I.O.S.

SIZEWELL – DUNWICH BANKS FIELD STUDY

B J LEES

Topic Report : 1

(a) Introduction

(b) Geological Background

Report No 88

1980

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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by the Department of the Environment.

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SUMMARY

The introductory section of this Report outlines the development of the Sizewell-Dunwich Banks Field Study since its inception in January 1975. At that time the project was conceived primarily as a regional study of an offshore bank and its relationship with shoreline equilibrium. Subsequently the programme evolved to its present wider concept, part of which examines the interrelation between coastline and offshore in general. More importantly it has, together with the Swansea Bay (Sker) Project, become an in-depth study of nearshore large scale processes of sediment transport under waves and tidal currents. An outline of the breadth of the research programme is included.

The second and main part of the report describes the geological background of the Sizewell-Dunwich Banks study area. The adjacent coastline, which forms the western boundary of this research area, is composed of relatively unconsolidated Pliocene and Pleistocene Crags. The hardest and oldest is the Coralline Crag outcropping in the S of the area, forming the core and seaward extension of Thorpeness. The bedrock in the remainder of the area comprises sediments of the Norwich Crag Series lying unconformably against the Coralline Crag. Their surface shows an overall dip to the E. In the N the Crag is overlain by a marine alluvial clay beneath which infilled channels have been detected. The alluvial deposit probably results from the transgression of a former broad coastal estuary. The clays are almost certainly continuous with the clay in the present day marshes between Southwold and Dunwich, and probably that in the marsh further south comprising the Minsmere Nature Reserve.

Overlying the alluvium, and the Norwich Crag Series in the S, are the modern sands which are up to 9.5m thick; and intercalated sands, silts and clays. Together these form the Sizewell and Dunwich Banks and nearby areas. These two types of sediment show seasonal variation in their distribution. The sands are well sorted and of fine to very fine grade.

a) INTRODUCTION

Because this is the first Topic (as distinct from Progress) Report it is useful to provide a general Introduction to the project as a whole, before discussing the geological background of the Sizewell-Dunwich area of East Anglia. The geological description forms the second and main part of the Report.

From the beginning of the financial year 1976/77 the project has been financed entirely by the Department of the Environment.

1. Research objectives

The Institute of Oceanographic Sciences began work in 1975 in the Sizewell-Dunwich Banks area off Suffolk (Fig 1) with a view to developing a regional multi-disciplinary study to evaluate the relationship between an offshore bank and shoreline equilibrium. It was envisaged also as an attempt to understand the mechanism by which banks are formed and the way in which some banks reach overall stability and others do not.

The project developed through 1976 as an examination of a relatively simple and stable offshore sandbank with the short-term aim of resolving its sediment transport system. The long-term objective was to use the understanding gained for predictive purposes and as part of this aim to be able to provide useful information to those concerned with environmental problems. Examples of these are the effects of offshore dredging, coastal erosion, and the design of sea defences, (Lees, 1977: IOS Report No 38). Closely allied with the work in the early stages was a project to construct a finite-difference numerical model, firstly of the water flow, and later incorporating sediment transport terms and equations. The Sizewell-Dunwich Banks with their fairly simple geometric form were to be used as a prototype area for the validation of the model, and hence initially, data acquisition was considerably influenced by the model's requirements.

As the project developed further, from 1977 onwards there was a change of emphasis away from the regional aspect to a corresponding increase towards problem solving of a more general nature. The Institute of Oceanographic Sciences had been working since April 1974 on a question related to coastal erosion in Swansea Bay, South Wales, a project also largely funded by the Department of the Environment. In addition to comprising a study of the immediate area and its specific problems, this work was seen in the wider context of the general interrelation of the coastline and the offshore zone (Swansea Bay (Sker) Project series of Topic Reports). In particular, as the Swansea Bay and Sizewell-Dunwich Projects progressed, it became apparent that a great deal could be achieved by using the two widely contrasting coastal areas to enhance the broader goal. Sediment transport studies became increasingly important because of the need to compare measured with predicted rates of transport under different conditions of bathymetry, shoreline geometry, tidal regime and wave climate. Further factors requiring investigation have included assessing the influence of meteorological forcing on currents and therefore sediment transport, and the effect of waves in shallow water areas.

2. Outline of research programme

The Sizewell-Dunwich area is well-known both within and outside the scientific world for extensive coastal erosion which has occurred intermittently for centuries. In mediaeval times the area inshore from the Dunwich Bank, now under the sea, was part of the thriving city and port of Dunwich, probably at the peak of its prosperity in the 12th century. As a help towards the understanding of the present day offshore/coastline relationship, a historical survey has been undertaken, outlining the long term changes in the coastline and offshore banks (Carr, 1979: Topic Report No 2). Material used has included 16th and 19th century maps, hydrographic charts from 1824 onwards and other historical documents.

The main part of the research, however, was a field study. This commenced with a qualitative description of the topography and sedimentology of the area, using bathymetric, geophysical and grab sampling techniques. The partial bathymetric surveys were extended in 1977 by a complete echosounding survey of the banks. The initial grab sampling programme of 1975, with 251 samples, was supplemented by data from the 1978 bedload transport experiments mentioned below, where a grab was also used, thus showing sediment distribution changes over time. Further geological background information was obtained from 58 box cores, taken in 1975, 1977, 1978 and 1979, and also 20 vibrocores drilled in 1978 and 1979 at selected sites covering the study area.

The tidal current regime has been assessed since the beginning of the project by the deployment in the first instance of Aanderaa self-recording current meters, and subsequently Plessey MO21 meters. These were sited at midwater level, in line with the requirements of the numerical model, at over 30 stations for periods varying from 2 weeks to 2 months. One station was occupied for 2.75 years to assess long-term variability. The deployments began in 1975 and were completed in 1979. Velocity profiles were measured by various methods in order to assess the validity of using mid-water data (ie depth-averaged flow velocities) for the two dimensional numerical model. Such measurements also formed an integral part of suspended sediment transport studies.

The wave climate for the study area was monitored from early 1975 to May 1979 using frequency modulated pressure transducers at 3 sites, approximately 150m offshore and in mean water depth of 6-9m at Southwold, Dunwich and Aldeburgh. They were cabled to shore-based data loggers. An analysis of part of these data is given by Fortnum and Hardcastle, 1979: IOS Report No 65. A mean of over 90% valid data has been recorded for the 3 sites throughout the 4 years. Particularly useful measurements were made by deploying 2 Waverider Buoys simultaneously seawards and landwards of the Dunwich Bank to assess wave height attenuation by the bank during the winter of 1978-9. The Sizewell-Dunwich site has relied entirely on wind information for determination of wave direction.

A new phase of the study was initiated in 1977 in support of the change in emphasis towards the study of sediment transport processes. Experiments to measure suspended sediment transport rates were undertaken at 5 sites, each over one tidal cycle. These were followed in 1978 by the main bedload transport measurements using a fluorescent labelled tracer. It proved necessary to use this tracer labelling method rather than a radioactive one in order to avoid major radioactivity monitoring problems for the nuclear power station at Sizewell. Pilot experiments had been carried out earlier resulting in considerable improvement in the techniques of injection and subsequent sampling. Essential depth of mixing measurements were made in box and vibrocore samples obtained in the area of the tracer cloud, both near the beginning and end of the experiment.

Ten beach profiles, approximately 2km apart and normal to the shore, were monitored for a period of 15 months in order to examine beach changes (Blackley, 1979: Topic Report No 3). No sediment transport experiments were undertaken along the beaches, partly due to the greater emphasis on the offshore aspects of the research area and to time constraints, and also to the narrow beach width, low tidal range and wide diversity of sediment size.

Apart from the Topic Reports already mentioned others are designed to cover tidal currents and residual flows, wave climate and transport and deposition of non-cohesive sediment.

The final stage of the research programme will involve detailed co-ordination of the results from both the Swansea Bay and Sizewell-Dunwich Projects. The aim will be to further the understanding of large-scale sediment transport processes under waves and tidal currents in a more general context.

b) GEOLOGICAL BACKGROUND

The following section of the report, after a brief outline of the local geology, describes the surface distribution and thickness of the superficial sediments. It also shows the changes in sediment distribution over limited areas during the period of study. Techniques used include geophysical surveying with "boomer" and "pinger", grab sampling, and box and vibrocoring.

The last geological maps of the area published by the Geological Survey were in 1886 (southern sheet) and 1887 (northern sheet). Funnell and West (1977) suggested a definitive classification of the early Pleistocene deposits of East Anglia, and the areas of Pliocene and Pleistocene Crags shown in Fig 9 are taken from Fig 18.1 of their paper. The distribution of alluvial clay, which will be shown later to be relevant when considering the offshore geology, is taken from the 1886 and 1887 maps, and apart from some erosion at the shoreward side is not expected to be significantly different today.

The term Crag is one used locally for any shelly sand (Chatwin, 1961). The Pliocene representative is the Coralline Crag, outcropping in the S near Aldeburgh and almost certainly continuing for a short distance offshore as the core of Thorpeness. Further N the character of the Crag changes to beds of sand, laminated clays and pebbly gravels lying unconformably against the Coralline Crag. These deposits are known as the Norwich Crag Series and are of preglacial Pleistocene age (Funnell and West, 1977). The Westleton Beds form a gravel horizon at the top of the series and are exposed at Dunwich. Offshore the bedrock is Norwich Crag and it is overlain in the northern part of the area by alluvial clays. Modern deposits of clays, silts, sands and gravels lie above the alluvium in the north, and directly on the Norwich Crag sediments elsewhere.

1. Seabed Topography

The coastline in the study area curves inland very gently from a slight ness at Southwold in the N to a similar, but more prominent feature at Thorpeness in the S (Fig 2). A small river, the Blyth, flows into the sea immediately S of Southwold. Offshore there is a gently sloping platform reaching a mean depth of 15m below Chart Datum approximately 4km offshore. Lying on this platform is a linear sandbank with its long axis parallel to the coastline and about 2km from it. There is a central col separating Dunwich Bank to the N from the Sizewell Bank to the S. The two together are 11km long and approximately 1km wide, with mean slopes of 1 in 60 to the W, and 1 in 200 to the E. Inshore from the bank is a trough, again elongated parallel to the coastline, and reaching a mean depth of just over 9m below Chart Datum. There is a 6m to 8m deep channel between Thorpeness and the southern end of the Sizewell Bank.

2. Data collection and analysis

2.1 Position-fixing

At the beginning of the study in 1975 position-fixing was achieved using Decca Main Chain only. In the Sizewell-Dunwich area the fixed errors are 0.1 lane to be added to the red pattern readings and a similar amount to be subtracted from the green pattern readings. The variable errors, due to interference between signals, are such that there is a fix repeatability error, not exceeded on 68% of occasions, of approximately 40m (Decca Navigator Operating Instructions and Marine Data Sheets). The geophysical survey and most of the first grab sample and box core surveys used this system. The more sophisticated system of HiFix 6 was in use from the end of the first and during the second field work season of 1976. This equipment has a fix repeatability of 5m (Blaiklock and Strafford, 1976). The initial grab sampling survey was completed during this time.

During the last 3 fieldwork seasons, 1977-79 inclusive, the Del Norte Trisponder system, belonging to IOS, was utilized. The remainder of the box core, all the vibrocore samples, and the grab samples, taken as part of the 1978/79 fluorescent tracer experiment (see below), were obtained using this system which has a range accuracy of $\pm$ 3m. Remote stations were set up at Southwold and Sizewell with a third at Dunwich during the first year. Dunwich proved to be an unsuitable site because of signal masking by the cliffs, and a site at Minsmere was selected for the remaining two years (Fig 1).

2.2 Continuous seismic profiling (CSP) and sidescan sonar

A combined geophysical and sidescan sonar survey was undertaken in 1975. The trackplot is shown in Fig 3. A Huntec ED10 Boomer and Huntec ST2 high resolution streamer were used together with an EG and G dual channel sidescan sonar system. An ORE Pinger fish was towed at the same time, but gave unsatisfactory results mainly due to acoustic interference from the ship's variable pitch propeller and electrical "noise" from generators and similar equipment.

There was a masking of information on many of the sidescan sonar records for these reasons also and additionally because the relatively shallow water caused the fish to be towed within the ship's wake.

The boomer transmitted energy pulses of known frequency to the seabed. There part of the signal was reflected whilst the remainder penetrated the various layers of sediment with their differing acoustic properties, giving successive partial reflection from the interfaces. These reflected signals were received at the streamer and recorded on an Alden 19" recorder located in the ship's laboratory. In the E G and G sidescan sonar system a sonar transducer emitting a fan-shaped acoustic pulse was towed behind the ship. This pulse was returned from a strip of the seabed 150m wide and recorded on a facsimile recorder. For both types of survey fix marks were recorded on the charts as the ship progressed and Decca coordinates were logged synchronously.

All calculations of depths and thicknesses for the construction of an isopachyte map have assumed the velocity of sound in both water and sediment to be a constant 1500m s^{-1}. Sound passing through unconsolidated sediments and any older geological deposits would travel at slightly higher velocities than this, and therefore any depths or thicknesses below the seabed may be subject to small errors.

2.3 Grab sampling

A grab sampling survey was undertaken in 1975 to supplement the geophysical data. A total of 251 samples was obtained using a van Veen grab. The sampling positions were spaced over a grid with intervals of approximately 500m, covering the area shown in Fig 4. Further data were obtained over a small area at the SE corner of the Dunwich Bank during a fluorescent tracer experiment in 1978. A "background" survey, made immediately before the experiment began covered the area shown in Fig 5. Additionally over a hundred grab samples were taken during each of 5 subsequent surveys, over a maximum area of 1600m x 400m (Fig 6A-F), in order to locate the sand labelled with fluorescent dye. For these a Shipek grab was used.

Both Shipek and van Veen grabs take slightly disturbed bulk samples to depths of between 10cm and 20cm. Although such samplers have their disadvantages in gravelly areas, because individual pebbles can prevent the jaws from closing, they performed very well in the study area, where the sediments vary from clean sand through to silt and clay.

The samples were described in the field using an IOS Grain Size Comparator Disc (Kirby, 1973), which allowed the grain size to be designated according to the Wentworth Scale. Four grab samples from the sand areas (Fig 1) were sieved at $\frac{1}{4}\phi$ intervals. ($\phi = -\log_2$ grain diameter in mm). Those from near the Sizewell Bank were partly for the purpose of matching the fluorescent tracer sand to that on the seabed. The results are shown in Table 1.

2.4 Vibrocoring

Cores 8cm in diameter and up to 4.2m long were obtained with a slightly modified version of the Institute of Geological Sciences vibrocorer (Kirby, 1972). For ease of handling and to minimise disturbance once the sample had been taken, the plastic core tube liners were cut into 1m lengths, sealed on board ship, and were stored vertically during transport. Twenty vibrocores were obtained (Fig 1).Those at stations VC13, 14 and 15 were drilled in the area of the fluorescent tracer experiments for measurements of the depth of mixing of the tracer. Station VC3 is not shown on Fig 1 because no core was obtained. It proved impossible to keep the vibrocorer upright in the shallow water near Thorpeness where a sampling station had been planned.

The remaining cores were halved lengthwise. Non-cohesive ones were impregnated and clay samples were X-rayed. The non-cohesive samples were allowed to dry a little, then the upper surface of each sample was coated with several layers of lacquer. This penetrated the sediments to different depths according to their grain size and therefore permeability. When the coating was dry, it and the incorporated sediment were removed, brushing away any loose particles. The remaining material was then available for further analysis. The parts showing a yellow or reddish colour, which suggested that the sediments may be Crag or derived from Crag, were examined for suitable shells or shell fragments to provide palaeontological evidence concerning their ages.

Occasionally the vibrocoring disturbed the natural sedimentological structures. For example, the top few cm of the vibrocores tended to be a little disturbed due to vibration especially when some sediment had been forced past the piston. Drag features were also induced in the outer 2 to 3mm layer of each core throughout its length as the plastic liner penetrated the sediments. Occasionally drag effects known as flame features were induced in deeper parts of a core, eg in VC9 from 1.22m to 1.66m depth.

Clay samples were also sliced longitudinally, sealed with polythene sheeting to prevent drying and distortion, and then X-rayed. The intensity of the X-rays passing through the fine sediments was affected by the density or grain size of the material present. The resulting contact negatives revealed the detailed internal structure of the cores. Representative samples were also taken and washed over a 40 mesh sieve, dried and the organic remains floated off in carbon tetrachloride for subsequent microscopic examination.

2.5 Box coring

Two types of box corer were used, one being the Reineck Corer (Bouma and Marshall, 1964). The other was designed at the Ministry of Agriculture, Fisheries and Food at the Lowestoft laboratory (Tennant, in preparation). It operates on a similar principle to the Reineck, but without the bulky supporting frame. It uses identical sampling boxes which give relatively undisturbed samples 28 x 18cm in surface area, and up to 45cm deep. From these, subsamples were taken, using either metal boxes 5 x 18 x 30cm for sedimentological analysis or rigid plastic tubing 6cm in diameter for depth of mixing measurements of the fluorescent tracer. Nine cores were obtained in 1975 and a further 32 in 1977, on the eastern flanks of the banks, both in sand and in areas of soft sand, silts and clays. They were used as additional data in the construction of the sediment distribution maps (Figs 4 and 5). The 17 cores taken in 1978-79 were for depth of mixing determinations alone. (Topic Report No 4, in preparation). The top 3cm of 8 cores (Fig 1) were sieved at $\frac{1}{4}\phi$ intervals. The results are given in Table 1. The sieving was again primarily for the purpose of matching fluorescent tracer to the seabed sand.

3. Sediment distribution (Figs 4, 5 and 6A-F)

Evidence from all sources ie CSP, sidescan sonar, grab samples, box and vibrocores has been combined to provide a brief geological interpretation of the study area. The sediments present have been divided into five main types, and beginning with the oldest they are: iron-stained sands, followed by blue-grey clay, gravel, intercalated sands, silts and clays, and bank sand.

The geophysical records reveal the presence of at least 4 reflectors which can be correlated with 4 of the above named sediments seen in the grab and core samples. Two of these give good reflections. One shows some penetration, but appears to be homogenous internally and can be identified as the blue-grey clay. The other good reflector, with very little acoustic penetration, can be correlated with the gravel. Poorer reflections with some penetration, but many small scale internal irregularities are given by the intercalated sands, silts and clays. The last reflector is again good, with good penetration, and is sufficiently consistent for the thickness of the sediment type to be determined over all but the southernmost part of the study area (Fig 7). This sediment is identified as bank sand and its distribution and thickness are described in more detail below.

In describing the evidence available for the distributions of each type, samples such as vibrocores are, where practical, considered in geographical order moving from north to south. All locations are shown in Fig 1.

3.1 Iron-stained sands.

These sands vary from very fine to coarse with comminuted and fragmented shell, and range in colour from bright ochre-yellow through amber-yellow to reddish. The macro-fossil content of the various sands shows them to belong to sediments ranging from Coralline Crag and the Norwich Crag Series to more modern sediments, containing derived material from the older Crag beds. A list of species, together with their location, is given in Appendix 1.

The sands fall naturally into two groups. The first group includes the orange-yellow sands found on the seabed in grab samples taken in September 1975, in a strip following the shoreline from the limit of the survey at Thorpeness to S of Minsmere Cliffs. There was a gap in this strip opposite the Sizewell Power Station. Similar coloured sands were visible in VC 21 (Fig 8D) from the surface to the bottom of the core at 1.19m depth below the seabed. From the seabed surface to 0.17m depth the sands are modern with derived Coralline Crag content. Below this to the base the core comprises Coralline Crag. The mean grain size ranges from very fine to coarse sand. Coralline Crag in situ has been tentatively identified at 1.56m depth to the base of VC 8 (Fig 8B) with derived Coralline Crag immediately above in an 8 cm thick band of sediment. Sidescan sonar records indicate rock exposures on the seafloor near Thorpeness with a WSW-ENE strike (Fig 4). These are almost certainly Coralline Crag in situ. No iron-stained sand was detected at the sites of VCs 2 and 4 (Fig 1),

The second group comprises the iron-stained sands recognised at the bottom of eight of the vibrocores (Fig 9, VCs 1, 5, 6, 7, 8, 16, 18 and 20). These too vary in mean grain size from very fine to coarse sand. The very fine non-fossiliferous sands are found in cores VC 5 and VC 6 (Fig 8A) at depths of 1.75m and 1.70m respectively and show current bedding. Above them lie 0.15m and 0.06m respectively of yellowish, shelly fine and medium sands with granules and pebbles also showing current bedding. These last sands, granules and pebbles contain fossils indicating modern sediments with possibly derived Norwich Crag material. The most northerly of the cores to reach the iron-stained sands is VC 18 (Fig 8D) at the N end of the Dunwich Bank, and here there is fine sand at 2.55m depth to at least the base of the core at 2.66m. Silt and clay immediately above are stained with the same reddish-yellow colour. The fossils show the sediments to be modern, with possibly derived Norwich Crag material. There are also fine yellow sands in VC 1, SE of the Sizewell Bank at a depth of 2.72m. This core penetrated to 3.64m without finding the lower surface of these sands. They are not homogeneous but become a little coarser with depth (Fig 8A). Their faunal content shows them, and also the coarse sand plus pebbles immediately above, to be Norwich Crag.

Medium sands are found in VC8 (Fig 8B) at a depth of 1.39m. They are modern to a depth of 1.48m, but with derived Norwich Crag material. VC20 is located in an area where the geophysical records suggest reflecting interfaces at close intervals, eg 8 per 2.0m, giving a mean thickness of 0.25m (Fig 10A). The vibrocore (Fig 8D) shows alternating layers of medium yellowish sand and clay from 0.27m to 1.95m, again with a mean thickness of 0.25m. The fossil content identifies the sand as Norwich Crag.

The coarse sands were located by cores VC7 (Fig 8B) and VC16 (Fig 8C) at depths of 3.95m and 1.17m, and both contain fresh fragmented shell showing the sands to be modern, but with some possibly derived Norwich Crag shell fragments also. VC's 2 and 4, immediately SE of Thorpeness, penetrated to depths of 4.05m and 4.21m respectively without passing through any iron-stained sediments (Fig 8A).

3.2 Blue-grey clay

This has a plastic consistency and contains lenses of silt and also black, slightly oily patches, probably of organic origin. There is frequently a veneer of brownish sand and silt, only a few grains thick, which could be an artefact of sampling. When the tide is flowing there is always sand in suspension, which may settle out during the sampling process. Local colour variations include brown and turquoise. The latter colour is due to the presence of vivianite, a hydrated iron phosphate, $Fe_3(PO_4)_2 \cdot 8H_2O$, and is seen in VC9 from 0.05m to 0.55m and 1.22m to 1.66m (Fig 8B). The clay contains abundant benthonic foraminifers, including specimens reworked from the Crag and the Chalk, also ostracods, large centric diatoms, and much plant debris. Fragments of bryozoans, echinoid spines and larval bivalves occur in most samples (Funnell, personal communication).

In the N of the area this clay forms a relatively stable platform underlying the sand. The sand and silt content increases to the S. Beginning in the N, the first core is VC11 (Fig 8B) which penetrated 0.10m clay above the gravel infill of a buried channel. VC12 (Fig 8B) reached a depth of 3.80m, locating clay to 0.54m, then very fine sand to 1.13m and then clay, with silt and occasional shell fragment layers from this horizon to the base. VC18 (Fig 8D) located clay at 2.04m depth for a thickness of 0.46m. The clay contained the fewest reworked Chalk foraminifers of all the samples. At VC17 (Fig 8C) just on the W side of the Dunwich Bank, the core is 3.35m long and almost entirely clay with laminations and bioturbation. Clay has been penetrated at VCs 13, 14 and 15 underlying sand at 2.35m, 2.82m and 1.49m respectively, but the lower limit was not reached at any of the three (Fig 8B and 8C).

VC6 (Fig 8A) inshore from the N end of the Sizewell Bank, has clay from 0.14m to 1.08m. The core was probably taken near the boundary of the offshore continuation of the Minsmere Nature Reserve alluvium. The clay horizon contains abundant reworked Crag foraminifers. To the E of VC6, at VC7, there is clay underlying bank sand from 1.07m to 3.95m (Fig 8B). VC8 (Fig 8B) passed through a narrow band of clay from 1.13m to 1.24m. This underlies the sands forming the eastern flank of the Sizewell Bank. SE of this core at VC1 (Fig 8A) clay was found to a depth of 1.99m. This should probably be correlated with the alluvial clays as the microfossil content is similar. Further S, VCs 2 and 4 (Fig 8A) both penetrated bioturbated clay below the sand thicknesses, mentioned below, of 1.42m and 1.12m respectively. Neither had reached the base of the clay, which also includes horizons of very fine sand and silt, at 4.05m and 4.21m (bases of cores). Reworked Crag foraminifers are again very abundant in VC4, as in VC6.

3.3 Gravel

The gravels comprise mainly rounded, subangular or angular flints. They are orange-brown in colour, and the maximum length of the pebbles sampled is 80mm. Quartzites, quartz and a small number of other types are also present. The indigenous fauna is mainly sessile. Often the gravel forms a veneer and the van Veen grab penetrated to the sands or clays beneath, resulting in the inclusion of very fine to medium sands with whole, fragmented and comminuted shell, or silts and clays.

The area covered by gravel is depicted on the sediment distribution map in Fig 4. Fig 10B shows clearly on the geophysical record the change from gravel to sand at the seabed surface. Subsurface reflectors can be identified in the sand area, but there is insufficient acoustic penetration of the gravel to locate horizons beneath it. The sand/gravel boundary identified by boomer and grab samples, is confirmed by sidescan sonar to the N of the Dunwich Bank.

VC19 (Fig 8D) was sited in the gravel area, 2km seawards of the sand/gravel boundary, but it shows the gravel to be only 0.09m thick. It lies above 0.13m sands, silts and clays, whilst beneath these sediments are 0.18m chalk, presumably a small, isolated patch, then 0.36m clay, all overlying sand. The presence of much glauconite in the sand gives it a green colour. These sediments beneath the gravel may be estuarine deposits.

Of the four cores drilled to locate the buried channels SE of Southwold (Figs 7 and 8B), VCs 9, 10 and 11 penetrated sediments comprising rounded and subangular pebbles in very fine to coarse sand matrices, probably infill material. VC9 (Fig 8B) passed through gravel at two levels from 0.55m to 0.86m, and 1.73m to 1.91m (base of core). The top 0.33m of the core comprises very fine sand whereas the remaining two bands consist of silty clay. VC10 penetrated to 1.59m and VC11 to 0.87m, both without reaching the base of the gravel. The geophysical records show that the beds of these buried channels were too deep to be reached by the vibrocorer, which has a maximum penetration of 5.0m (Fig 10C and D).

3.4 Intercalated sands, silts and clays.

These are usually grey or brown in colour, becoming darker with depth and are of a rather fluid consistency. Owenia fusiformis, a tube worm, was present in large numbers in the order of 1.5×10^3 individuals m^{-2}, far outnumbering animals of any other species visible to the naked eye, in any of the samples taken. Although there is a sharp distinction between the firm blue-grey clays in the north of the area and the fluid clays in this admixture, samples can be found showing gradation from one to the other.

The micropalaeontological content of all these clays presents a similar general aspect (Funnell, personal communication) and has been described above in paragraph 3.2. The sediments were located during both the 1975 and 1978 surveys to the E of the central part of the Sizewell-Dunwich Banks systems, and in a smaller area to the W, immediately offshore from the Sizewell Nuclear Power Station (Figs 4 and 5). During the 1978 durvey they were also found in the col area extending W and E to the limits of the survey (Fig 5). Their distribution over a smaller area, sampled at intervals during the period August 1978 to April 1979, is shown in Fig 6A - F.

The following cores were sited in areas covered at some time by sands, silts and clays, and are all shown on Fig 1, the location map. VC16 (Fig 8C) is located at a site which in 1975 was near the boundary between sand and clay SW of the Dunwich Bank, and in 1978 was adjacent to the clay and sands, silts and clays boundary. This is reflected in the core itself which shows alternating bands, 2 to 14cm thick, of clay and medium sand with layers of fragmented shell, down to 0.67m. From 0.78 to 1.17m depth, there is clay overlain by 0.17m of material ranging in size from clay particles to pebbles. VC6, sited almost 2km S of VC16, penetrated sands, silts and clays from 1.08m to 1.64m. Layers of clay with sand patches, alternating with fine to medium sand with shell fragments and some bioturbation to a depth of 1.60m, are shown in VC5 (Fig 8A). This core was sited immediately offshore from the power station. The clay horizons in all 3 of these cores contain abundant reworked Crag foraminifers. The remaining core, VC1 (Fig 8A), was also sited in an area of sands, silts and clays E of the Sizewell Bank and S of the gravel area. In this core clay is found to a depth of 1.99m with silt and sand laminations and some bioturbation and has been mentioned under 'Blue-grey clay'. There are medium and fine sands underlying the clay. It is not clear whether these deposits form part of the blue-grey clays or the intercalated sands, silts and clays.

3.5 Bank sand.

The most important sand area is that which includes the banks. The sand is compact, clean and varies in colour from creamy-grey to brown. Very little iron-staining is shown. There is a high percentage of quartz, many grains being angular with a few exhibiting frosted surfaces. Surface textures alone, however, are not sufficient bases for the determination of environmental origins (Soutendam, 1966; Baker, 1976). A little glauconite is present. Many samples contain comminuted shell, or laminae of entire and fragmented shell, all of unaltered appearance. Bioturbation is also shown in some samples, with worm burrows and sea-urchin feeding trails. Clay pellets found in some of the sand samples from the eastern part of the banks are likely to be erosion products from the intermittent exposure of the underlying sediments.

The field logs using the grain size comparator disc show that the bank comprised mainly very fine sand in 1975, with some fine and a little medium sand towards its edges (Fig 4). In 1978 there appeared to be a higher proportion of fine sand. The graphical method of Folk and Ward (1957) was used to calculate the means and standard deviations of the sieved grab and box core samples, giving a range of mean grain sizes from 3.38ø to 2.19ø ie very fine to fine sand. The grab sample, ie 1975, mean values have been incorporated into Fig 4, but the box core samples date from 1977, so are included as an inset to Fig 5. The limited statistical parameters show that the finer sediments were found towards the crest of the bank in 1975, and in the col in 1977. The consistently small standard deviations which range from 0.26ø to 0.71ø are indicative of well-sorted to moderately well-sorted sediments.

In the northern part of the area the sand forms the Dunwich Bank. To the NW, the boundary between the bank sand and the clay, identified by boomer and grab samples, is supported by sidescan sonar evidence. The distribution of the sand surface has been found to change with time (Figs 4, 5 and 6A-F). A comparison of the 1975 grab sample survey with the background tracer survey of August 1978 (Figs 4 and 5) shows that the Dunwich Bank sand became less extensive to both the W and E and thereby uncovered the underlying blue-grey clay. In contrast the veneer of sand at the northern end of the bank was thicker in 1978. Both surveys show that over most of the exposed blue-grey clay there is frequently a veneer of sand, often brownish and only a few grains thick, although this may be an artefact of sampling (see P 11).

Fig 6A-F shows the results of grab sampling over a limited area at the SE corner of the Dunwich Bank, no more than 1.6km long and 0.5km wide. There were six surveys made at intervals from 22 August 1978 to 9 April 1979 and the amount of clean sand exposed on the seabed varied from survey to survey. In February 1979 the area surveyed comprised almost entirely sand, while in April 1979 there was more pure sand than the sand, silt and clay admixture. However in the August and October 1978 surveys, the sands, silts and clays assemblage predominated.

The thickness of the sand has been determined from the geophysical records with the vibrocores adding further detail in certain areas. Its base is easily recognised beneath the crest of the Dunwich Bank, but becomes more difficult to distinguish further S. The sand has a maximum thickness of 9.5m over the Dunwich Bank and probably more than 7.0m over the Sizewell Bank. The sediment shows a seismically srtuctureless layer up to 2.0m thick at the surface, possibly representing the surface mobile layer (Fig 10E and F).

Analysis of VC 18 sited N of the banks (Fig 8D) shows a well sorted very fine sand, creamy-grey in colour when dry, from the surface to a depth of 2.04m. Sand in VC 12 (Fig 8B), N of VC 18, was 0.59m thick during the same survey, but it lay beneath 0.54m clay. The sand is lithologically different from that in VC 18, particularly in being poorly sorted and containing virtually no calcium carbonate, compared with 15% in VC 18 sand. It therefore cannot be classified as bank sand, but is more likely to be part of a series of estuarine deposits.

At VC 17 (Fig 8C), on the inner edge of the bank, the bank sand was 0.18m thick. The sand thickness in VCs 13, 14 and 15, located at the SE corner of the Dunwich Bank was 2.35m, 2.82m and 1.49m thick respectively. This sand also is very fine, and creamy-grey when dry, but with occasional darker clay laminations and it too is classified as bank sand.

In the S the sand forms the Sizewell Bank and extends over much of the peripheral area to the E and S (Figs 4 and 5). The col area between the banks was composed of sand at the seabed surface in April 1975 and February 1979, but soft clays, silts and sands in August and October 1978, and April 1979 (Fig 4). VC 7 (Fig 8B), located near the centre of this area, and obtained in March 1978 shows very fine sand to a depth of 0.94m and silty clay below this to a depth of 3.95m.

Three vibrocores were drilled in the Sizewell Bank area of sand. VC 8 on the seaward edge (Fig 8B) shows the very fine sand to be 1.39m thick. The sand is creamy-grey in colour, similar in appearance to the sand at the top of VC 18, but additionally contains some clay, and fragmented and comminuted shell. VCs 2 and 4, further S (Fig 8A) penetrated sand with a thickness of 1.42m in VC 2 (coarse and medium sand) and 1.12m, with current bedding in VC 4 (fine and very fine sand). These sands are not part of the bank sands sensu stricto. Although the base of the sand is less clear on the geophysical records in this southern area, the sand appears to have a maximum thickness of 7.3m at the northern end of the Sizewell Bank. South of this the horizon cannot be identified with any certainty.

Immediately E of the Sizewell Bank sand is an area of sands, silts and clays and there is a zone of medium sand to the E of that (Fig 4). However, these sand sediments are away from the study area and have not been analysed further.

4. Discussion

Although a detailed geological investigation is not within the remit of this project, a knowledge of the local geology is helpful when considering the materials which contribute to an overall sediment budget.

In the SW of the area around Thorpeness, the yellow sands on the seabed are modern, incorporating fossils derived from the Coralline Crag as shown at the top of VC 21. The Coralline Crag itself is present in VC 21 at 0.17m below the seabed surface thus supporting the hypothesis that the core of Thorpeness is composed of this Pliocene rock (Fig 11A). Sidescan sonar records confirm that there is rock exposed on the seafloor in this area showing a WSW - ENE strike. The absence of Coralline Crag in VCs 2 and 4 suggests that the rock either dips sharply to the SE, or more probably that the formation does not extend any further S in that particular area.

The main bedrock in the area, lying unconformably against the Coralline Crag is the Norwich Crag Series of Pleistocene age, recognised by the fossils in the yellow sediments at the base of cores VC 1 and VC 20 (Fig 11A, B and C). At least the uppermost sediments of this Crag, seen in VCs 5, 6, 7, 8, 16 and 18 (Fig 9) are reworked, as they contain fragments of fresh shells in addition to the Norwich Crag fauna. The junction between the Crag and overlying sediments cannot be readily identified by geophysical means because of the unconsolidated nature of much of the bedrock material, and hence it is not possible to determine the total thickness of the overlying sediments. However, vibrocore evidence suggests that there is an overall dip of the surface to the E. This evidence includes a minimum depth of 10.4m below OD Newlyn at VC6 (reworked Norwich Crag) to a maximum of 25.0m below OD at VC1 (Norwich Crag in situ, Fig 9). The vibrocores which have penetrated Norwich Crag or derived Norwich Crag are situated away from the thickest superficial sediments, ie the bank area, and all show thicknesses above the Pleistocene of less than 2.6m below the seabed surface.

The sticky blue-grey clay in the north of the area lying above the Norwich Crag Series, and forming the platform on which the Dunwich Bank rests, is, judging by the microfossil content, of marine alluvial origin, probably found in a broad coastal estuary, (Fig 11B). It is a continuation offshore of the alluvium in the valleys now represented by Dingle, Westwood and Corporation Marshes, the Minsmere Nature Reserve (Fig 1), the River Blyth, and the buried channels offshore (Fig 7). Vivianite, found in VC9, is often associated with such clays, because a source of phosphate is provided by fossil bones and shells (Read, 1972). The abundant reworked Crag foraminifers in the clays of VCs 4, 5, 6 and 16 indicate the proximity of the Crag coastline to these sites.

The chalk found within the clay stratum of VC19 may possibly have been derived either directly from the Chalky Boulder Clay of Anglian age (West, 1977) or washed downstream by the proto-Blyth river. The microfossil content is dominated by plant debris, with gypsum crystals and benthonic foraminifers in the upper part, and in the lower, a few benthonic foraminifers, but mainly ostracods (Funnel, personal communication). The deposits in this core could perhaps be lagoonal in origin.

The sand forming the banks is different from the iron-stained sands on the seabed near Thorpeness in showing a small mean grain size, and a relative absence of iron-staining. There is also a higher percentage of mainly angular quartz grains, a few of which show frosting. A little glauconite is present, but no derived Pliocene or Pleistocene fossils have been found. The mean grain size shows an overlap with sands from the Minsmere cliffs. The products of cliff erosion are one possible source of sand to the area, but sources outside the study area should also be considered, particularly when bearing in mind the strong tidal currents which run parallel to the coast.

Over most of the northern part of the study area the bank sand lies directly on the alluvial clay (Fig 11B). At VC12 there is very fine sand beneath 0.54m of blue-grey clay, but it differs from the bank sand in sorting and composition as well as in lying beneath the clay and therefore should not be considered as part of the bank. The sand at the top of VC9 is probably a continuation of the shore sand below low tide level.

It is not clear whether the changes in the col area between the banks from sand to intercalated sands, silts and clays and back are longterm or seasonal;

more probably the latter. Sampling showed the following sequence: April 1975, sand; March 1978, sand (one vibrocore); August 1978, sands, silts and clays; October 1978, sands silts and clays; February 1979, sand; April 1979, sands, silts and clays.

Although it seems possible that the gravel to the E forms a thin layer only, (grab samples and VC 19) it appears from the biota to be fairly stable. The gravel is not a contributory deposit when considering sediment movement in the banks area.

The presence of the Sizewell Nuclear Power Station intake and outfall appears to have some effect on the sediment distribution. It seems likely that the immediately adjacent areas are kept clear of sand by the increased water flow which prevails.

5. Conclusions

The structure of the study area is summed up in the schematic sections through the seabed shown in Fig 11.

The oldest in situ rock identified is the Coralline Crag of Pliocene age. It forms the core and seaward extension of Thorpeness at the southern end of the area, and has a WSW - ENE strike. Much of the Coralline Crag is harder and therefore less easily eroded than sediments outcropping further along the coast to the North. The upper surface has been reworked, incorporating the iron-stained sands and shells into modern sediments and these appear to have spread northwards over the seabed in a strip close to the shore. They may have spread as far as Minsmere Cliffs, but it is also possible that this iron-staining of the sands has been derived from sediments of the Norwich Crag Series.

Unconsolidated Pleistocene sediments of the Norwich Crag Series of sands, clays and gravels mentioned above, comprise much of the coast between Thorpeness and Dunwich, and also the main bedrock offshore lying unconformably against the Coralline Crag. Norwich Crag in situ has been identified in two cores at depths of 14.5m and 25.0m below O.D. approximately 4.0 and 4.5km offshore respectively. Reworked sediments from the top of this Crag, retaining the iron-staining, have been located in eight vibrocores, the depths showing an overall dip of the Norwich Crag surface to the E.

In the N the Crag is overlain by a marine alluvial clay beneath which infilled channels have been detected. These may be part of the proto-Blyth river system or glacial channels. The alluvium is almost certainly similar to that in the valley system represented by the present day marshes between Dunwich and Southwold and those forming the Minsmere Nature Reserve and indicates the site of a former broad coastal estuary with the coastline at one stage near the site of VCs 4,5,6 and 16. At present the marshes are partly protected from the sea by a shingle ridge and dunes.

The most recent sediments are the sands and intercalated sands, silts and clays. Together they form the Sizewell and Dunwich Banks and adjacent areas. They lie on the alluvium in the N and probably on reworked Norwich Crag in the S.

There is variation in the distribution of these two types of sediment relative to one another, which is probably a seasonal phenomenon. Whereas the banks themselves are always composed of sand, up to 9.5m thick in the N and 7.3m in the S, surveys have shown that the surface of the col area between comprises sand in winter and sands, silts and clays in summer and autumn. It seems likely that minor variations occur all the time, but that the seasonal one predominates. It is these bank sands which are of particular importance for sediment transport measurements. The sands are well sorted and of very fine or fine grade, with some fine and medium sands at the edges of the bank. They have only some properties in common with the local shore sands (Topic Reports 2, 3). It seems reasonable to envisage more than one source, especially as the coast of East Anglia has extensive unconsolidated sediments giving potentially rich sources of sediment supply. There is material in suspension throughout the water column overlapping in grain size with the bank sand, and strong tides with speeds up to 150cm s^{-1} flow parallel to the coast.

A study of the tidal dynamics at present being undertaken for a subsequent Topic Report will provide further evidence towards understanding how sediment behaves in this area. A later Topic Report will discuss the experiments which have measured directly rates of sediment transport of sand in suspension and along the seabed.

6. Acknowledgements

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TABLE 1.

Grain size analysis of selected grab and box core samples.

Type of sample and number	% of mud	% of sand	% of gravel	Mean of sand fraction	Standard Deviation of sand fraction
Grab sample					
128	Nil	94.2	5.8	1.06∅	0.71∅
141	8.7	91.3	Nil	3.09	0.46
143	Nil	100.0	Nil	2.55	0.26
169	Nil	100.0	Nil	2.12	0.58
Box core					
12	5.8	94.2	Nil	3.38	0.64
14	1.0	99.0	Nil	2.89	0.32
18	0.3	99.7	Nil	2.52	0.47
20	0.3	99.7	Nil	2.19	0.48
23	1.0	99.0	Nil	2.74	0.33
31	2.0	98.0	Nil	3.02	0.43
37	1.0	99.0	Nil	2.92	0.43
41	1.6	98.4	Nil	3.01∅	0.38∅

APPENDIX 1 List of macrospecies found in iron-stained sands from vibrocores

Vibrocore number + depths	Lamellibranchiata	Gastropoda	Other species	Age
1 2.18m to 3.64m	Yoldia lanceolata Mytilus edulis Spisula Chlamys opercularis group Macoma praetenuis? Cardium edule group Mya	Littorina	Barnacle valves	Norwich Crag Series
5 1.52m to 1.77m	Nucula "Mactra" Macoma balthica Abra Cardium + derived Norwich Crag Series forms: Mytilus, Chlamys, Cardium, Yoldia, Littorina			Recent
6 1.64m to 1.70m	Nucula Macoma balthica			Recent
7 3.95m to 3.98m	Nucula Macoma	Hydrobia		Recent
8 1.24m to 1.56m	Nucula "Spisula" Macoma balthica Ostrea	Hydrobia Buccinum		Recent
1.56m to 2.09m	Ostrea Chlamys + Coralline Crag "Rockbed"		Bryozoa Regular echinoid (fragment) Barnacle valves	Coralline Crag
16 1.17m to 1.47m	Nucula "Spisula" Abra	Hydrobia		Recent

APPENDIX 1 (continued)

Vibrocore number + depths	Lamellibranchiata	Gastropoda	Other species	Age
18 2.58m to 2.69m	Nucula			Recent
20 0m to 0.17m	Nucula Mytilus edulis			Recent
0.17m to 1.87m	Yoldia lanceolata Mytilus edulis Spisula Chlamys opercularis group Cardium Macoma ?praetenuis Macoma ?obliqua Ensis Corbula Hiatella arctica	Nucella Buccinum Turritella ?incrassata	Barnacle valves	Norwich Crag Series
21 0.13m to 1.19m	Chlamys opercularis group Coralline Crag "Rockbed"	Scala	Bryoza Barnacle valves	Coralline Crag

Location map of Sizewell-Dunwich Banks showing Trisponder & vibrocore stations; also grab sample & box core stations mentioned in text.

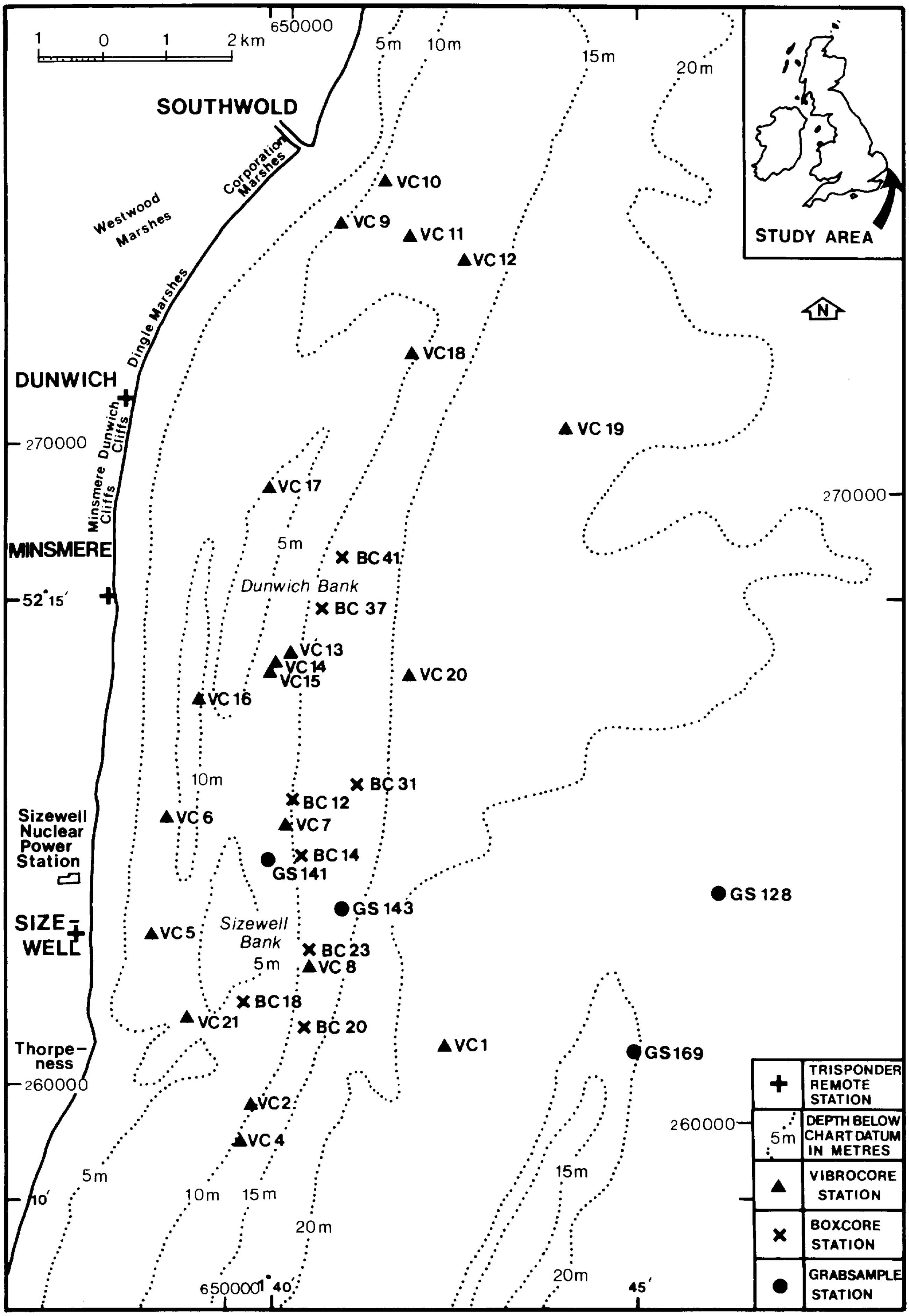


Fig.1

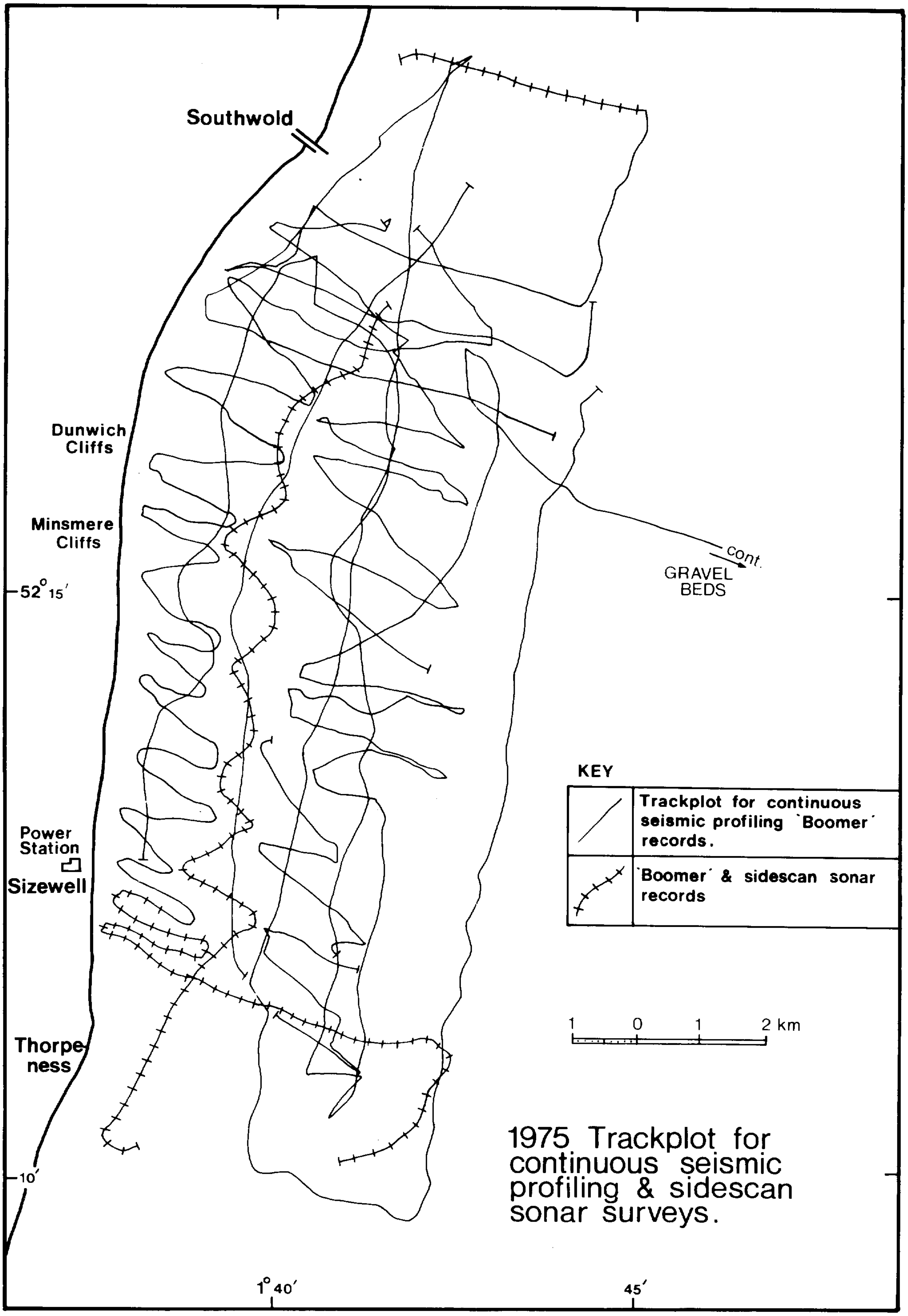

Southwold
Dunwich
Cliffs
Minsmere
Cliffs
52° 15′
Power
Station
Sizewell
Thorpeness
10′
1° 40′
45′
cont.
GRAVEL
BEDS
KEY
Trackplot for continuous seismic profiling 'Boomer' records.
'Boomer' & sidescan sonar records
1 0 1 2 km
1975 Trackplot for continuous seismic profiling & sidescan sonar surveys.

Fig. 3

Key for figs 4 and 5

a Exposures of rock ridges (Coralline Crag), with strike direction as shown by sidescan sonar.

b Gravel. Angular and rounded pebbles, mainly orangey flints. Good fauna, mainly sessile forms.

c Medium sand)
d Fine sand } Clean, brownish to yellowish, firm.
e Very fine sand)

f Intercalated sands, silts and clays. Mainly grey. 'Fluid'.

g Sticky blue-grey clay, often with veneer of brown silt or sand.

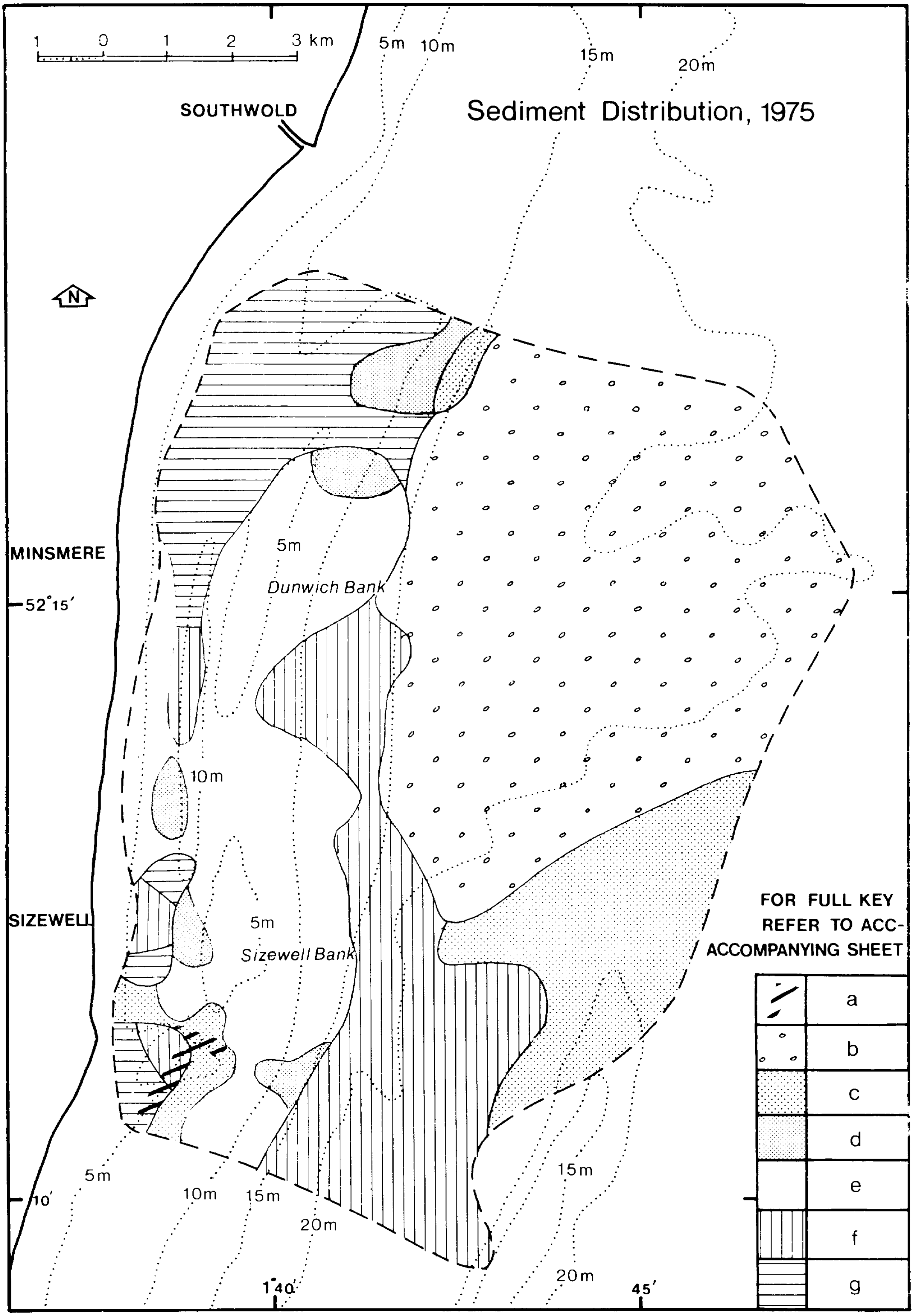

1 0 1 2 3 km
SOUTHWOLD
Sediment Distribution, 1975
5m
10m
15m
20m
MINSMERE
52°15′
5m
Dunwich Bank
10m
SIZEWELL
5m
Sizewell Bank
FOR FULL KEY REFER TO ACC-ACCOMPANYING SHEET
a
b
c
d
e
f
g
10′
5m
10m
15m
20m
15m
20m
1°40′
45′

Fig. 4

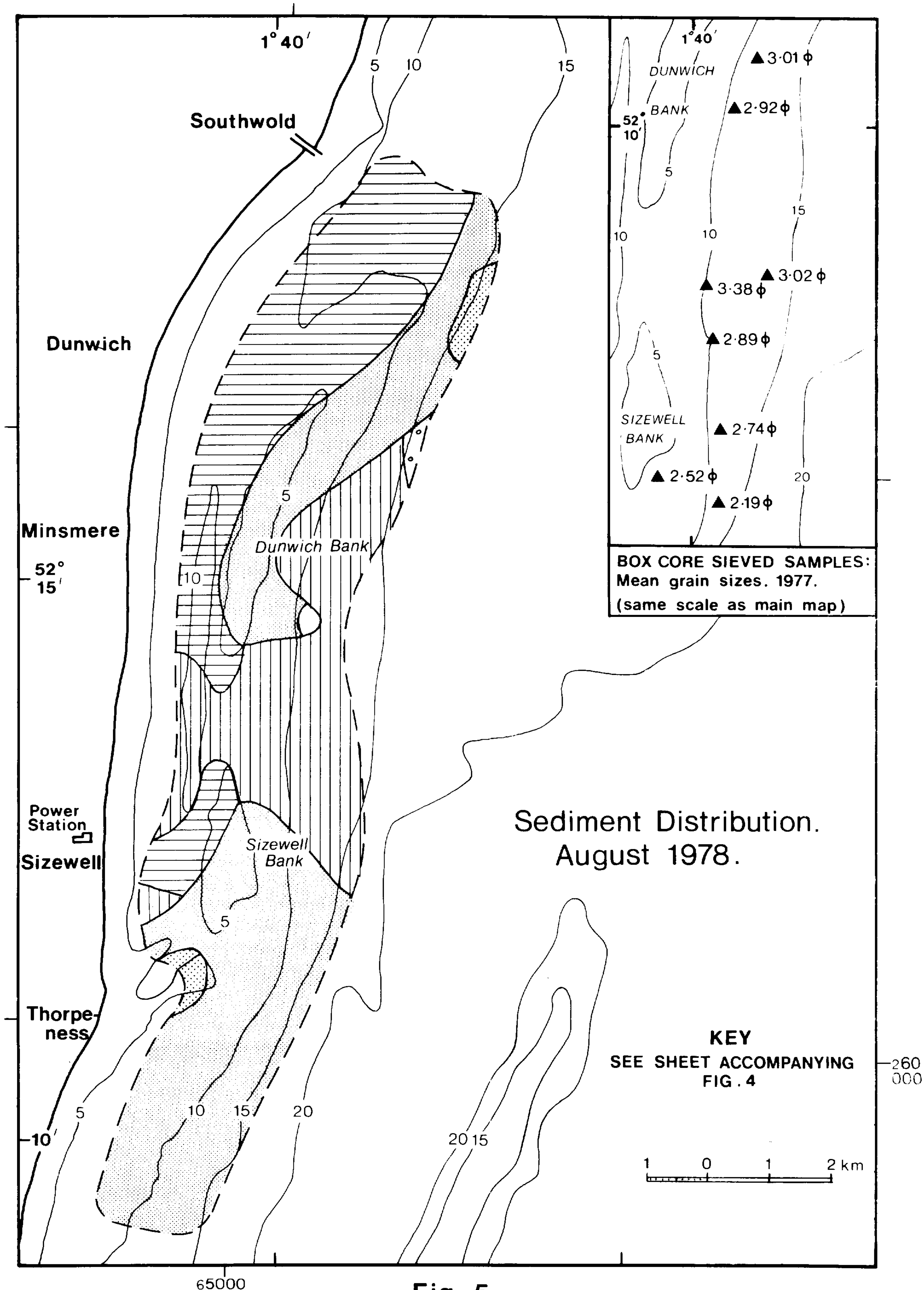
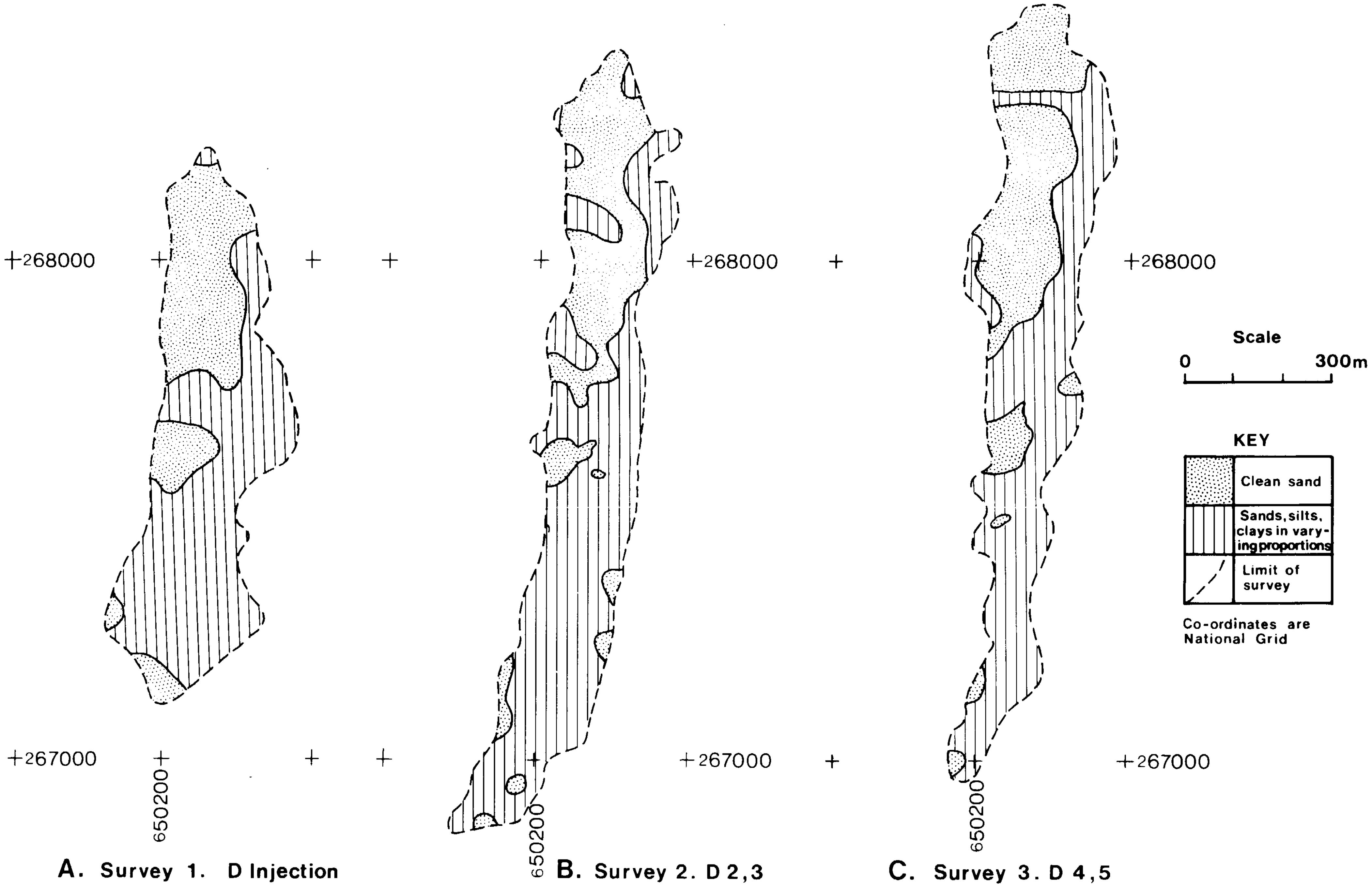

1° 40′
Southwold
Dunwich
Minsmere
52° 15′
Power Station
Sizewell
Thorpe-ness
-10′
5
10
15
20
Dunwich Bank
Sizewell Bank
65000
260 000
Sediment Distribution.
August 1978.
KEY
SEE SHEET ACCOMPANYING FIG. 4
1 0 1 2 km
DUNWICH BANK
52° 10′
SIZEWELL BANK
3·01 ϕ
2·92 ϕ
3·38 ϕ
3·02 ϕ
2·89 ϕ
2·74 ϕ
2·52 ϕ
2·19 ϕ
BOX CORE SIEVED SAMPLES:
Mean grain sizes. 1977.
(same scale as main map)

Fig. 5



A. Survey 1. D Injection
22 Aug. 1978

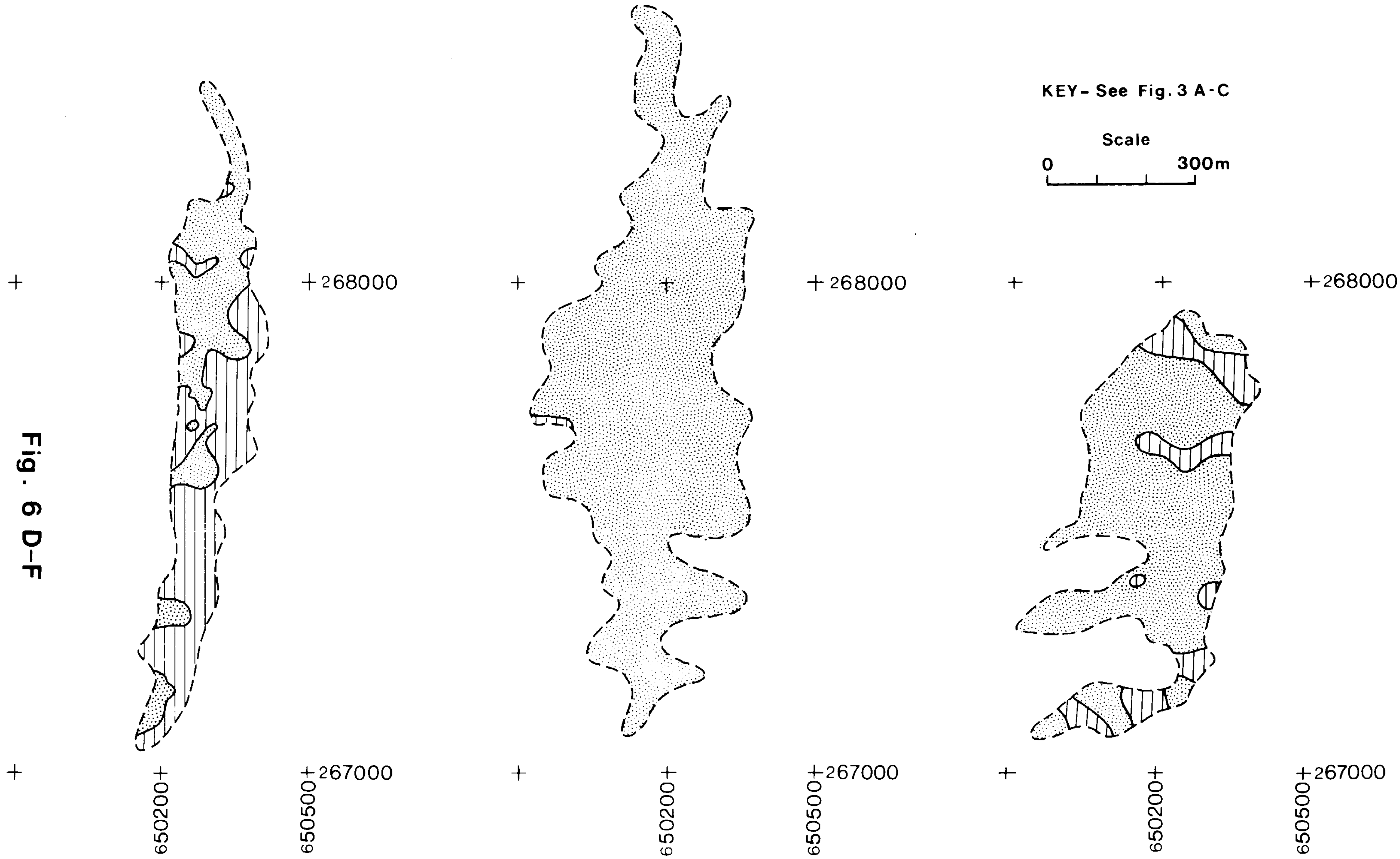
B. Survey 2. D 2,3
24-25 Aug. 1978

C. Survey 3. D 4,5
26-27 Aug. 1978

Fluorescent tracer surveys showing sand, and sand, silt, clay distribution.

Fig. 6 A-C

Fig. 6 D-F



D. Survey 5. D49-51
10-12 Oct. 1978

E. Survey 6. D164,165
2-3 Feb. 1979

F. Survey 7. D229,230
8-9 April 1979

Fluorescent tracer surveys showing sand, and sand, silt, clay distribution.

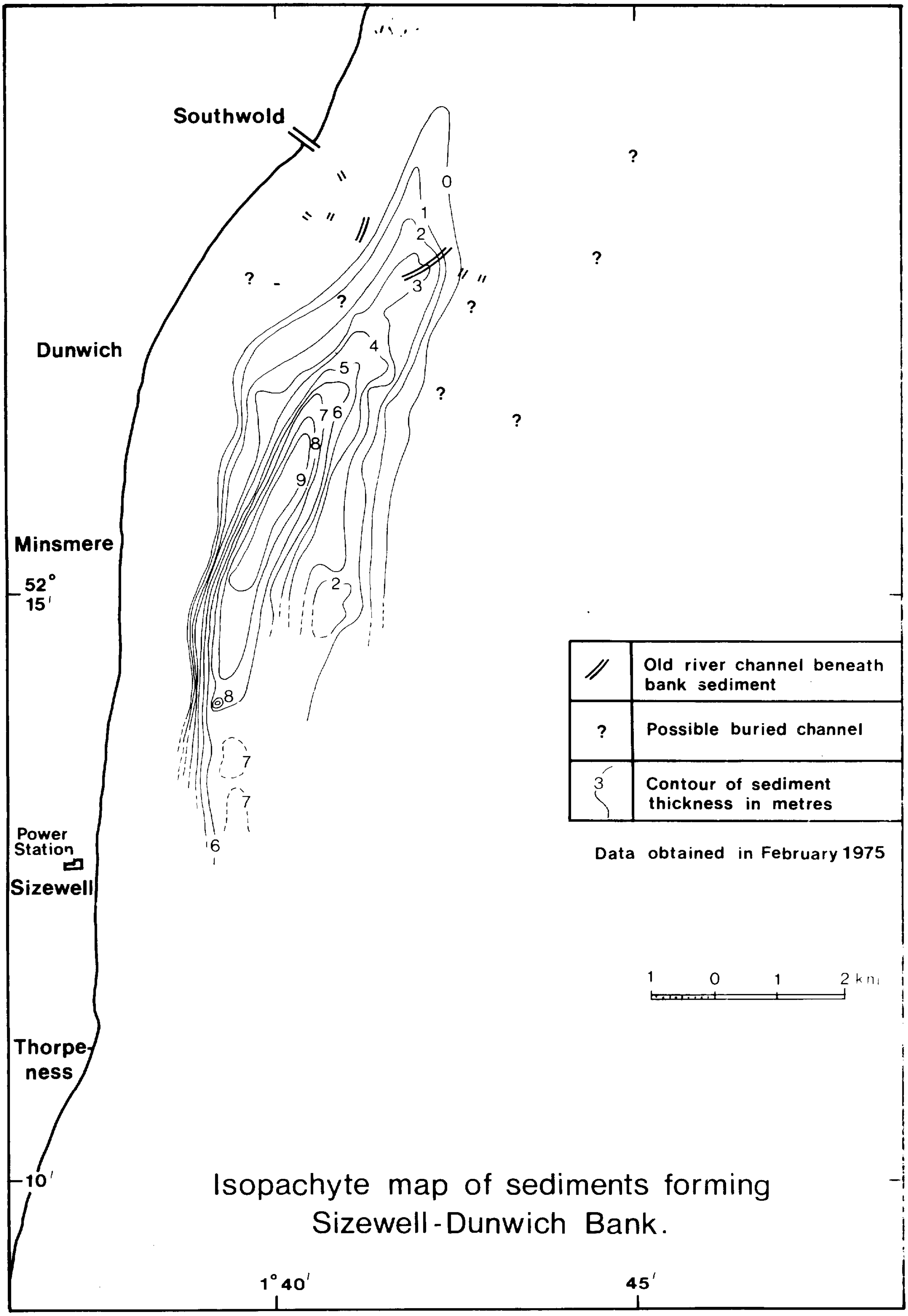

Southwold
Dunwich
Minsmere
52° 15′
Power Station
Sizewell
Thorpeness
10′
1°40′
45′
Old river channel beneath bank sediment
Possible buried channel
Contour of sediment thickness in metres
Data obtained in February 1975
1 0 1 2 km
Isopachyte map of sediments forming Sizewell-Dunwich Bank.

Fig. 7

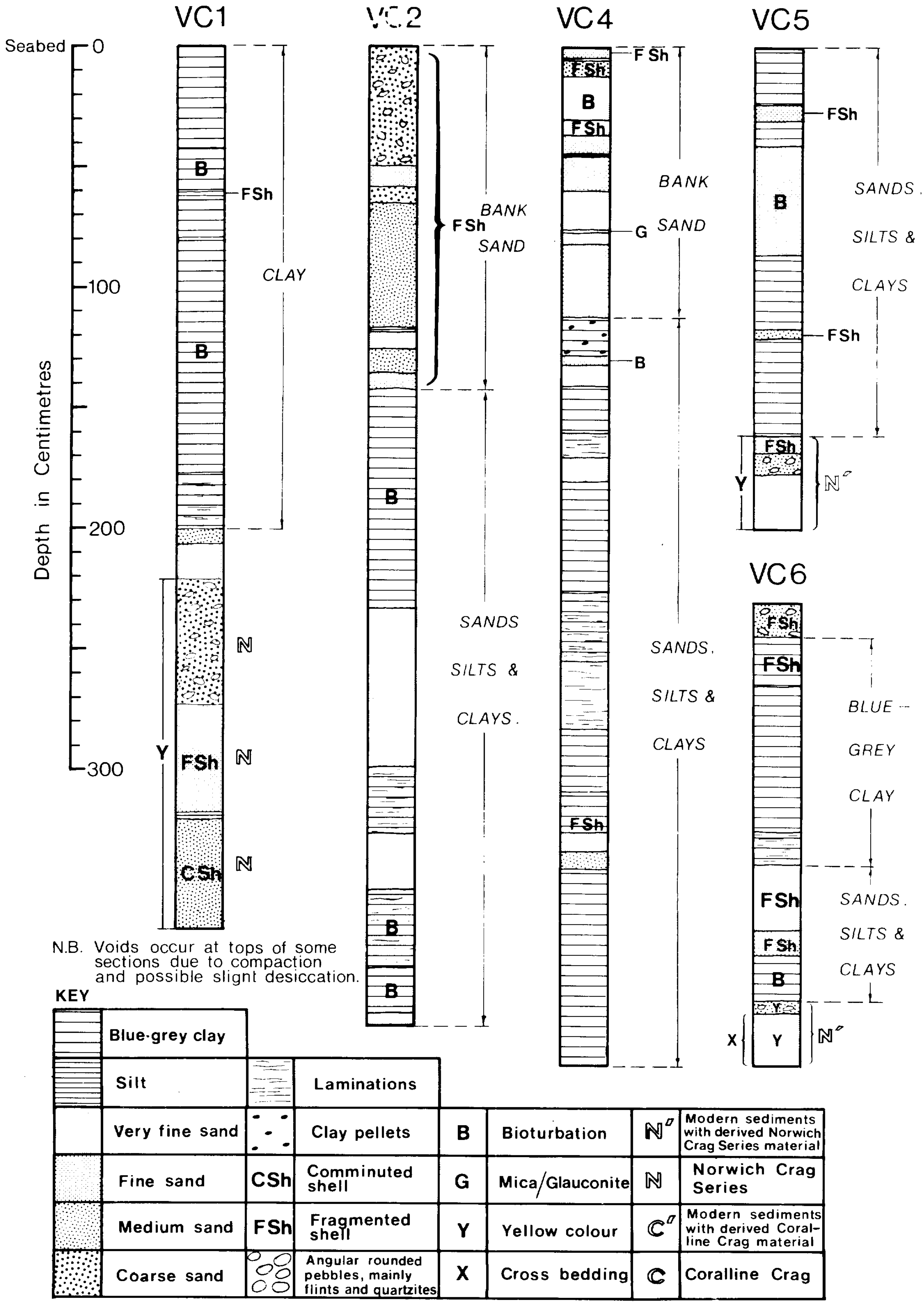

VC1
VC2
VC4
VC5
VC6
Seabed
0
100
200
300
Depth in Centimetres
B
FSh
CLAY
B
N
Y
FSh
N
CSh
N
BANK
SAND
FSh
B
SANDS
SILTS &
CLAYS.
B
B
F Sh
F Sh
B
F Sh
G
BANK
SAND
B
SANDS.
SILTS &
CLAYS
FSh
FSh
B
SANDS.
SILTS &
CLAYS
FSh
FSh
Y
N
FSh
FSh
BLUE-
GREY
CLAY
FSh
SANDS.
SILTS &
CLAYS
F Sh
B
Y
X
Y
N
N.B. Voids occur at tops of some sections due to compaction and possible slight desiccation.
KEY
Blue-grey clay
Silt
Laminations
Very fine sand
Clay pellets
B
Bioturbation
N
Modern sediments with derived Norwich Crag Series material
Fine sand
CSh
Comminuted shell
G
Mica/Glauconite
N
Norwich Crag Series
Medium sand
FSh
Fragmented shell
Y
Yellow colour
C
Modern sediments with derived Coralline Crag material
Coarse sand
Angular rounded pebbles, mainly flints and quartzites
X
Cross bedding
C
Coralline Crag

Fig. 8A

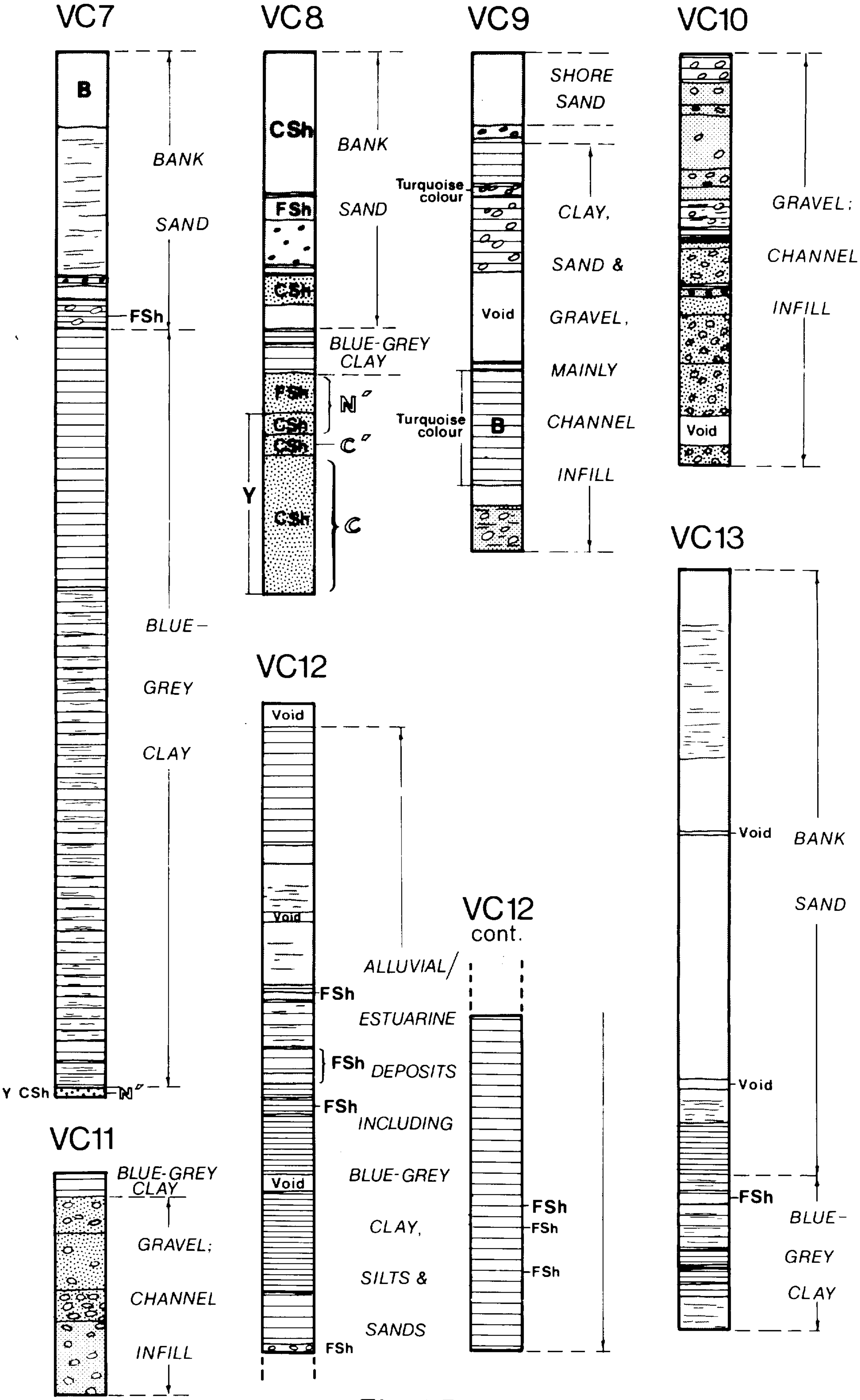

VC7
B
BANK
SAND
FSh
BLUE-
GREY
CLAY
Y CSh
VC8
CSh
BANK
FSh
SAND
CSh
BLUE-GREY
CLAY
FSh
CSh
CSh
Y
CSh
VC9
SHORE
SAND
Turquoise colour
CLAY,
SAND &
GRAVEL,
MAINLY
CHANNEL
INFILL
Void
Turquoise colour
B
VC10
GRAVEL;
CHANNEL
INFILL
Void
VC11
BLUE-GREY
CLAY
GRAVEL;
CHANNEL
INFILL
VC12
Void
Void
FSh
FSh
FSh
Void
FSh
ALLUVIAL/
ESTUARINE
DEPOSITS
INCLUDING
BLUE-GREY
CLAY,
SILTS &
SANDS
VC12
cont.
FSh
FSh
FSh
VC13
Void
BANK
SAND
Void
FSh
BLUE-
GREY
CLAY

Fig. 8B

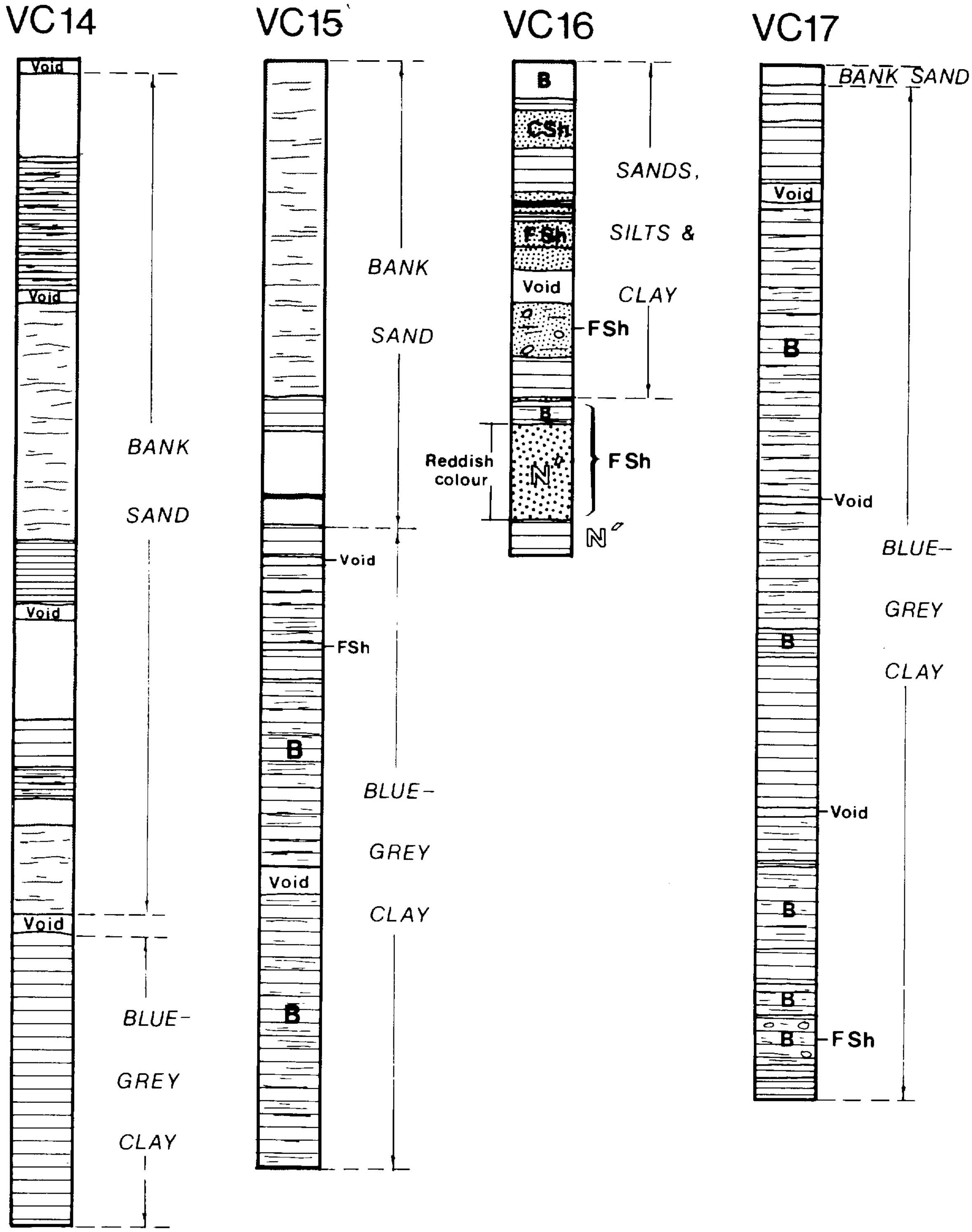
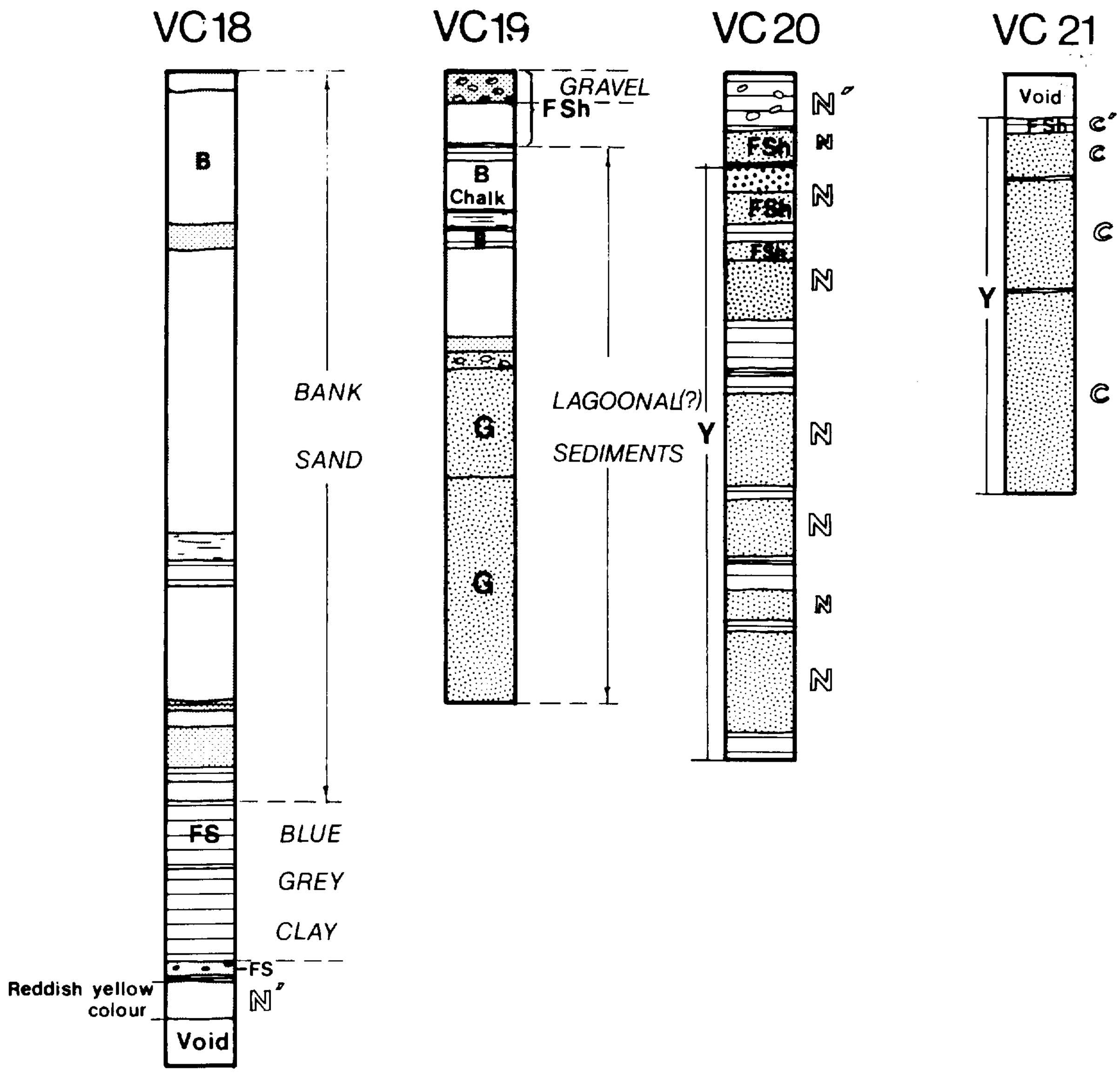
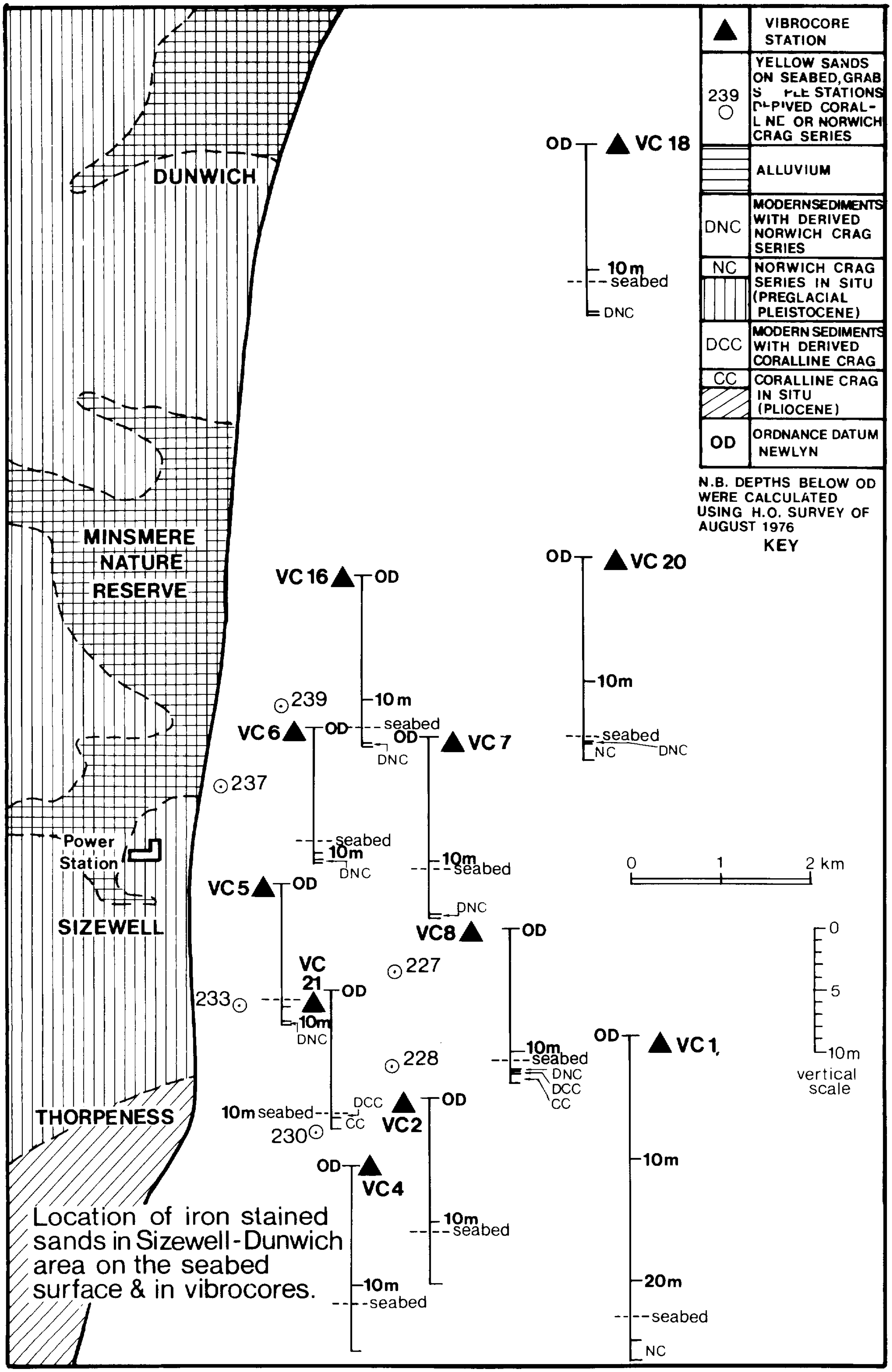

VC14
Void
Void
BANK
SAND
Void
Void
BLUE-
GREY
CLAY
VC15
BANK
SAND
Void
FSh
B
BLUE-
GREY
CLAY
Void
B
VC16
B
CSh
SANDS,
SILTS &
CLAY
FSh
Void
FSh
B
Reddish
colour
FSh
VC17
BANK SAND
Void
B
Void
BLUE-
GREY
CLAY
B
Void
B
B
B
FSh

Fig. 8 C



VC18
VC19
VC20
VC 21
B
BANK
SAND
FS
BLUE
GREY
CLAY
FS
Reddish yellow colour
Void
GRAVEL
F Sh
B
Chalk
G
G
LAGOONAL(?)
SEDIMENTS
FSh
FSh
FSh
Y
Void
FSh
Y

Fig. 8D



VIBROCORE STATION
239
YELLOW SANDS ON SEABED, GRAB S PLE STATIONS DERIVED CORALLINE OR NORWICH CRAG SERIES
ALLUVIUM
DNC
MODERN SEDIMENTS WITH DERIVED NORWICH CRAG SERIES
NC
NORWICH CRAG SERIES IN SITU (PREGLACIAL PLEISTOCENE)
DCC
MODERN SEDIMENTS WITH DERIVED CORALLINE CRAG
CC
CORALLINE CRAG IN SITU (PLIOCENE)
OD
ORDNANCE DATUM NEWLYN
N.B. DEPTHS BELOW OD WERE CALCULATED USING H.O. SURVEY OF AUGUST 1976
KEY
DUNWICH
MINSMERE NATURE RESERVE
Power Station
SIZEWELL
THORPENESS
VC 18
VC 20
VC 16
VC 6
VC 7
VC 5
VC 21
VC 8
VC 2
VC 4
VC 1
OD
10m
20m
seabed
239
237
233
227
228
230
0
1
2 km
0
5
10m
vertical scale
Location of iron stained sands in Sizewell-Dunwich area on the seabed surface & in vibrocores.

Fig. 9

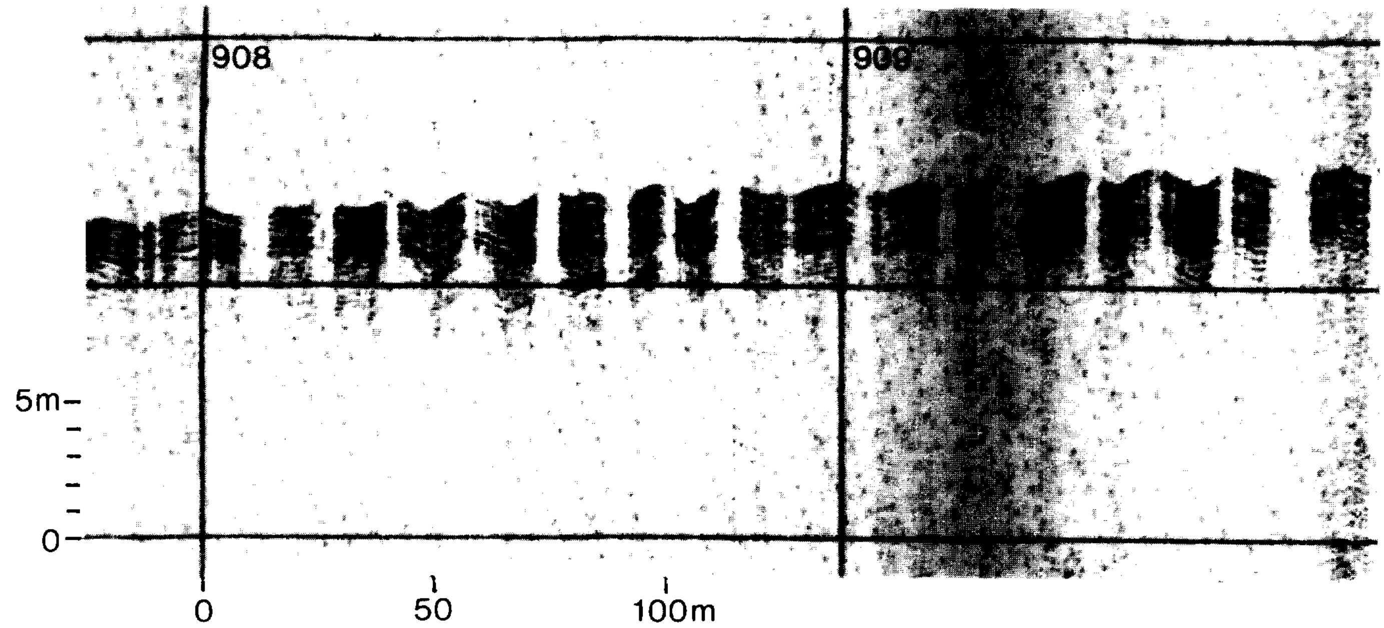


Fig. 10 A Part of geophysical record showing reflections from alternating layers of sand and clay of Norwich Crag Series.

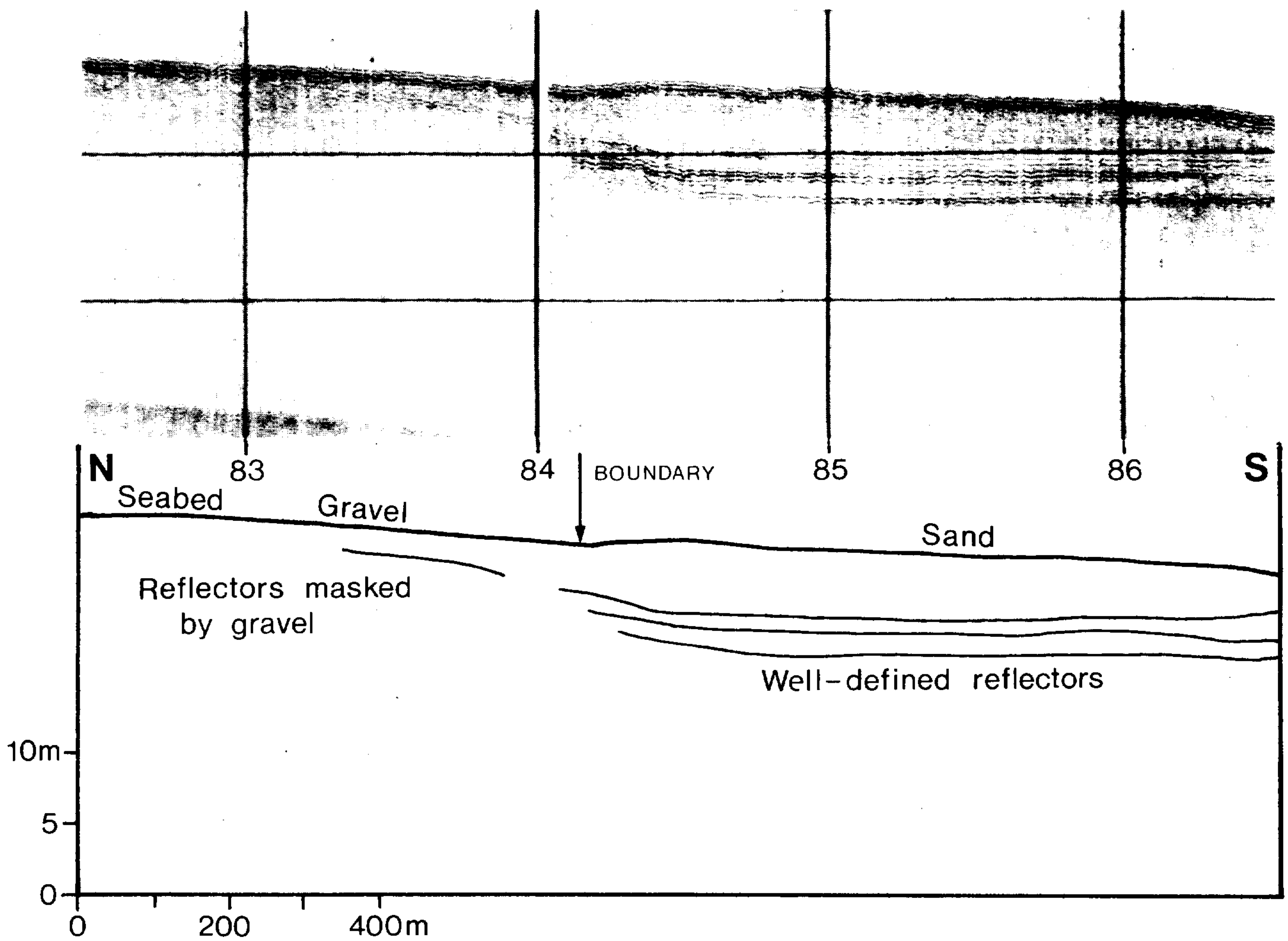


Fig. 10 B Traverse showing boundary between gravel and sand on seabed surface.

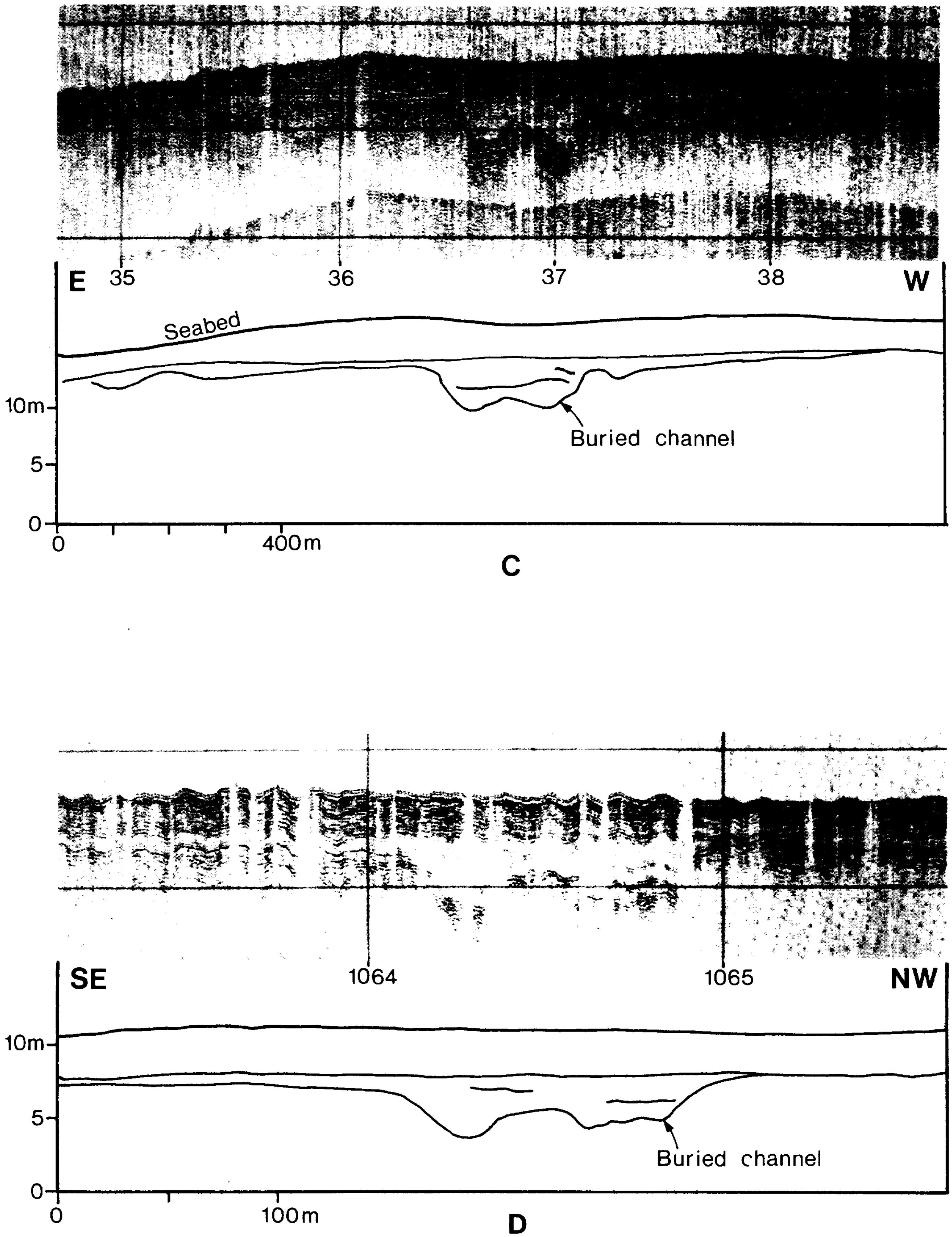


Fig.10 C& D. Two traverses of a buried channel 2 km SE of Southwold harbour entrance.

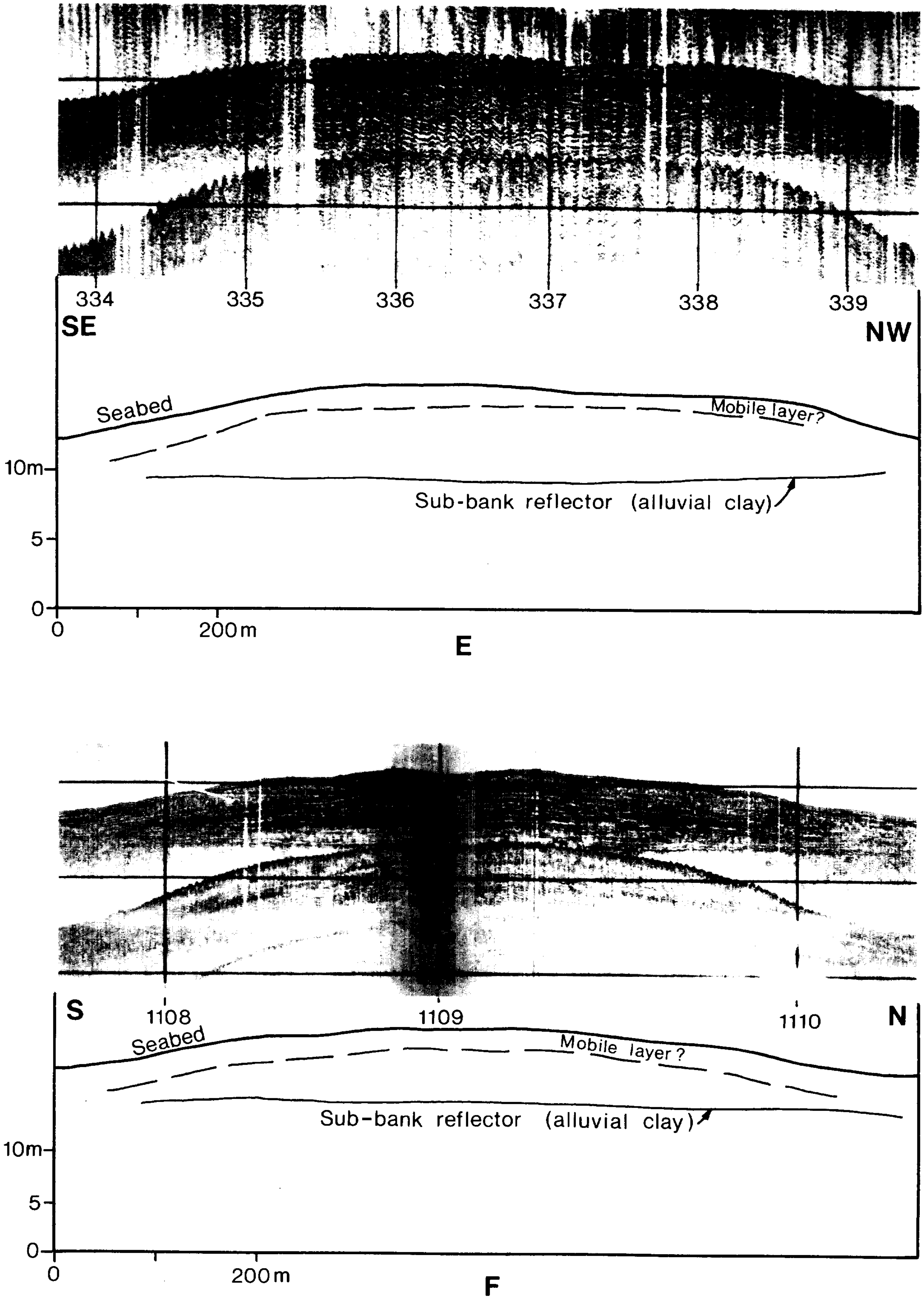
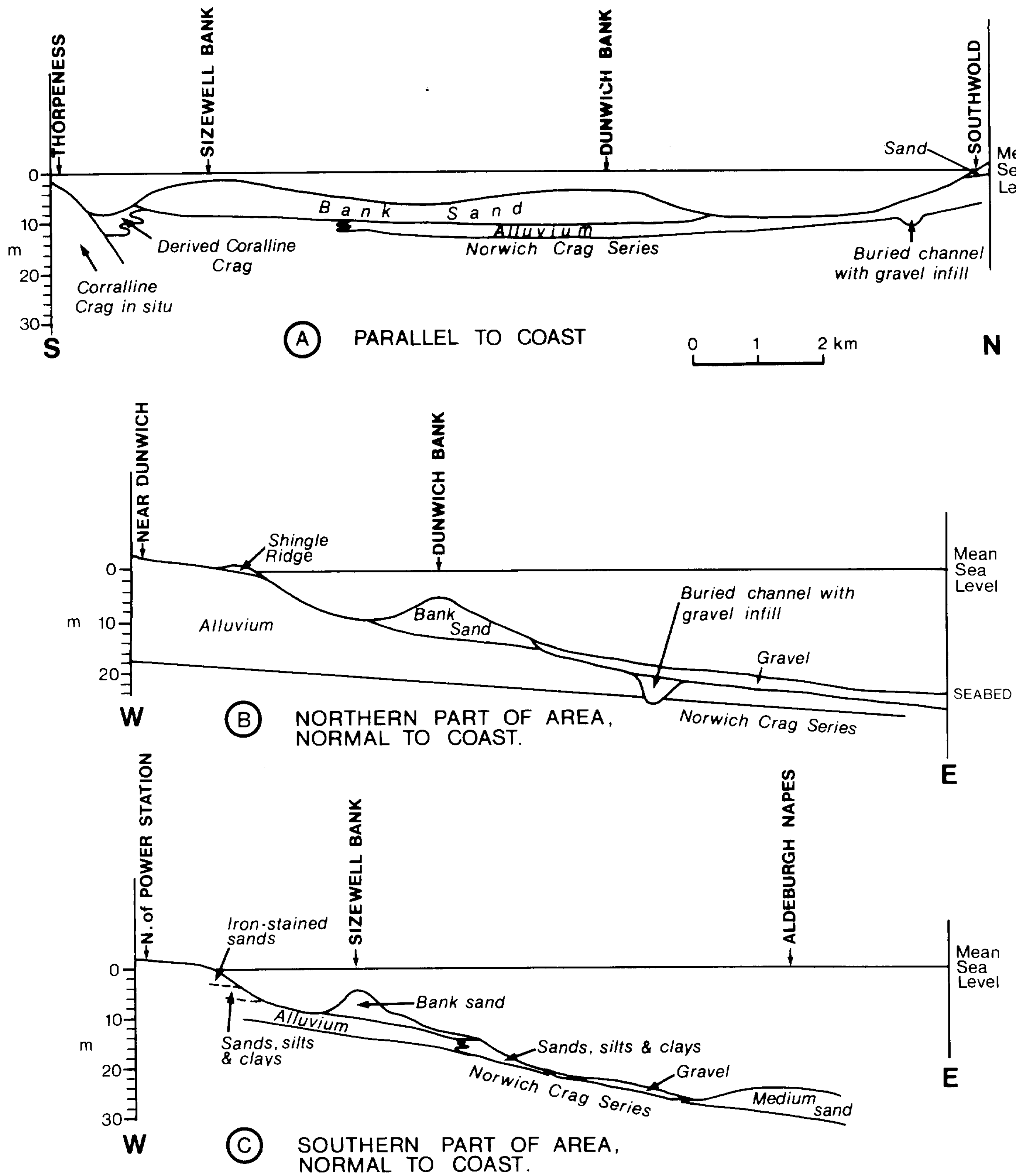


Fig. 10 E & F. Traverses of SW part of Dunwich Bank showing sediments lying on alluvial clay, with probable mobile layer at surface.



Schematic sections of seabed.

Fig.11