredging feature and may have formed in this unique anthropogenic environment as a result of changes in the local environment, for example, protection from the stress of strong tidal currents and the deposition of fine sediment rather than current winnowed gravel on pit floors. The steep sided margins of the pits are characterised by relatively well-sorted pebble gravel (Figure 24) which is typical of the fluvial channel sediments deposited in the channel infill system (Figure 10).

5 CEFAS Biotopes

The following is a description of the biotopes derived by CEFAS from their investigations in the Shoreham Box. It is taken from Brown & others (2001) and the CEFAS text has been italicised. BGS comments on the biotopes and their relationship with the BGS sea bed facies interpretation is given in normal type. The relationship between the CEFAS and BGS interpretations is also shown graphically in Figure 11.

The derivation of biotopes was based on the statistical analysis and interpretation of the biological, video and geophysical data sets at each site. Where possible, both Hamon grab and beam trawl data were used to obtain a good cross section of the benthic assemblages from each physical habitat. However, it was not always possible to deploy the 2m beam trawl due to the uneven and rocky nature of the seabed in a number of the acoustic regions. It should, therefore, be noted that the biotopes derived from these regions may be missing important characterising species which are not frequently sampled by grabs (e.g. large or mobile epifaunal species). In some cases, the assemblages identified by one sampling method (e.g. grab) from an acoustic region were statistically distinct, but when sampled by a different method (e.g. trawl) were judged to be similar to assemblages from surrounding regions. Under such situations it was necessary to take account of all available data from the region (underwater video, AGDS) and make a subjective decision as to whether the region should be classed as a distinct biotope or not. Using all the available information it was therefore possible to identify discrete biotopes at each of the survey sites. A list of the biotopes identified is presented below.

***CEFAS Biotope SA/B** (Shoreham):- Echinoderm dominated (*Echinocyamus pusillus *and* Psammechinus miliaris*) gravelly sand with occasional sand veneers.*
Regions SA and SB at the Shoreham study site, whilst acoustically different, were very similar in terms of sediment characteristics and the benthic fauna. Particle size analysis revealed that both regions consisted of gravelly sands, with a high proportion of gravel on the seabed surface (determined from the video camera attached to the grab). Region SB differed due to the presence of sand veneers over parts of the area, but the presence of these veneers did not appear to have a major influence on community structure. Both regions could not be statistically separated in terms of community structure (using faunal category 1 from the Hamon grab data), and were characterised by high numbers of the echinoderms Echinocyamus pusillus *and* Psammechinus miliaris.

<u>BGS Comment</u> - Region SA equates to the Gravel – Palaeovalley facies whilst SB equates to the Sand wave and megaripple trains with gravel windows facies. There is reasonably good agreement between the mapped areas of both interpretations. However, CEFAS merged these regions because they could not be statistically separated in terms of community structure. From a facies perspective there is considerably more sand covering the sea bed in region SB, especially in the eastern half and there are distinctive bedforms which distinguish the two regions. Within region SB, which covers an area of about 48 km^2, there are seven sample stations, four of which are in the western half. It is therefore possible that benthic sampling may have preferentially sampled gravelly sediment rather than sandy sediment within this region.

Biotope SC *(Shoreham):- <u>Clean mobile sand with</u>* <u>Abra prismatica</u>*<u>.</u>*
Region SC at the Shoreham study site was characterised by moderately large sand waves. Transport features suggested that the region was mobile and unstable, and this was reflected in the low number of species and densities within the area. The main characterising species identified from the Hamon grab survey was Abra prismatica *and, despite an average abundance of only 1.2 individuals, it accounted for 49.5% of the similarity between samples collected from this region. The shrimp* Crangon allmani*, the polychaete* Ophiura albida *and hermit crab* Anapagurus laevis *were also identified as characterising species from the beam trawl survey.*

<u>BGS Comment</u> – Region SC lies within the Palaeovalley margin. BGS sub-divided this sandy biotope into two facies, sand waves and megaripple trains, based on their primary bedform (Figure 18). In terms of bedforms the areas are distinctive, however both are characterised by mobile sandy sediment with high current shear stresses acting on the sea bed. These environmental factors may be a greater feature in controlling the benthos rather than any major variations in the physical form of the sea bed.

Biotope SE *(Shoreham) - <u>mussel beds on mixed, heterogeneous sediments.</u>*
Although not present across the whole of acoustic region SE, and not identified as characterising species from the Hamon grab survey, the underwater drop camera revealed that large areas within this region were dominated by Mytilus edulis*. The Hamon grab survey failed to characterise the fauna and underlying sediments within these areas of dense mussel beds, and as a result they could only be described from the underwater video footage collected through deployment of the drop camera frame.*

<u>BGS Comment</u> – This is the dredged zone within the Owers Bank licence area. Although the dredged zone can be readily mapped using sidescan and its areal extent delimited, it is a difficult area to precisely sample because of its pitted hummocky nature. The video evidence suggests that it is not an area of completely heterogeneous sediment, it can be divided into pit floors where fine sediment is common (Figure 22 & 23), and pit walls comprised of pebble gravel (Figure 24).

Biotope SD/E *(Shoreham):- <u>Polychaete dominated mixed, heterogeneous sediments</u>.*
At the Shoreham study site, region SD and parts of region SE not covered by mussel beds consisted of very mixed, heterogeneous sediments and, although these regions appeared very different acoustically, they supported similar benthic communities. Both regions contained a large percentage of coarse sediments, and whilst the surface topography appeared very different between regions, particle size distributions were similar. Both regions had very high numbers of species and individuals, and were dominated by polychaetes such as Lumbrineris

gracilis *and Maldanid species, as well as a number of molluscan species. Particle size distributions were similar to those in regions SA and SB, but with a higher percentage of coarse material, and there were common, characterising species between all four of these regions (e.g*. Echinocyamus pusillus, Psammechinus miliaris, Lumbrineris gracilis*). However, differences in habitat and community structure were great enough to distinguish between biotope SA/B and SD/E.*

BGS Comment – Region SE, which is the dredged area, is distinctive enough in terms of its physical form to be distinguished from region SD. The mapped area of region SE should therefore be confined to the dredged area. The fact that grab samples from region SE were not statistically different and indeed were very similar to region SD can be explained by the failure of the grab survey, owing to the random positioning of the grab sample sites, to adequately sample the regions of mussels or the base of the pits within the dredged area. Clearly, based on underwater video evidence, sediments and benthic assemblages within parts of region SE were very different from region SD (Figure 21 – 24).

Region SD lies within what BGS has defined as Gravel – Coastal platform. BGS data confirms there is a higher percentage of coarse cobble gravel on the coastal platform than on the palaeovalley floor. The palaeovalley floor gravel is in deeper water, probably older, and been abraded, sorted and reworked by currents and other forces over a longer period of time to produce a predominantly well-sorted pebble gravel (Figure 20). These gross variations in gravel particle size are additional evidence to confirm the differences in habitat and community structure noted by CEFAS between the palaeovalley floor gravel (Biotope SA/B) and coastal platform gravel (Biotope SD & SH).

Biotope SH *(Shoreham):-* *Cobbles with algae (unidentified), and* Crepidula fornicata. *Underwater video at the Shoreham site revealed that region SH was very distinct from other regions. The substrate within the region was very coarse, consisting of a high percentage of cobbles and gravel supporting a large number of epifauna and flora (algal species were abundant within the region but were not identified or quantified). The region supported very high numbers of* Crepidula fornicata*, which was identified as the main characterising species from both the beam trawl and Hamon grab surveys. Other characterising species included* Scalibregma inflatum, Lumbrineris gracilis*, and* Ascidiella scabra*.*

Region SH/F (Shoreham) did not appear to be a distinct region. Problems were encountered identifying the boundaries of the region from the sidescan sonar record, and the region appeared to form a transition between regions SH and SF. For this reason the area has not been identified as a separate biotope, and has been treated as a zone of transition between the two neighbouring regions.

BGS Comment –Much of region SH is not covered by the sidescan survey (Figure 5 & 11) and therefore has not been fully included in the sea bed facies interpretation (Figure 6). It is also an area with a paucity of sample and video stations. That part of the area covered by sidescan does not show any marked change in reflectivity from the gravel substrate which has been interpreted as gravel – coastal platform. The frequency of the sidescan signal may not be able to distinguish variations in gravel size, especially on a relatively flat sea bed. However, this does not nullify the value of distinguishing region SH. The very coarse nature of the substrate is a significant variable in terms of facies, although a denser grid of video and sample sites would be required to confirm its nature. In this area of the English Channel with Chalk exposed on the coast, there is evidence of coarsening of gravel from the offshore towards the coast, with cobbles and boulders becoming more abundant. Coastal erosion and retreat has fed coarse sediment into the nearshore and the primary source, in this area, are flint gravel liberated from the Chalk. The northern limit of the Shoreham Box is underlain by Chalk for about two to three kilometres and this will account for the cobble and probably boulder gravel covering this area of the sea bed. The limited video coverage suggests that region SH may have a high abundance of algal species that would distinguish it within the gravel - coastal platform. Further sampling in shallower water and on a tighter grid is required to confirm the interpretation and extent of biotope SH and the transition between SH and SF.

Biotope SF *(Shoreham):-* *Sand and gravelly sand* with Ophelia borealis, Bathyporeia sp. *and* Pomatoschistus minutus.
The seabed surface within region SF at Shoreham was predominantly rippled sand, which was clearly identified from the acoustic record and underwater video/photography. Particle size analysis revealed that the region contained a higher percentage of coarse material than initially expected and, as a result, the particle size distribution of sediments within this region was not statistically distinct from most other regions. However, the surface material appeared to be predominantly sandy, and this was reflected in the characterising fauna, Ophelia borealis, Bathyporeia sp. and Pomatoschistus minutus*, all of which prefer sandy substrates.*

BGS Comment – Region SF equates to megaripples – coastal platform facies although the sea bed facies interpretation has delineated a smaller area than outlined for region SF (Figure 11 & 25). The BGS sidescan interpretation suggests that the megaripple field does not extend northwards into water shallower than about 17 m and the northern part of the region covered by sidescan interpretation is gravel covered. The higher percentage of coarse material sampled by CEFAS may be explained by some of the stations possibly not being positioned on megarippled sand but on gravel or sandy gravel. There may also be a higher percentage of shell material in the samples which could skew the results to a coarser fraction. The fact that the characterising fauna prefer sandy substrates is a confirmation of the interpretation of a sandy facies.

6 Controls and influences on the distribution of sea bed facies and biotopes (by proxy)

There appears to be a reasonable gross correlation between the distribution of sea bed facies interpreted by BGS and the biotope regions of CEFAS (Figure 11). These results suggest that a primary influence on biotope distribution is the nature of the unconsolidated sediments at the sea bed surface in terms of their texture and bedform. However, how much is this conclusion predicated by the fact that the sampling programme and statistical analysis of benthos is based primarily on the sea bed facies distribution? What if the sampling programme and statistical analysis were based on other geologically based elements such as solid geology or Quaternary geology or other criteria such as bed shear stress or sea bed morphology. Would the resulting biotope map be radically different from Figure 11?

6.1 Solid Geology

The solid geology of the area (Figure 9) is varied in terms of its lithology and structure and from a geological perspective these variations could be significant in terms of biotopes. It comprises a narrow strip of Cretaceous **Upper Chalk** in the north overlain unconformably by Tertiary sediments of the **Lambeth Group (Woolwich and Reading Beds), London Clay** and **Poole Formation** and **Barton Clay**. Structurally the regional dip of these rocks is to the south (Figure 4). This gentle dip is disturbed by flexuring which form minor east-west trending synclinal and anticlinal folds. These folds in the Tertiary sediments are well seen in the boomer seismic records and they are relatively steeply dipping in some parts of the area (Figure 13, 14 & 17).

The contrast between hard and soft bedded rocks within the Tertiary sediments form small scale scarp features on the sea bed which are well illustrated in Figure 13. These indicate that the veneer of sea bed sediment is very thin and the morphology of the sea bed in this area, even on a very minor scale, is controlled by the underlying solid geology. The solid geology also controls some of the larger scale morphological features at the sea bed. Figure 14 shows relatively soft rock within the core of an anticline forming a depression up to 5 m deep with a resistant band of rock forming a steep margin. These depressions form enclosed environments for the development of megaripples and small sand waves (Figure 16). The Palaeovalley margin is also associated in part with a major structural feature. Figure 17 shows the margin on the southern limb of a major anticline with sand banked against it. A case of simple morphology controlling the distribution of sea bed facies.

Lithologically the **Upper Chalk** typically consists of thickly bedded, white limestone with common flints and nodular bands and marls. The solubility of chalk means that only the flints and some nodules are the product of the erosion of chalk. Flint gravel veneers are likely to dominate the sea bed underlain by Chalk.

The **Woolwich and Reading Beds** mainly comprise red and grey mottled silty clays with sandy intercalations. A bed of partly worn flints commonly occurs at their base.

The **London Clay** consists predominantly of medium to dark grey, pyrite-rich clays which also commonly have a pebble bed at the base.

The **Poole Formation** are a highly fossiliferous unit of clays and marine sands.

There is therefore a significant variation in lithology within and between these rocks, in terms of grain size, petrology, density and chemistry. These variations could have a significant effect on biotopes, influencing both the infaunal and epifaunal assemblage composition. Some of these rocks may be soft enough for burrowing organisms to colonise. This significance could be tested with a sampling strategy and statistical analysis based in part on the distribution of the solid geology formations. The relationship between these rocks and the nature of the unconsolidated sediments which overlie them could also be investigated. For example, is the gravel overlying the Chalk significantly different from the gravel overlying the London Clay. If so, how does this affect the biotopes?

6.2 Quaternary Geology

Superimposed on to the solid geology within the Shoreham Box are a series of unconsolidated Quaternary sediments principally infilling incised channels into the solid geology (Figure 10 & 13). These channel infills are the primary source of aggregate within this area and therefore it is important to ascertain whether these have an influence on biotope distribution.

In the English Channel a considerable period of time elapsed between the deposition of the Tertiary sediments and the onset of Quaternary sedimentation. Compared to the Tertiary sediments and Chalk the Quaternary sediments are limited in volume and extent, being mainly confined to channel infill and a thin veneer of sea bed sediments. During the Quaternary a number of glacial and interglacial periods occurred within which sea level rose and fell. In times of low sea level the area was subject to subareal erosion and river systems developed across the emerged sea bed. Subsequent sea level rise infilled, modified and planed these river systems.

Offshore across southern England palaeovalleys can be traced in a number of localities back to rivers which currently flow into the English Channel (Figure 3). In the area between Beachy Head and Selsey Bill the link between onshore rivers and offshore palaeovalleys can be detected. The courses of the rivers Arun, Adur and Ouse can be traced offshore (Hamblin and others, 1992; Bellamy, 1995). Cores within these palaeovalleys west of Beachy Head proved soft, grey clays, silts and sands and included scattered pebbles, shells, organics and a peat band. These are soft sediments which would be easily eroded by strong current action. Palaeovalleys in the area have been mapped with infill sediments up to 20 m thick.

The bulk of Quaternary sedimentation on the sea bed is predominantly a veneer of coarse lag deposit generally less than 0.5 m thick. This lag may be locally overlain by a suite of finer grained material, mainly sands. The lag deposit generally comprises gravel, sandy gravel and gravelly sand, the finer fractions having been winnowed out during the rise in sea level at the end of the last glaciation and associated high-velocity currents. Where the lag comprises gravels and sandy gravels the sand fraction is generally coarse grained.

Within the lag gravel clasts are dominated by flints; these include fresh, almost unworn flints derived from the Chalk and brown, worn flints reworked from the erosion of Tertiary gravels. Both varieties are thought to be derived by sea bed or cliff erosion during marine transgression or fluvial transport during sea level falls. Hamblin & Harrison (1989) record that 80% of the gravel fraction overlying the Chalk outcrop off Beachy Head is flint.

The dredged area (biotope SE) lies within a Quaternary channel infill. Dredging in this environment appears to have had an effect on the biotope although CEFAS analysis of grab samples from the dredged area (biotope SE) and the adjacent biotope SD showed they were not statistically different. However the question remains: Is there any variation in biotopes between undredged sea bed lying on channel infill and adjacent sea bed lying on solid geology? This could be tested with a sampling strategy and statistical analysis based in part on the distribution of channel infill and surrounding solid geology outcrops. The results could be significant in terms of aggregate extraction policy if the channel infill areas were proven either to support a unique biotope compared to the areas between these channels or not.

6.3 Currents

What influence does the current regime within the area have on biotopes? It’s simple to draw the relationship between currents and their influence in fashioning bedforms and then to biotopes. Is there a relationship between bed shear stress and distribution of biotopes on gravel substrates? The example of the dredged area (biotope SE) where the floor of the pits appear to be protected from the stress of current shear suggests this can occur.

7 Sampling

The biological and ground truthing surveys undertaken by CEFAS were structured around their interpretation of the sidescan survey and the identification of acoustically distinct regions. These were the precursor to the biotope regions mapped by CEFAS (Figure 11)(Brown and others, 2001) The main sampling tool deployed by CEFAS was a 0.1m^2 Hamon grab fitted with a video camera and light. Sampling stations were randomly positioned within each acoustic region and the number of stations within each region was linked to the size of the area (Figure 6 & 11). A modified 2m beam trawl was also deployed at a number of sites and towed over a fixed distance of about 120 m across the sea bed to characterise the larger and mobile epifaunal species. However, CEFAS found it was not always possible to deploy the beam trawl because of the rocky and uneven nature of the sea bed in a number of areas. They note in their report that the lack of beam trawl data means that characterising species which cannot be sampled by grabs, such as large or mobile epifauna, may be missing from the interpreted biotope assemblage. They also noted that in some cases the assemblages derived from each sampling method, whether grab or trawl, did not always fall within the same biotope region when analysed statistically.

CEFAS are undertaking a review of sampling methodologies to which BGS has contributed (James & Limpenny, 2001), it includes techniques which complement the methods currently implemented. For example, grabs with relatively large footprints are available, such as the hydraulic clamshell grab which is the standard sea bed sampling tool adopted by the aggregate industry. Sampling methods adopted should be designed to produce representative samples of the benthos and sediment for each mapped facies and biotope irrespective of the criteria on which they are interpreted whether it is bedform, sediment texture, morphology or lithology. Visual examination through video and cameras should also be a primary investigation method. It is therefore recommended that a range of sampling techniques are employed in order to sample all relevant components of the seabed biology and geology.

Sampling programmes should be based on a thorough interpretation of the sidescan and seismic reflection surveys before sampling surveys begin so that all sea bed facies, morphology, Quaternary geology and solid geology features are covered in the subsequent analysis.

8 Conclusions

- There is evidence for a significant relationship between biotopes and sea bed facies with characteristic benthos associated with mapped areas of sea bed facies. The evidence is derived from a strategy based on the sampling and analysis of acoustically distinct regions identified from the interpretation of sidescan sonar. Other geophysical techniques or geological criteria were not utilised in the CEFAS investigation.

- There is evidence for a relationship between sediment distribution and geological structure in terms of folding, bedding and differential erosion controlling sea bed facies.

- The evidence for a relationship between solid geology and biotopes is not conclusive although the variety of rock type within the area suggests there could be a relationship. A sampling and analysis programme based on the distribution of the solid geology is required to test the relationship. A first step could be to analyse statistically the available benthos samples in areas of gravel cover using the solid geology boundaries as constraints. Its utility would depend on the number of samples available.

- The evidence for a relationship between channel infill sea bed sediments and biotopes has not been tested. This requires a sampling and analysis programme to compare channel infill sea bed sediments with adjacent non-infill sea bed sediments. A first step could be to analyse statistically the available benthos samples in areas of gravel cover using the channel infill boundaries as constraints. Its utility would depend on the number of samples available.

- It is important to run seismic reflection surveys as well as sidescan in areas of diverse sub-sea bed geology. It is only seismic reflection surveys that can indicate the extent of channel infills and the nature of the geology beneath the sea bed.

- Sampling programmes should be based on a thorough interpretation of the sidescan and seismic reflection surveys before sampling surveys begin so that the diversity of features that may control the distribution of biota, including sea bed facies, morphology, Quaternary geology and solid geology, are covered in the subsequent analysis.

- Sampling methods adopted should be designed to produce representative samples of the benthos and sediment for each mapped facies and biotope irrespective of the criteria on which they are interpreted whether it is bedform, sediment texture, morphology or lithology. Visual examination through video and cameras should also be a primary investigation method.

- The analysis and conclusions from marine habitat investigations should not be predicated by a sampling and survey strategy based primarily on one or two methods and the mapping and interpretation of one physical criteria such as the distribution of unconsolidated sediment at the sea bed. The use of a range of sampling and acoustic techniques to sample as many components of the seabed environment as possible provides a more accurate and robust interpretation of seabed habitats and assemblages.

- There is a growing demand for marine habitat mapping on a regional scale to address issues driven by legislation such as the EU Strategic Environmental Assessment Directive and Habitats Directive and developments in the marine environment such as wind farms and marine aggregates. The current project on the Shoreham Box has indicated there is value in integrating geological and biological data on a local scale. It would be pertinent to extend this type of analysis to a regional scale, utilising published BGS mapping and geological data allied to biological data. This approach will require the gathering of new geophysical and sample data for ground truthing. An area where this could be tested is in the Eastern English Channel, which is a prospective locality for marine aggregate extraction. It might also be pertinent to undertake a regional scale habitat mapping project in this area as a collaborative venture with the French to include their knowledge and data and also utilise available European funding.

9 Acknowledgements

Collection and interpretation of sidescan sonar and benthic samples by CEFAS was funded by DEFRA under project AE0908.

The channel infill interpretation, which comprises figure 10 of the report, was provided by United Marine Dredging Ltd, Hanson Aggregates Marine Ltd and South Coast Shipping Company.

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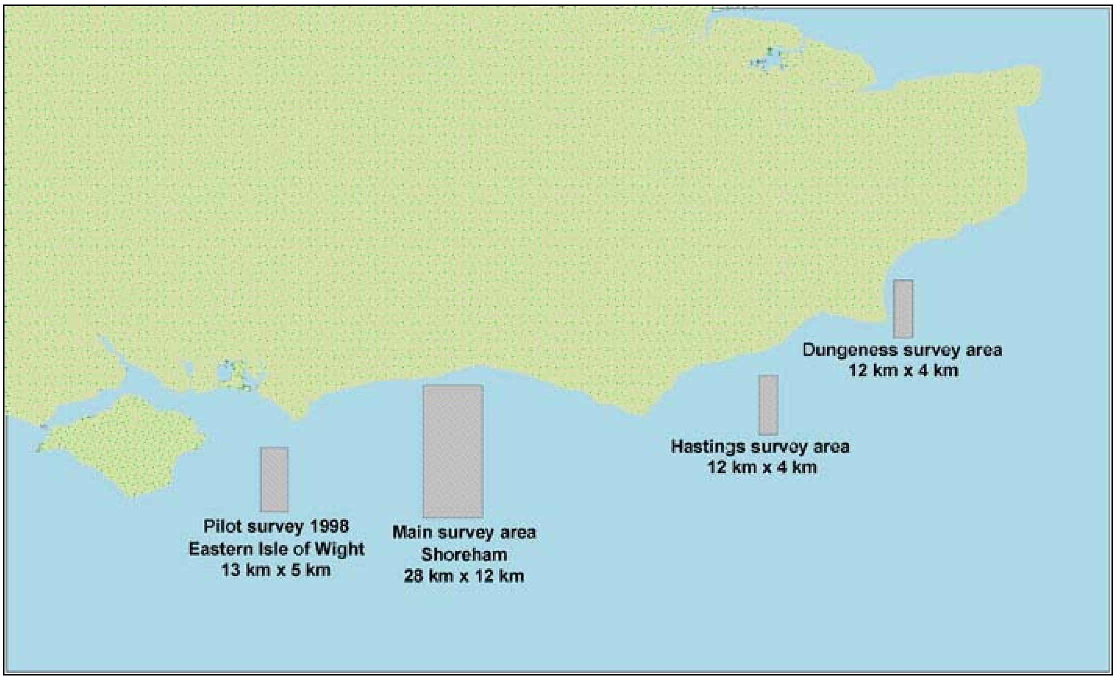

Figure 1 Survey areas for CEFAS Project A0908, eastern English Channel. (From Brown, 2000)

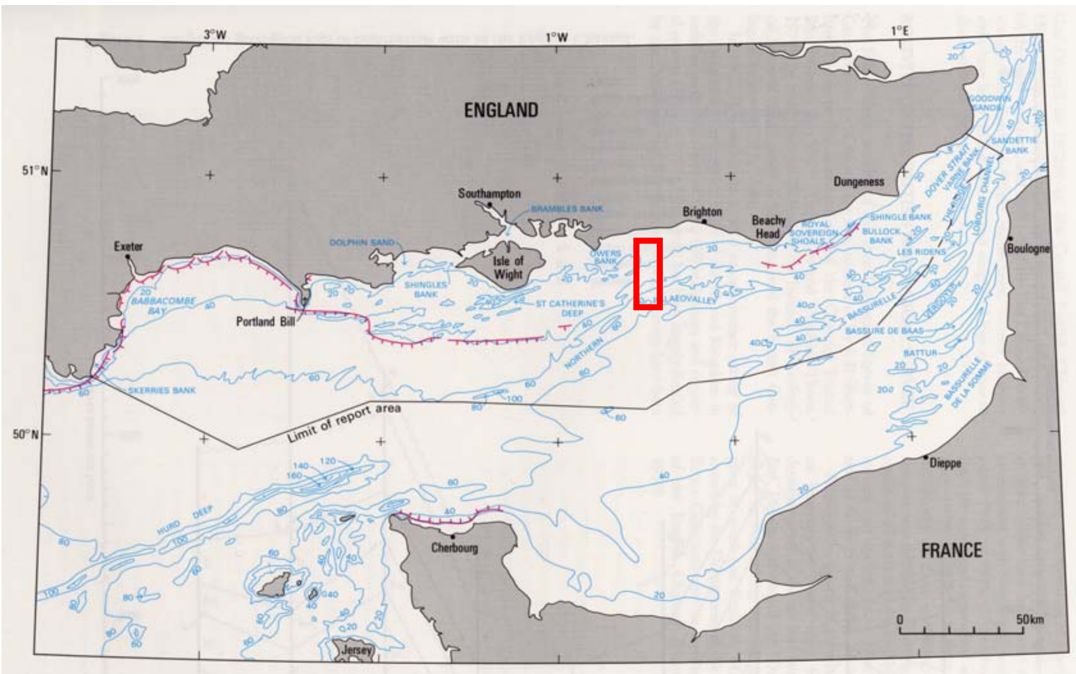

Figure 2 Bathymetry of the English Channel region (from Hamblin and others, 1992) Outline of Shoreham Box in red

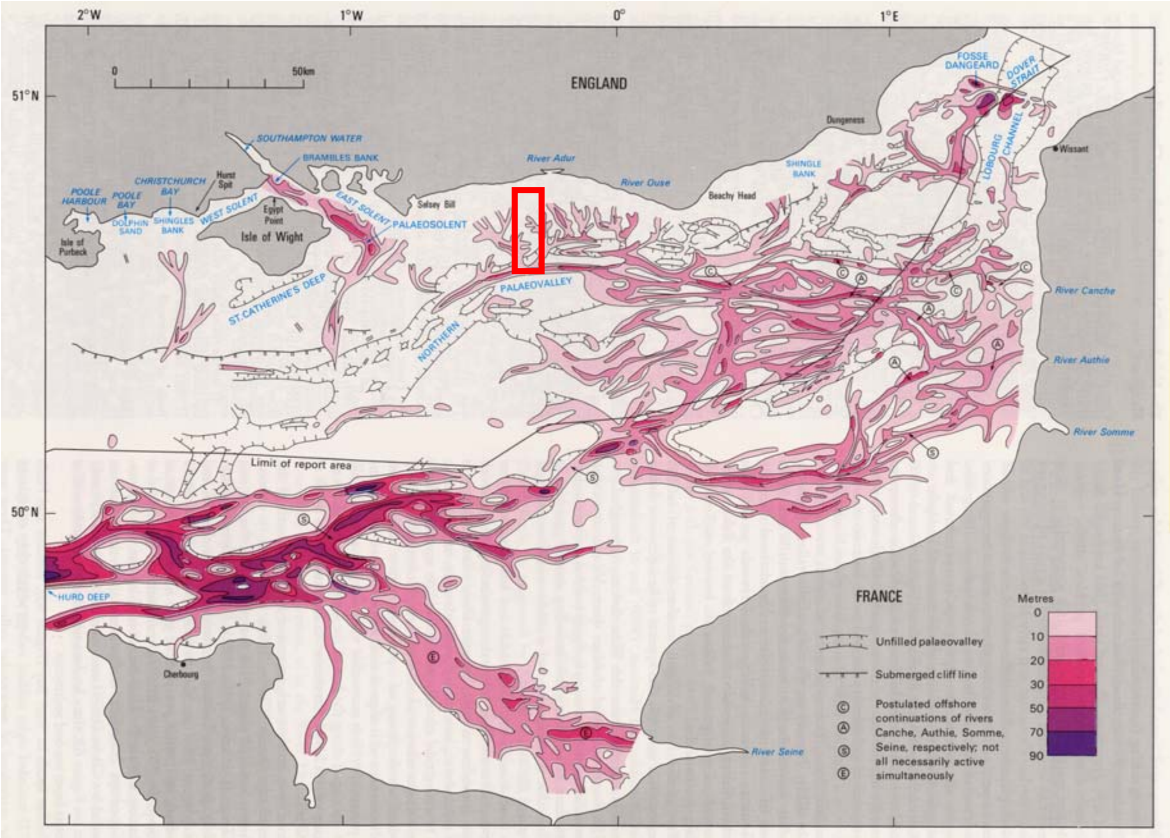

Figure 3 Palaeovalleys and thickness of infilling sediment in the English Channel region (from Hamblin and others, 1992) Outline of Shoreham Box in red

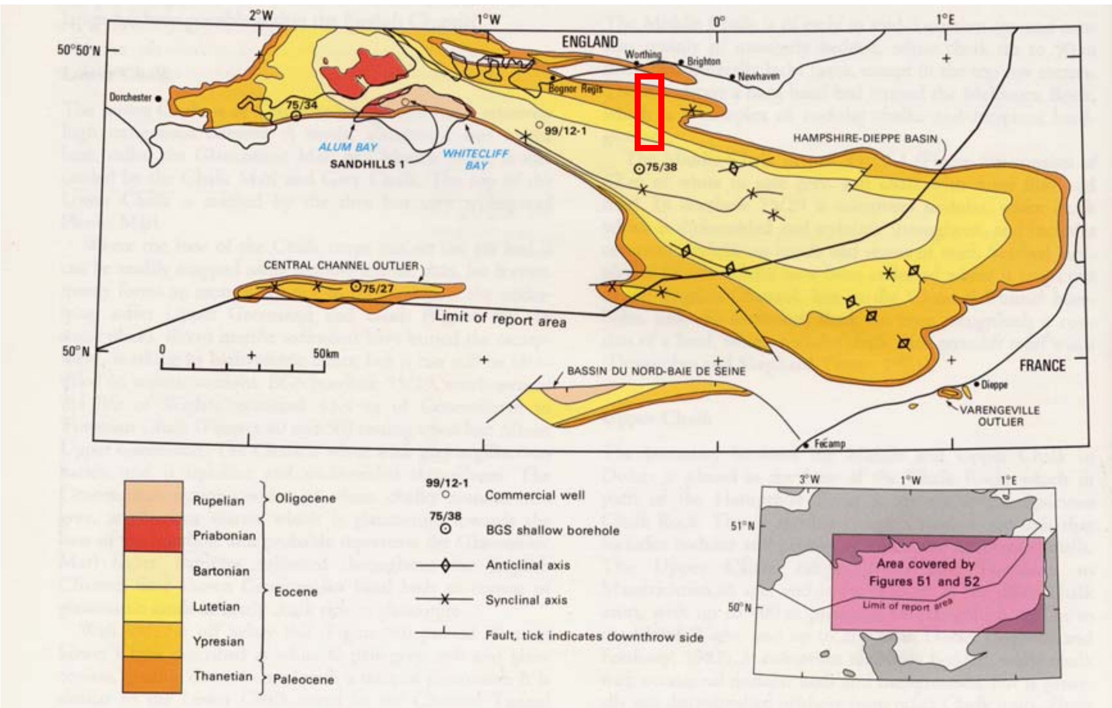

Figure 4 The distribution of Tertiary sediment in the English Channel region (from Hamblin and others, 1992) Outline of Shoreham Box in red

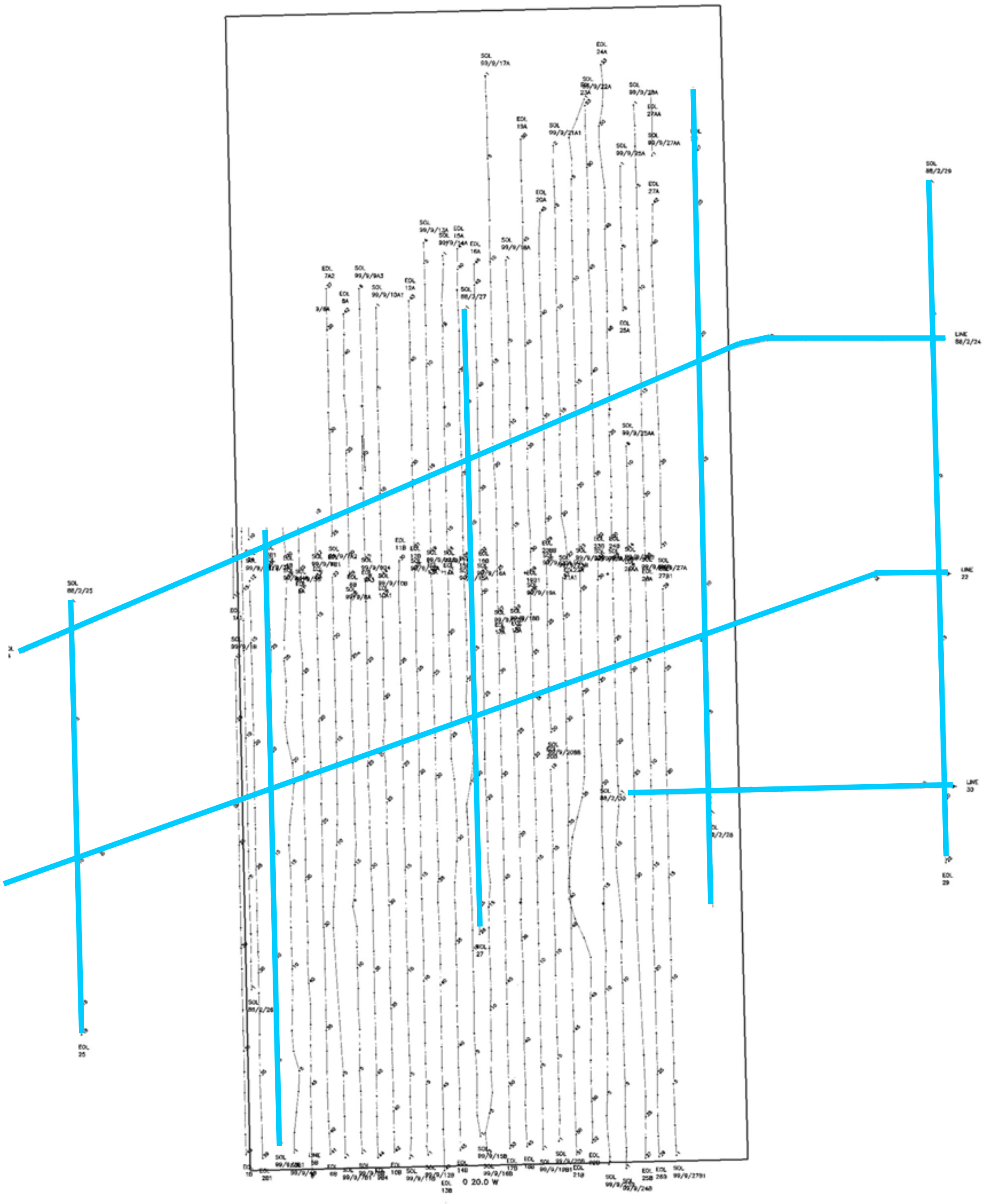

Figure 5 CEFAS sidescan and BGS seismic reflection survey tracks (highlighted in blue)

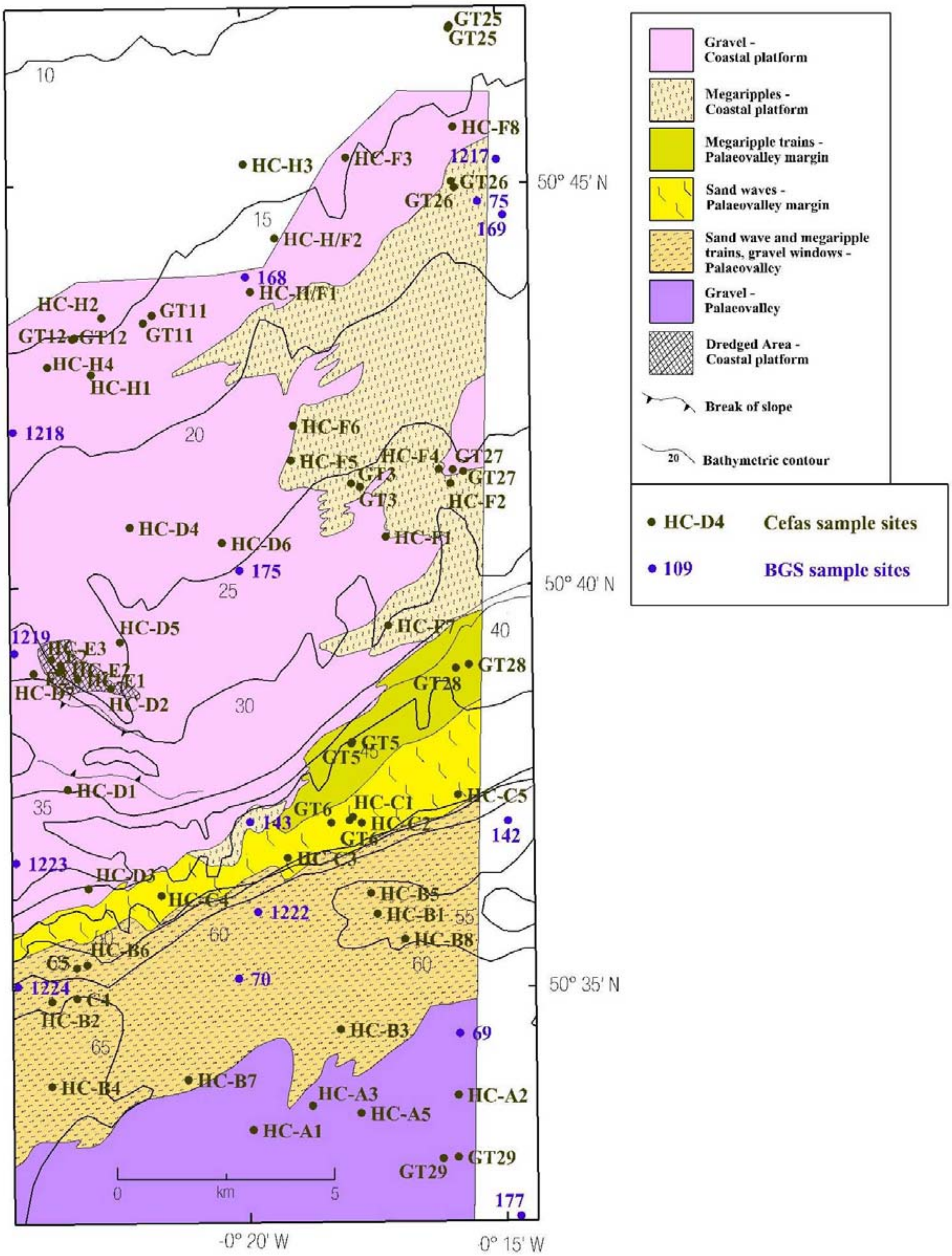

Figure 6 BGS interpretation of sea bed facies with sample sites

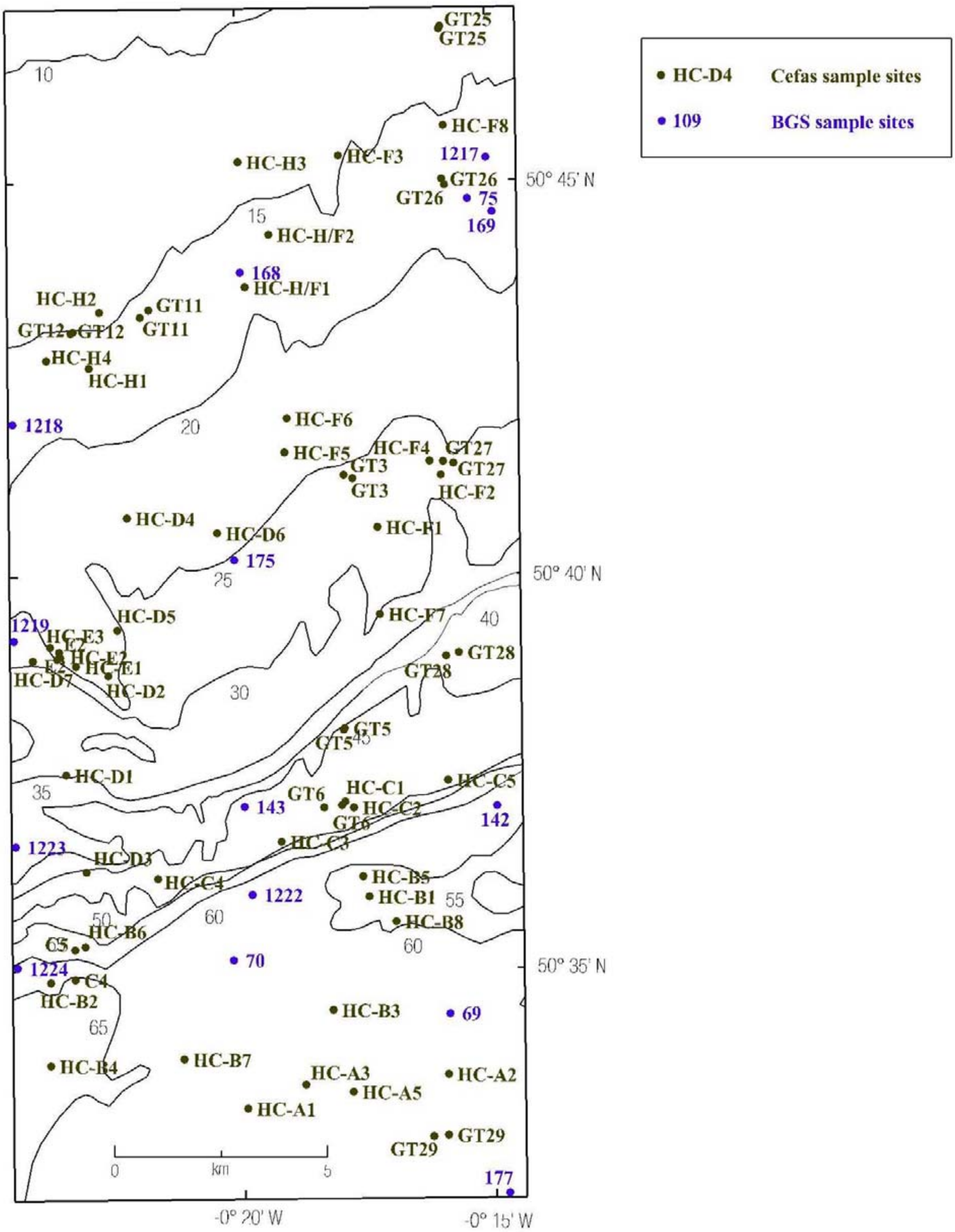

Figure 7 CEFAS and BGS sample sites

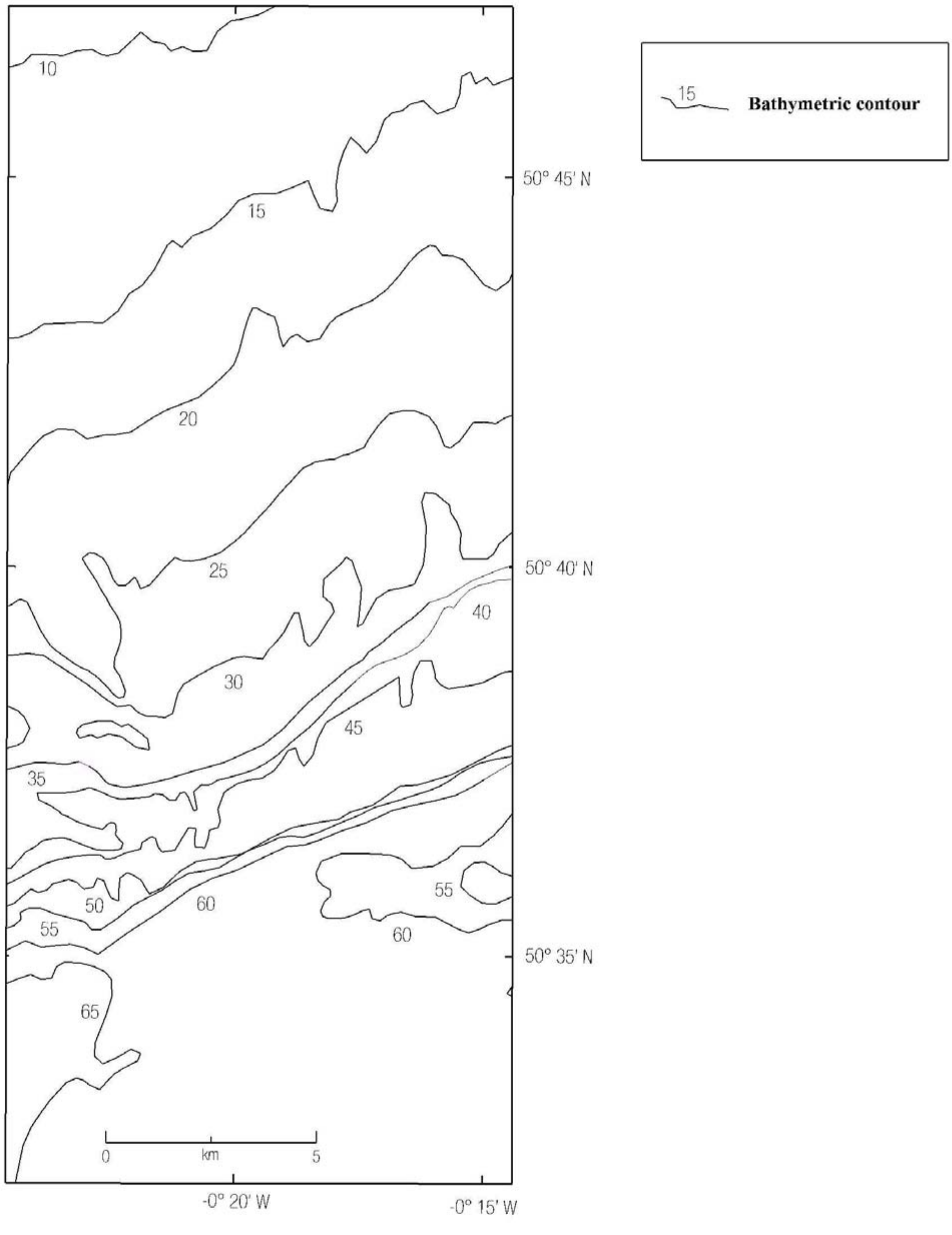

Figure 8 Bathymetry

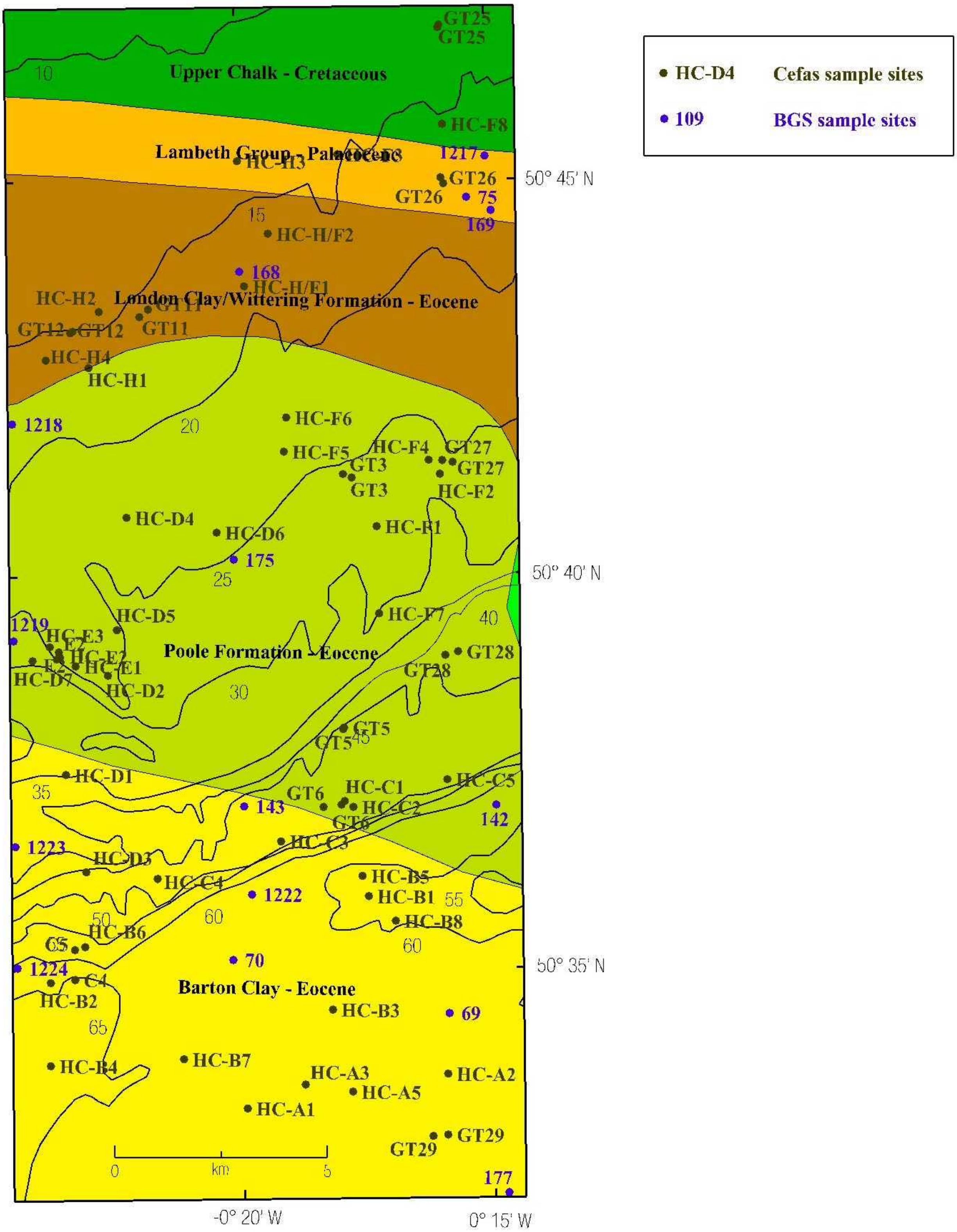

Figure 9 Solid geology with sample sites

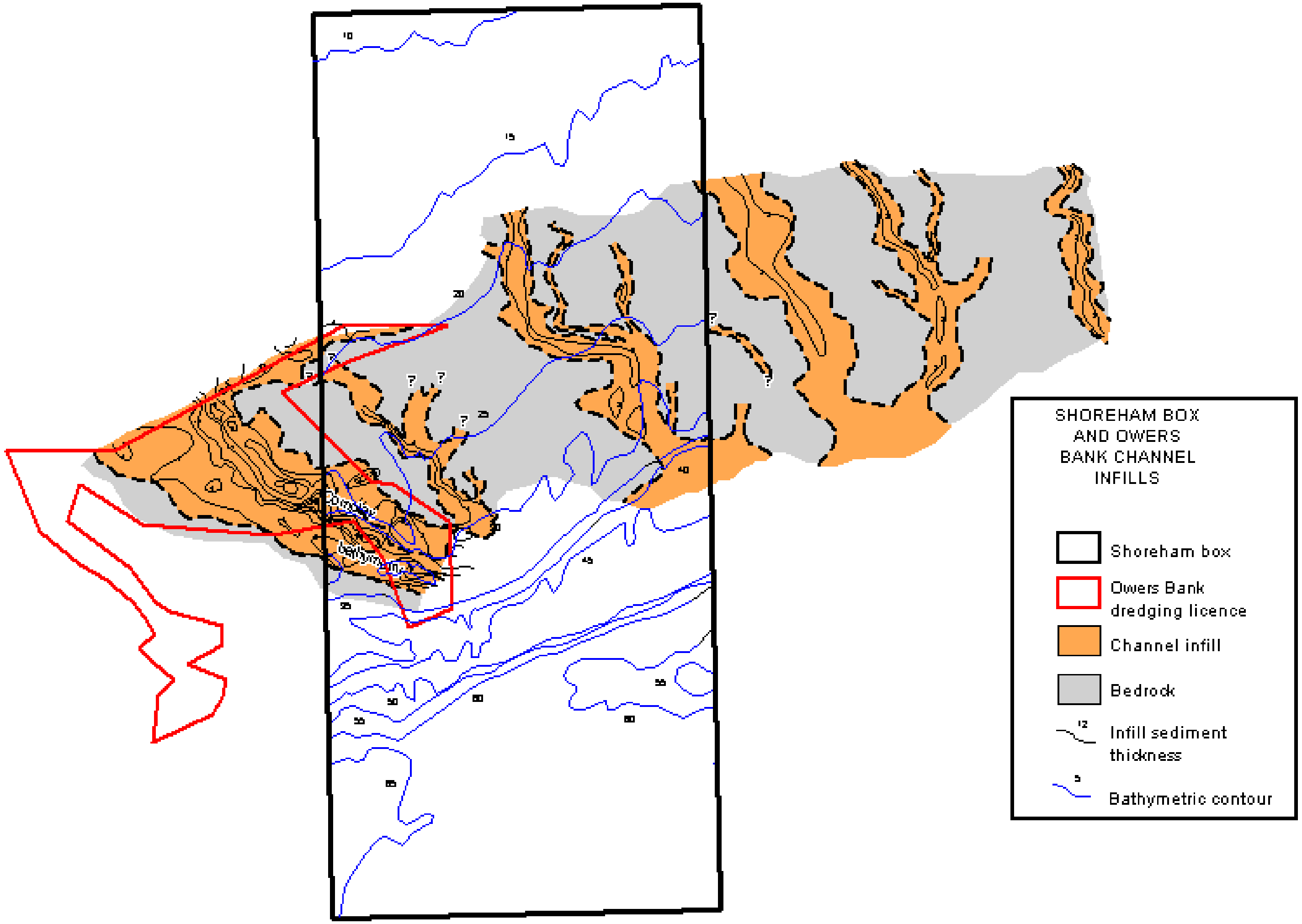

Figure 10 Distribution of channel infill sediments.
(infill interpretation from United Marine Dredging Ltd, Hanson Aggregates Marine Ltd & South Coast Shipping Co)

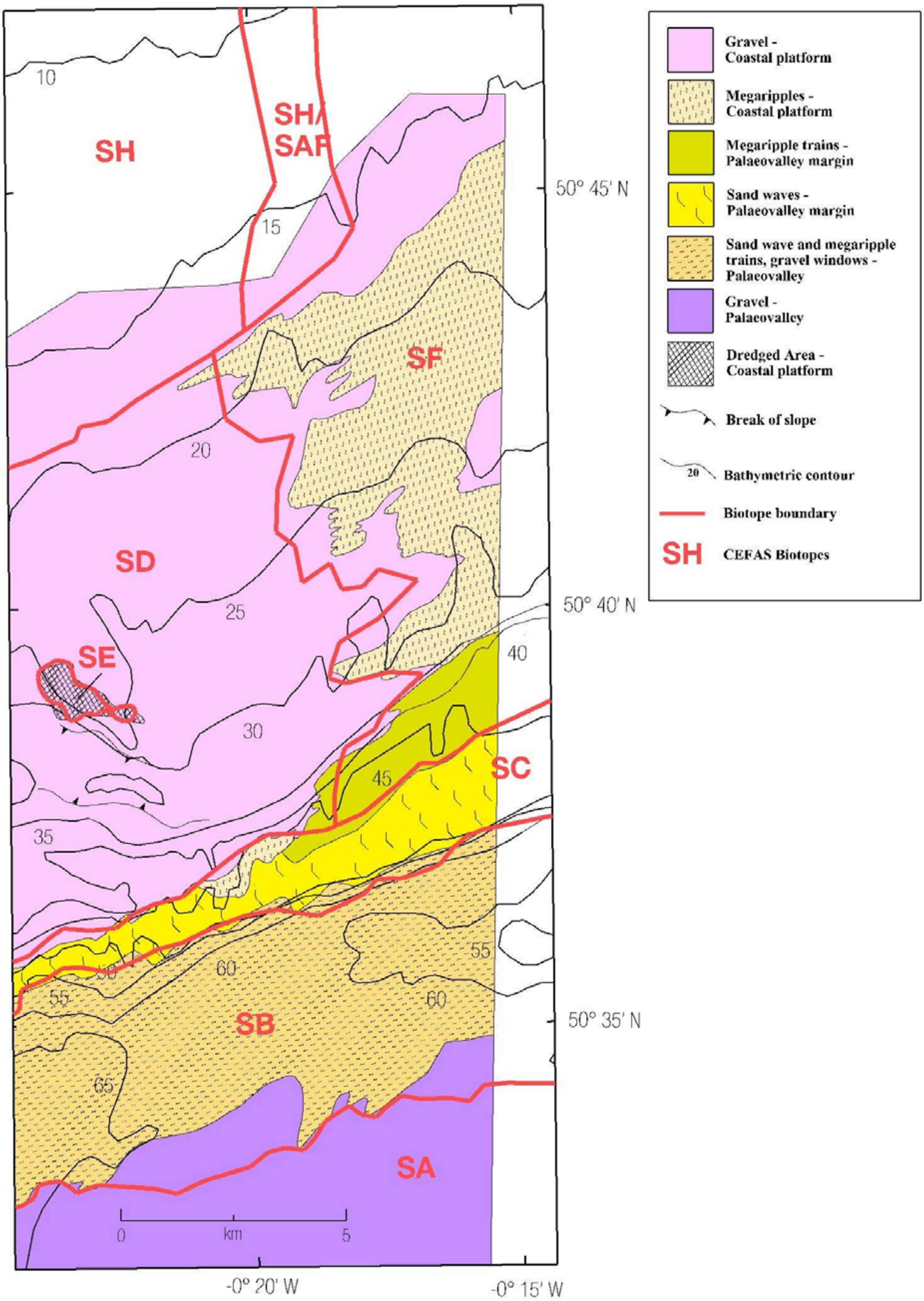

Figure 11 Relationship of BGS sea bed facies interpretation and CEFAS biotope interpretation

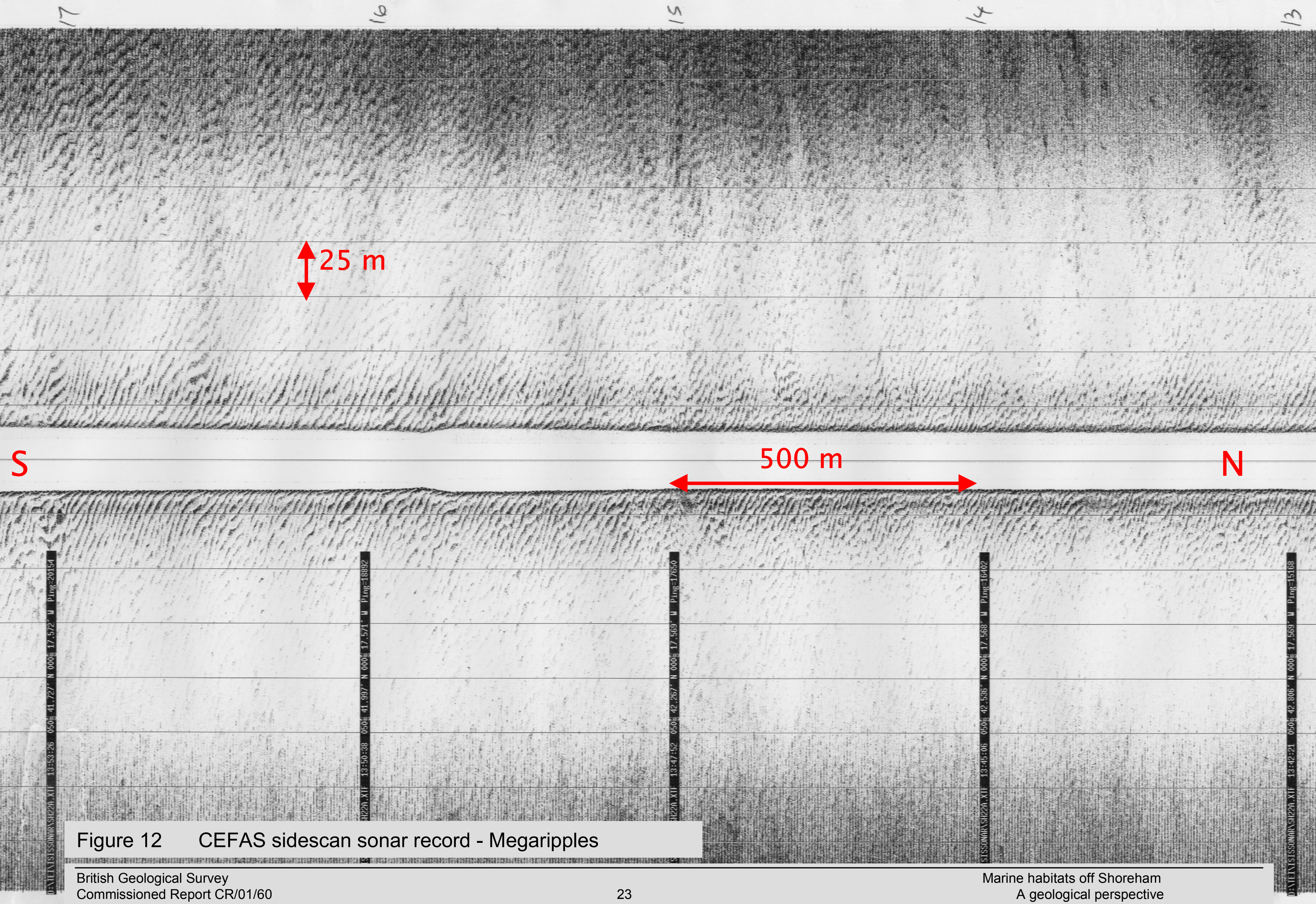

Figure 12 CEFAS sidescan sonar record - Megaripples

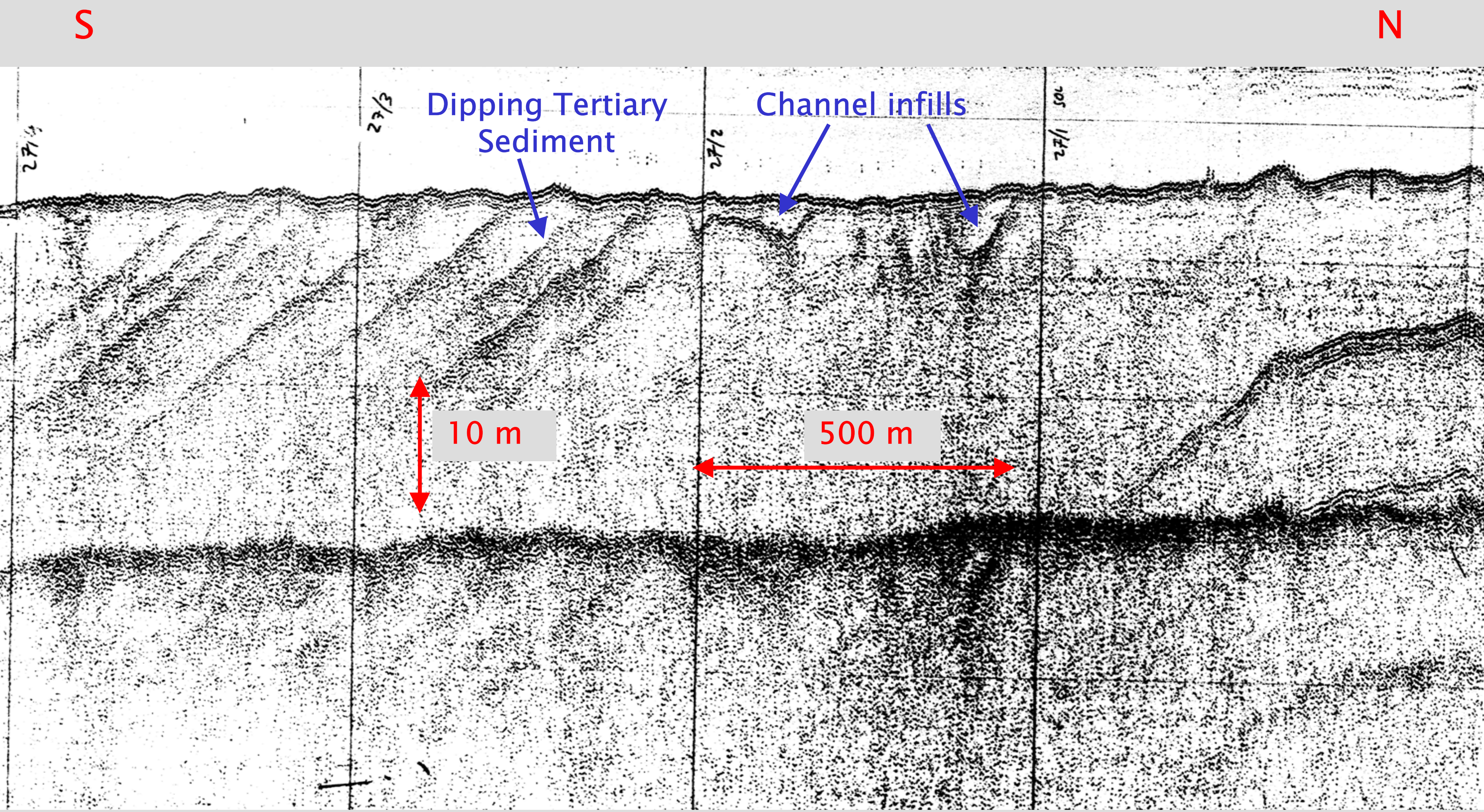

Figure 13 BGS Boomer seismic reflection record. Line 88/27
Dipping Tertiary sediment with two channel infills between fix 1 & 2

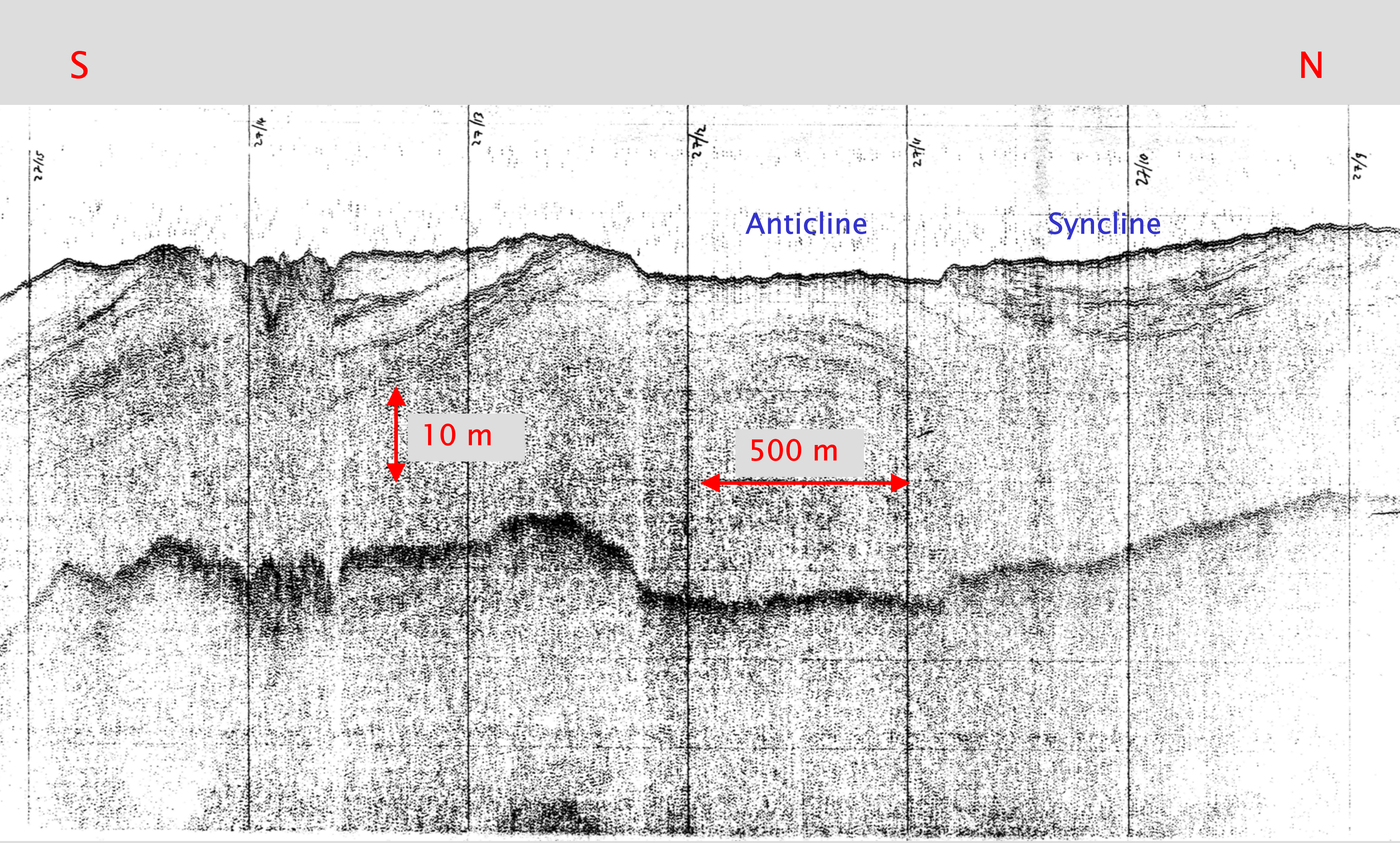

Figure 14 BGS Boomer seismic reflection record. Line 88/27.
Anticline and syncline in folded Tertiary sediment

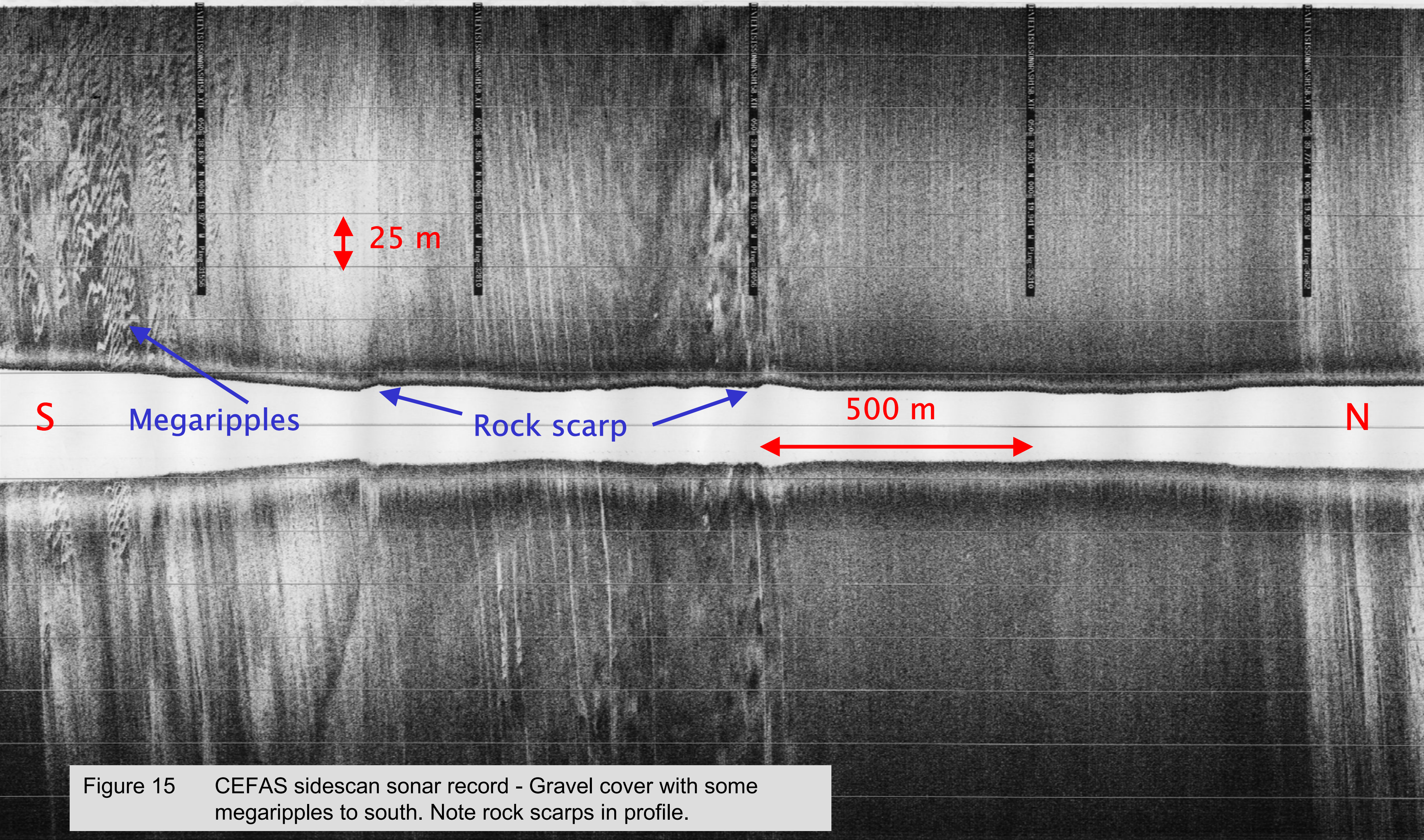

Figure 15 CEFAS sidescan sonar record - Gravel cover with some megaripples to south. Note rock scarps in profile.

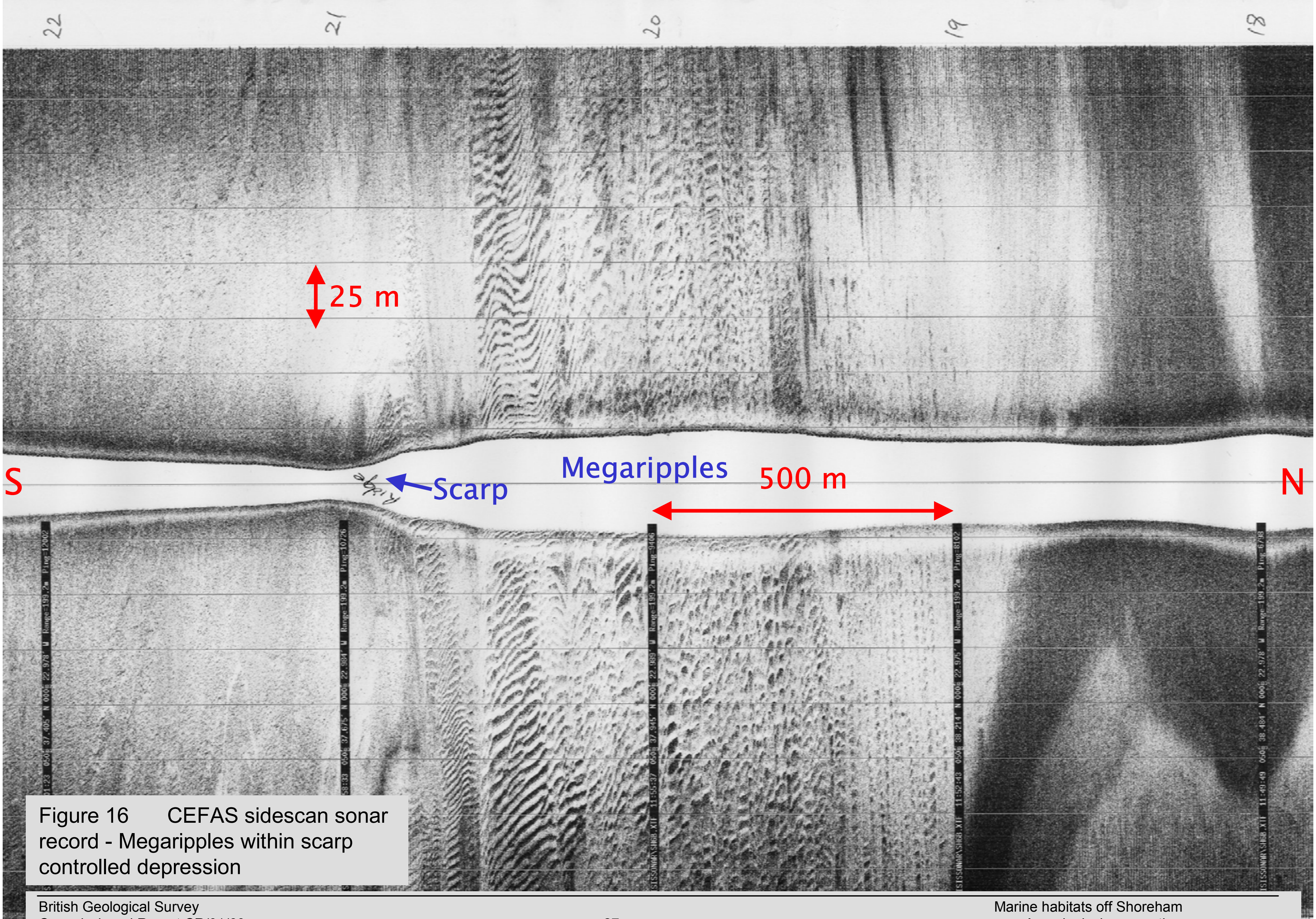

Figure 16 CEFAS sidescan sonar record - Megaripples within scarp controlled depression

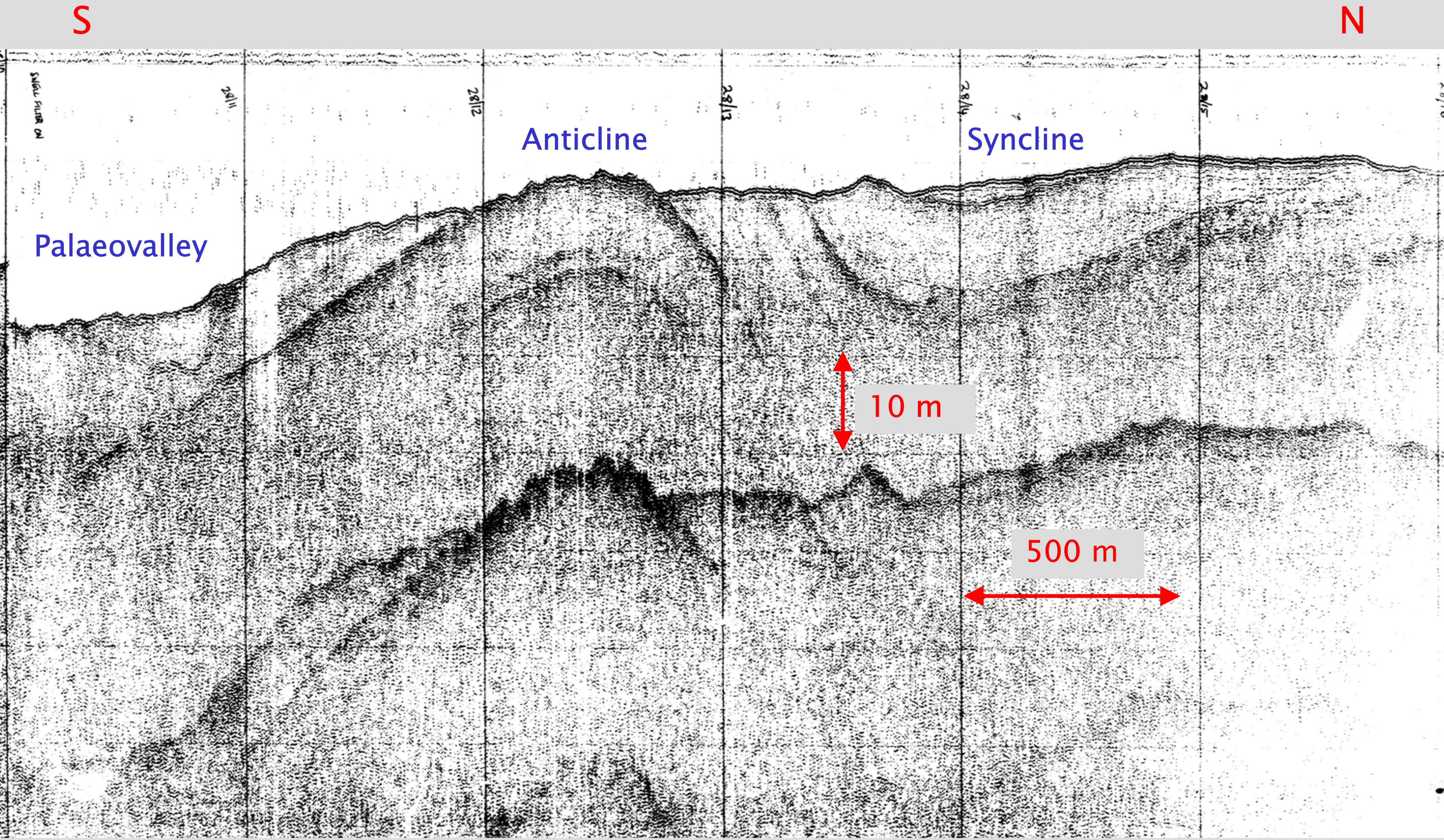

Figure 17 BGS Boomer seismic reflection record. Line 88/28
Anticline and syncline in folded Tertiary sediment. Palaeovalley margin to south with sand waves

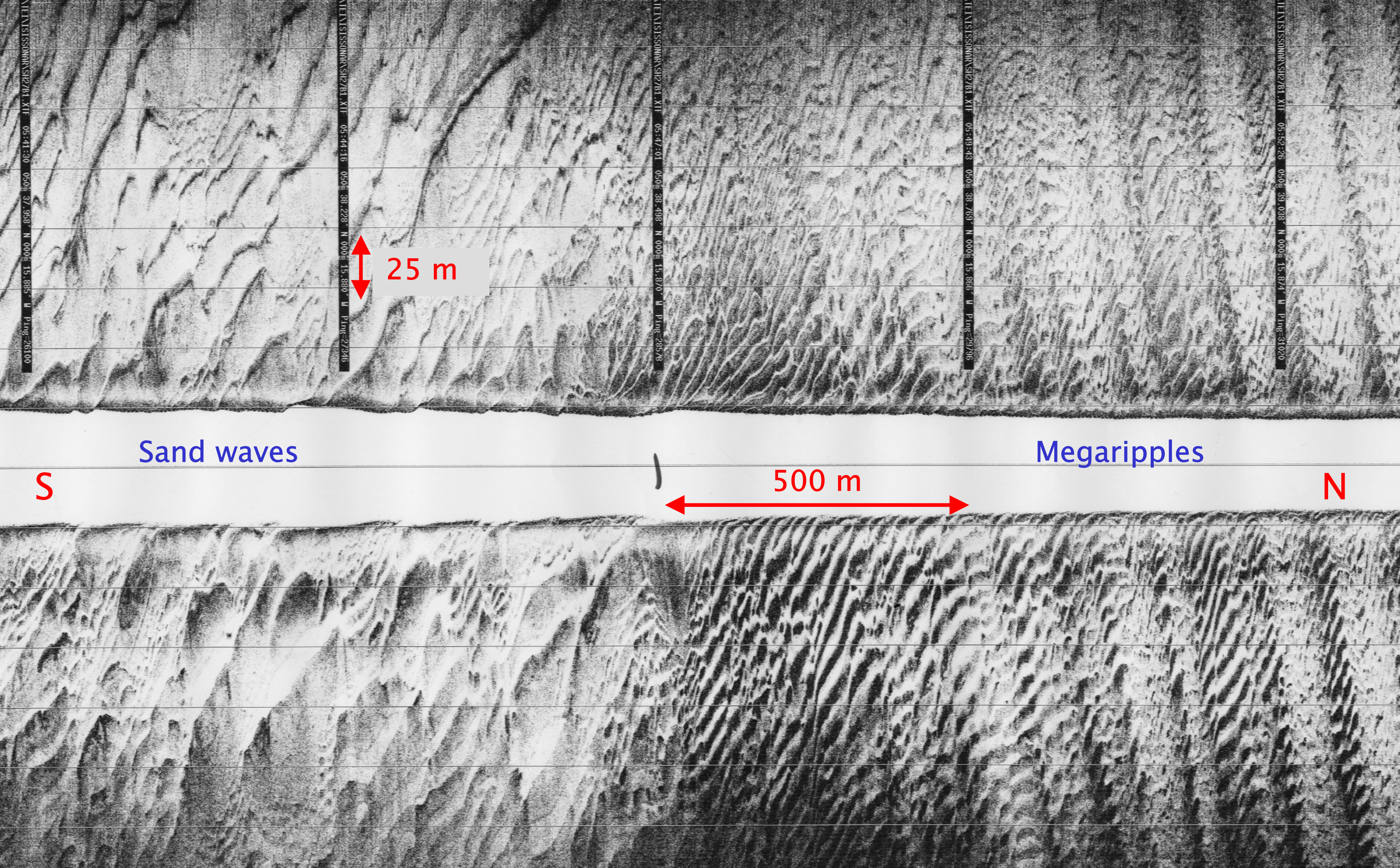

Figure 18 CEFAS sidescan sonar record - Sand waves to south, megaripple trains to north

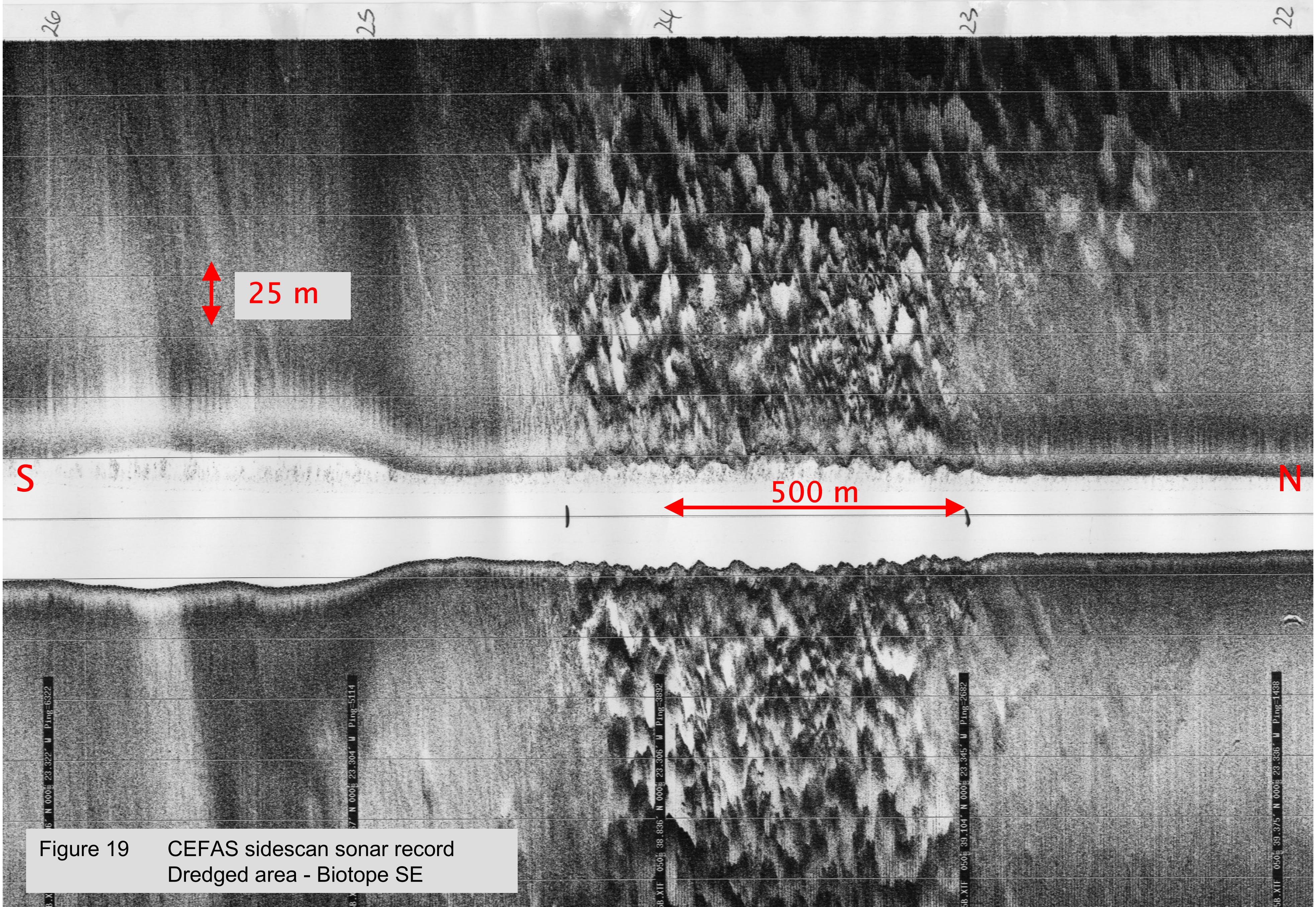

Figure 19 CEFAS sidescan sonar record
Dredged area - Biotope SE

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Figure 20 Sea bed video image: Palaeovalley gravel – well sorted pebbles

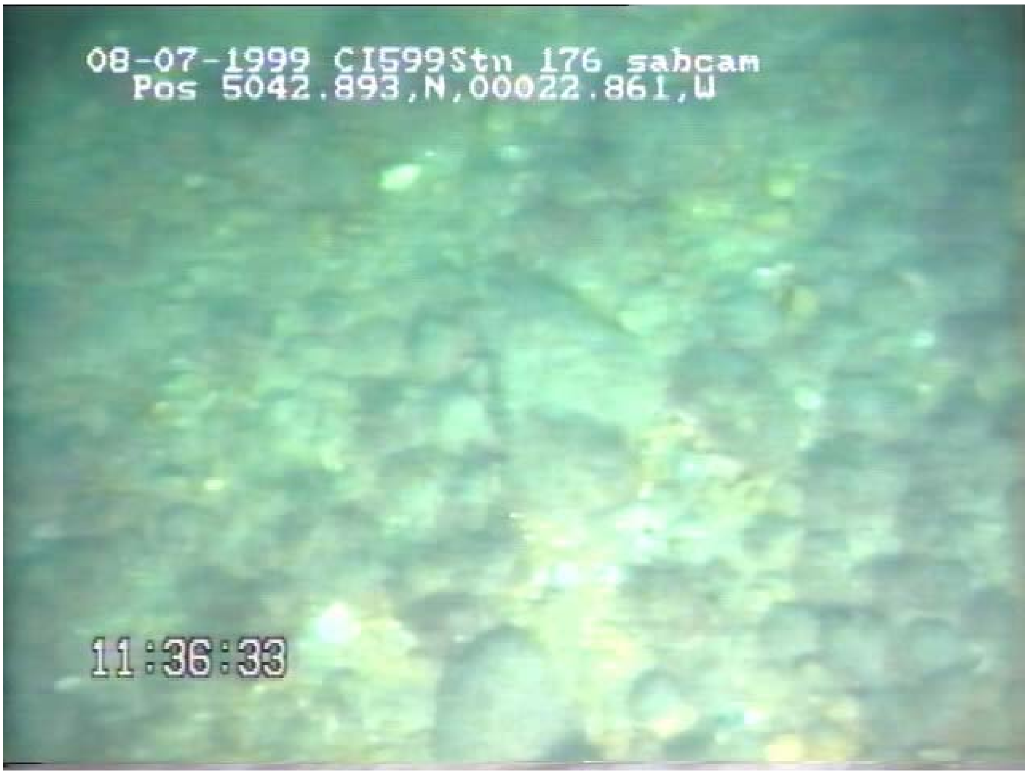

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Figure 21 Sea bed video image: Coastal platform gravel – Angular cobbles and pebbles

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Figure 22 Sea bed video image: Dredged pit floor with extensive colony of mussels, pit wall of gravel to right

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Figure 23 Sea bed video image: Dredged pit floor with fine sediment and mussels, branching bryozoa *Pentapora foliacea* in bottom of image

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Figure 24 Sea bed video image: Dredged pit wall – Pebble gravel from channel infill deposit, relatively well sorted

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Figure 25 Sea bed video image: Megarippled sand