PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Offshore Morphology and Sediment Distribution, Start Bay, Devon

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Offshore morphology and sediment distribution, Start Bay, Devon

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[Plates 3 and 4]

The bedrock morphology of Start Bay and structures within overlying sediments have been determined by a combined geophysical and geological survey. Analysis of about 50 vibrocore and 200 bottom samples show that three discrete lithologic units, invariably defined by sharp boundaries, can be identified within the Bay. These have been described as *barrier*, *bay* and *bank* deposits. The barrier deposits consist of shingle or beach gravel and occupy a relatively narrow zone extending from the backshore of barrier beaches to about 200 m beyond low water mark. The main constituents are flint, chert and quartzite with a small amount of rhyolite, felsite and granite. In contrast, the bay deposits are composed of medium- to fine-grained sand, with varying concentrations of silt, and whole and broken shell. Although the bay deposits attain a maximum thickness of 28 m, there are several areas in the nearshore zone where they are less than 1 m thick and where bedrock is exposed. The bank deposits are mainly coarse shelly sand and approximately occupy the area of the Skerries Bank which, in fact, consists of a drape of possibly unconsolidated material overlying the bay deposits.

A break of slope in the bedrock surface, traced along the entire length of Start Bay, and a step profile in the southern part of the Bay, may be either a legacy of submerged topography produced by vigorous tidal action or, alternatively, the product of subaerial and marine processes. Other significant geological features include buried channels and relict barrier beaches.

1. Introduction

There has been and still remains speculation about the origin and composition of some nearshore banks along the English Channel coast, and their relation to both the water circulation and sediment budget (and possibly their control on shoreline equilibrium) in adjacent bays. The Skerries Bank, Start Bay, Devon, is a typical example which, according to hydrographic surveys completed periodically since 1813, has been relatively stable for nearly a century while several other banks in shallow waters around the British coast have migrated steadily landward (Robinson 1961). Interest has also been centred on Start Bay for more than half a century now because of the conjecture about the severe damage sustained in 1917 by Hallsands fishing village, situated about 1.5 km north of Start Point, during a critical combination of north-easterly gales, spring tides and 12 m waves. Local opinion attributed the disaster at the time to the effects of dredging in the intertidal zone and to the removal of shingle from the foreshore during the period 1897–1902, but until recently this view had never been scientifically substantiated (Hails 1975).

It is not the intention here to review the possible causes of this long-standing controversy, but to describe very briefly the submarine geology and sediment distribution within the Bay as determined during an interdisciplinary research programme which has included continuous seismic profiling, bottom sampling, gravity and vibrocoring, an analysis of nearshore wave conditions, an investigation of tidal currents and the geological history of Start Bay. This work has been undertaken in conjunction with the Department of Physics, University of Bath, the Department of Maritime Civil Engineering, University of Liverpool, and the Institute of Geological Sciences, Continental Shelf Units I and II. The reader's attention is drawn to the more detailed results, and tentative conclusions reached, on the factors controlling sediment movement in the Bay which have been reported by the writer and colleagues in a series of papers published by the Geological Society of London (1975).

Physiography and geology

Start Bay is an asymmetrical embayment, approximately 60 km² in area, with a coastline dominated by east–west trending Lower Devonian clastic rocks known as the Dartmouth Slates, Meadfoot Beds and Staddon Grits (Ussher 1890; Dineley 1961; Richter 1967). The Dartmouth Slates are dominantly metamorphosed argillaceous sediments exposed almost uninterruptedly in the cliffs on both sides of the Dart ria,† apart from some local outcrops of diabase. In contrast, the Meadfoot Beds are essentially a shallow-water facies comprising a variable sequence of strata, frequently showing an alternation of fine laminae of slate and silty material, or consisting of cleaved massive mudstones and siltstones. On the other hand, the Staddon Grits consist of quartzose and quartzitic sandstones, interbedded with thinner shales and slates, and conglomeratic bands. South of Tinsey Head the Devonian strata are faulted against deeply weathered hornblende and chlorite schists which are evident behind Greenstraight (North Hallsands) beach (figure 1). Quartz- and mica-schists crop out in the cliffs between Greenstraight and Start Point, and although their origin is still unknown they are considered to be altered Devonian rocks, but may be remnants of a Lower Palaeozoic or even pre-Palaeozoic landmass that has been brought into contact with Lower Devonian rocks by faulting (Edmonds, McKeown & Williams 1969).

Slapton Ley is a coastal lagoon which now occupies the site of a former marine embayment, the limits of which are defined by a degraded cliff-line along the landward margin of the Ley (figure 1). Small streams which drain the land adjacent to Start Bay, and contributed sediment to the English Channel floor in the past, are now cut off from the sea by barrier beaches such as Bee Sands and Hall Sands and drain into either Slapton Ley or smaller coastal lagoons.

Morphology of the seabed

The submarine contour pattern in figure 1, depicted from Admiralty Chart 1634 on a scale of 1:25000, shows that the seabed forms a gently sloping shelf at a depth of 11–15 m, the outer edge of which is demarcated by a slightly curved break of slope trending in a general northeast–southwest direction. The axis of the Skerries Bank, which rests on this shelf near its outer margin, follows the line of the shelf.

2. Bedrock morphology and structures within overlying sediments

A Huntec 2B dual-channel continuous seismic profiling recording system and an EG & G dual-channel side scanning sonar, operating with a Huntec high resolution boomer and a 5 kHz pinger, were used during the geophysical survey. The bedrock morphology and nature

† Following Richthofen's definition, the term 'ria' is used here to denote a drowned river valley associated with geological structures transverse to the coastline.

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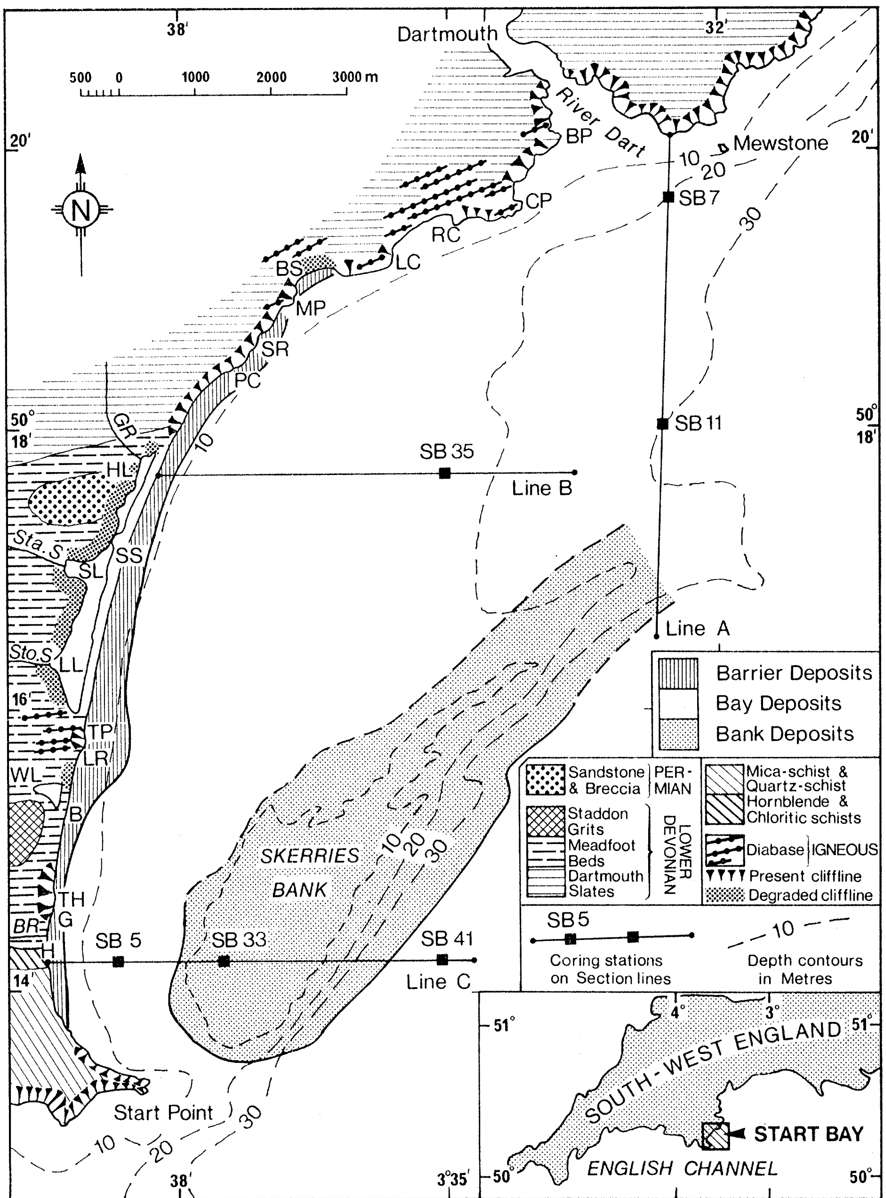
and structure of the overlying sequence of gently dipping superficial (Quaternary) deposits are shown on the three representative profiles in figure 2. Briefly, the salient features may be summarized accordingly. First, there is an erosion surface which truncates dipping strata considered to be Palaeozoic in age (reflector f, figure 2*a*). Secondly, a pronounced break of slope in the bedrock surface, at an average depth of 42 m, trends approximately parallel to the modern coastline along the entire length of the Bay. Thirdly, a number of buried channels, between 100 and 450 m wide, which appear to be the precursors of the present-day coastal streams, dissect the bedrock surface between the modern shoreline and the 42 m contour.



ABBREVIATIONS				
GR *Gara River*	BP Blackstone Point	MP Matthews Point	SL Slapton Ley	B Beesands
Sta S *Start Stream*	CP Combe Point	SR Shiphill Rock	LL Lower Ley	TH Tinsey Head
Sto S *Stokenham Str.*	RC Redlap Cove	PC Pilchard Cove	TP Torcross Point	G Greenstraight
BR *Bickerton River*	LC Leonards Cove	SS Slapton Sands	LR Limpet Rocks	H Hallsands
	BS Blackpool Sands	HL Higher Ley	WL Widdicombe Ley	

FIGURE 1. Locality map showing coastal geology, positions of representative profiles and lithologic units in Start Bay.

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Fourthly, gravel horizons mainly in an area 1 km wide and up to 6 km long between Redlap Cove and opposite approximately the middle of Slapton Ley (see also Kelland & Hails 1972; Kelland 1975). These are considered by the writer to be the positions of relict barriers, with typical features at depths of 17 m, 21 m and 30 m respectively, below chart datum. Significantly, the gravel horizons trend approximately parallel to the present-day shoreline. Inshore, they either pinch out against the shelving bedrock or outcrop at the seabed and disappear.

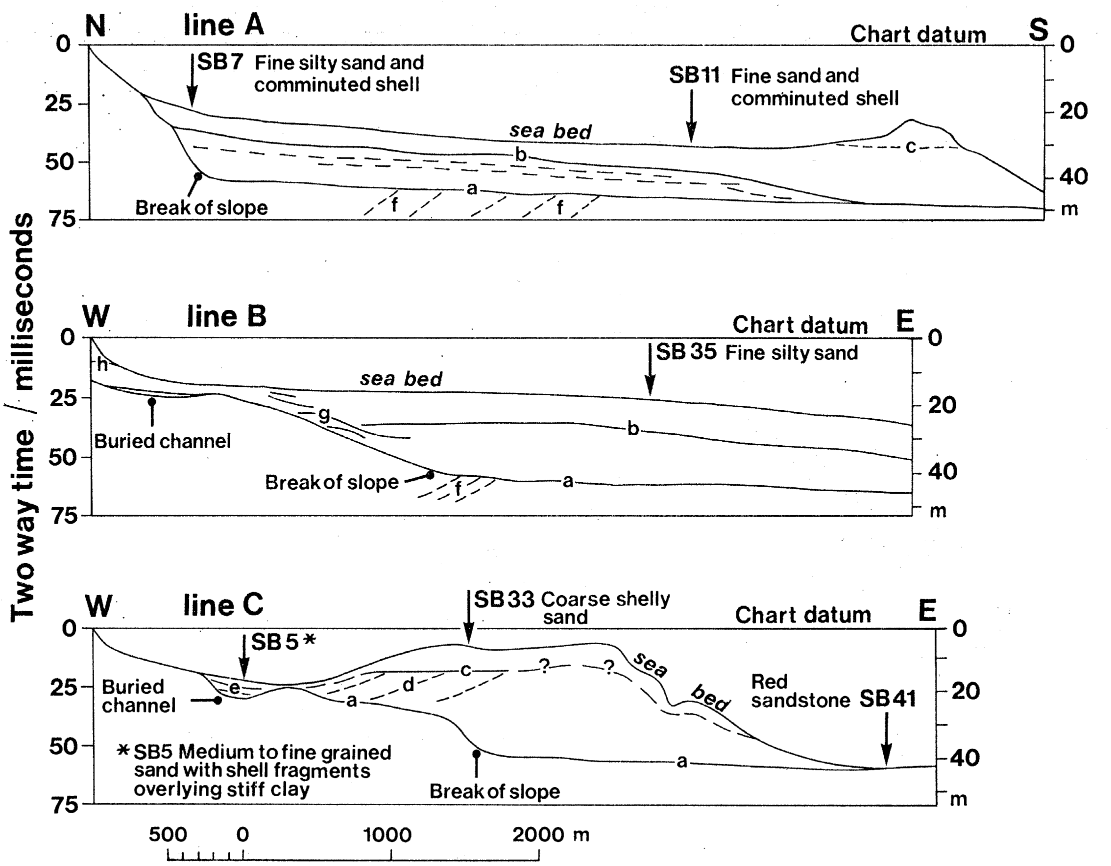

FIGURE 2. Interpreted continuous seismic profiles, Start Bay, showing bedrock morphology and structures within overlying superficial deposits. Chart datum is related to Ordnance Datum (Newlyn) which is approximately mean sea level. Reflectors: a, bedrock surface; b, unconformity within bay deposits; c, base of bank deposits; d, horizons within bay deposits; e, horizons within buried channels; f, horizons within bedrock; g, possible relict barriers; h, possible barrier beach deposits; ↓, coring position.

Interestingly, the depth of the break of slope is comparable to that of a submerged cliff near Plymouth reported by Cooper (1948), and what is considered by Clarke (1970) to be an ancient coastline in Tor Bay. In the vicinity of the Dart River and around Start Point the break of slope in the bedrock surface crops out at the seabed as a continuation of the modern cliffs (figure 2, line A).

3. SUPERFICIAL DEPOSITS

Seabed bottom and core samples

Analysis of seabed bottom samples obtained from various stations, other than those shown in figure 3 pertaining to gravity and vibrocores, indicate that the superficial sediments in Start

Bay can be divided into three descrete lithological units, described as *barrier*, *bay* and *bank* deposits by Kelland & Hails (1972), on the basis of their texture and composition (figure 1). The barrier deposits consist of shingle or beach gravel, with mean grain size values between -3.09ϕ (6.91 mm) and -2.36ϕ (4.25 mm), which are confined to a relatively narrow zone extending from the backshore of the barrier beaches above spring tide high-water mark (h.w.m.) to about 200 m beyond low-water mark (l.w.m.), although in the vicinity of the Torcross Point–Limpet Rocks headlands these have been traced nearly 400 m offshore. Sub-angular flints, including some black varieties, and well-rounded quartz pebbles are the dominant constituents, which comprise about 85% of the total population. Several other rock types are represented, including rhyolite, felsite, granite and quartz porphyry, together with locally derived fragments of mica-schist, shale and slate.

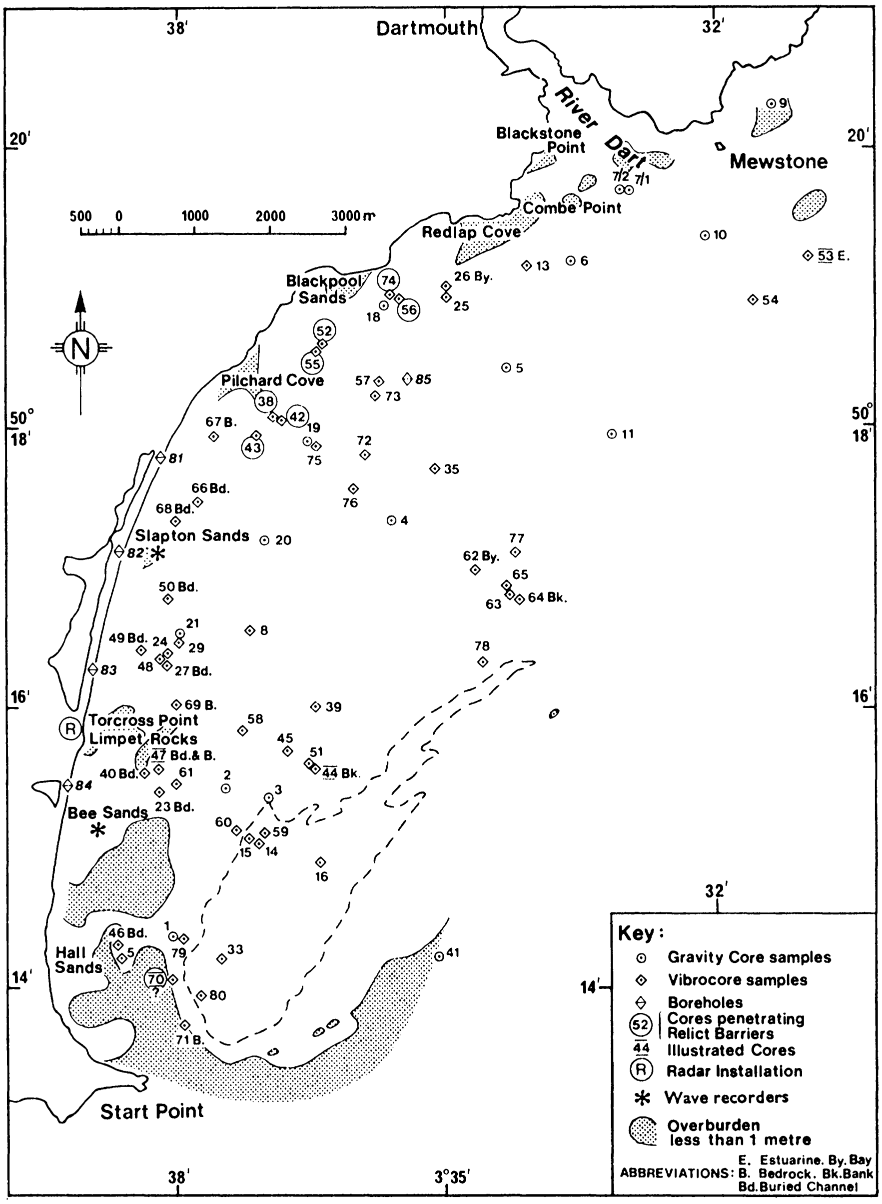

FIGURE 3. Gravity and vibrocore stations, Start Bay.

The bay deposits, composed of medium- to fine-grained sands 0.41ϕ (0.75 mm) to 3.99ϕ (0.06 mm)) with varying concentrations of silt, clay, whole and comminuted shell, attain a maximum thickness of 28 m about 2 km southeast of Blackpool Sands. Geophysical data show that these deposits are divided into an upper and a lower horizon by an angular unconformity with an inclination to the southeast of about 1:150 (reflector b, figure 2, line A). The lower bay deposits thin to a feather edge along a line trending approximately southwest to northeast which continues under the Skerries Bank. The upper horizon is characteristically grey or greenish-grey in colour owing to the presence of glauconite and chlorite, although a few samples have a reddish-brown or brownish-grey tinge, indicating the presence of fine-grained material derived from neighbouring Permo-Triassic strata. The composition and textural properties of the upper bay deposits recovered in 48 cores are similar to those of the seabed bottom samples. In contrast, the lower horizon consists predominantly of an intercalated sequence of estuarine sands, silts and clays figure 5, plate 3 (Lees 1975). The bank deposits, which unconformably overlie the bay deposits, are restricted essentially to the vicinity of the Skerries Bank (figure 2, line A). They are mainly composed of coarse shelly sand in the mean grain size range 0.88ϕ (0.54 mm) to 3.50ϕ (0.08 mm), and their maximum thickness is about 18 m. A total of 70 gravity and vibrocores, varying in length up to 4 m, have been collected from the three lithological units and also from the buried channels and relict barriers.

The petrographic characteristics of the bedrock penetrated at most core stations, usually where the unconsolidated sediments are less than 1 m thick, indicate a close affinity with the Lower Devonian strata which outcrop along the adjacent coastline (figure 4, plate 3). However, one core (no. 41, figure 3) on the Channel side of the Skerries Bank penetrated slightly weathered Permo-Triassic deposits. Similar bedrock material has also been recovered at a depth of 32 m near Blackpool Sands where, as already mentioned, the bay deposits are 28 m thick.

Only short cores containing bank deposits, on average 2–3 m in length, have been obtained so far because of difficulties encountered in vibrocoring coarse sand and comminuted shell.

The buried channel deposits recovered in ten cores (nos. 23, 27, 40, 46–50 inclusive, 66 and 68, figures 3 and 4) consist mainly of gravel set in a variegated matrix of fine- to coarse-grained sands, with thin lenses of silt and clay. Although their proportions vary from core to core, sub-angular flint and sub- to well-rounded quartz are the dominant constituents (90–95 %) with small amounts (5–10 %) of locally derived Lower Devonian rock fragments, granite felsite and volcanic pebbles.

Like the buried channel deposits, the relict barrier gravels in cores 38, 42, 43, 52, 55, 56 and 74 (figure 3) differ little in their composition, shape and size from the beach shingle along the modern shoreline.

4. Discussion

It has long been established that some of the constituents of the barrier deposits, particularly the granite and felsite, have been derived from the Dart catchment and subsequently eroded from the Triassic breccias and conglomerates of South Devon (Worth 1890). Petrographic studies by the writer have confirmed that most of the quartz pebbles have been derived locally from the quartz-schist at the southern end of Start Bay, and according to Worth (1890) the volcanic material may have a fairly local origin too. Nevertheless, it is apparent from the composition of the bedrock both along the coast and offshore that there is no local or

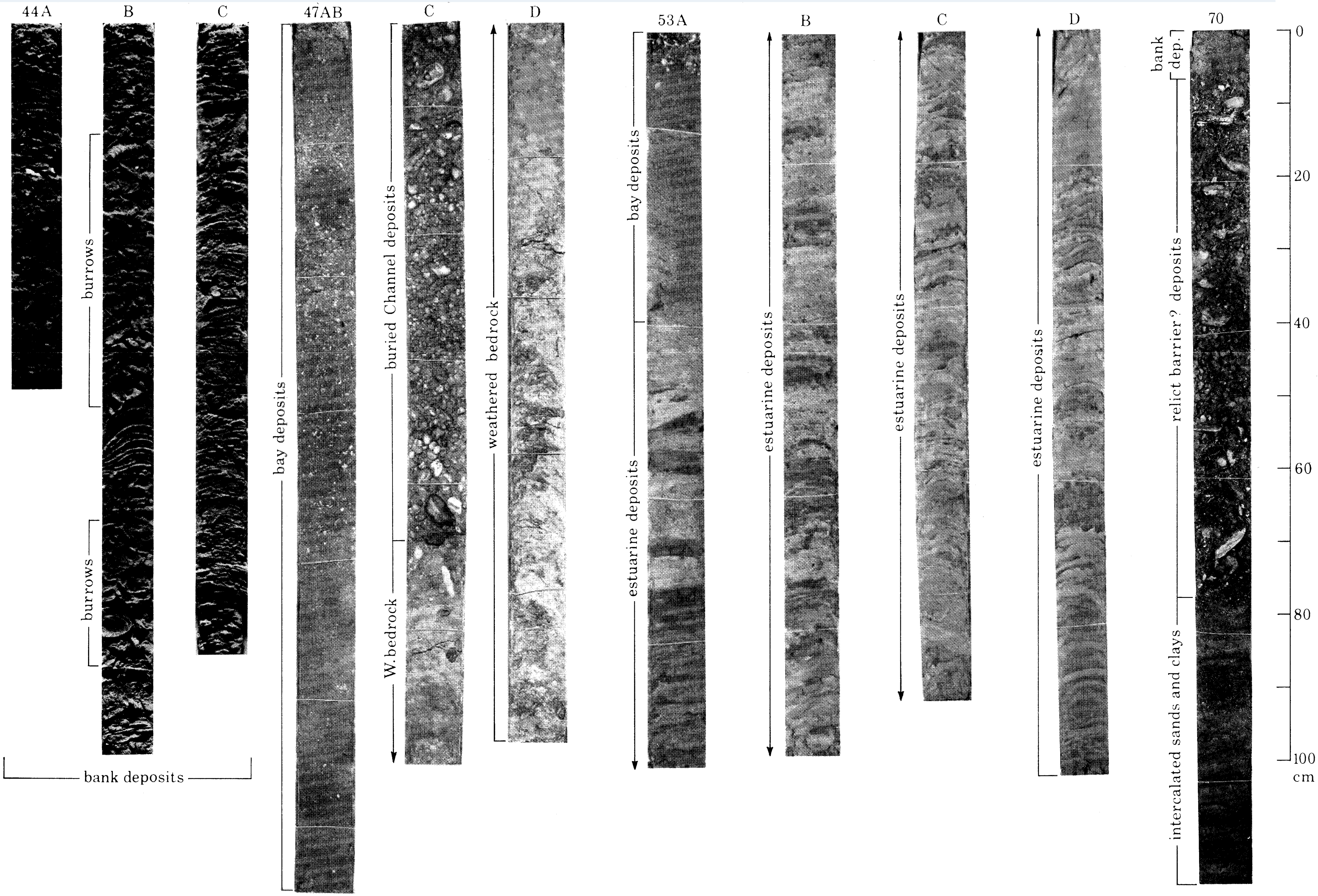

FIGURE 4. Section of vibrocores obtained from stations 44 and 47 showing bank deposits, and bay deposits overlying buried channel deposits and weathered bedrock, respectively.

FIGURE 5. Section of vibrocores obtained from stations 53 and 70. The former shows upper bay deposits overlying about 3.5 m of lower bay estuarine deposits, while the latter is a section through bank deposits, relict barrier? deposits and intercalated sands and clays.

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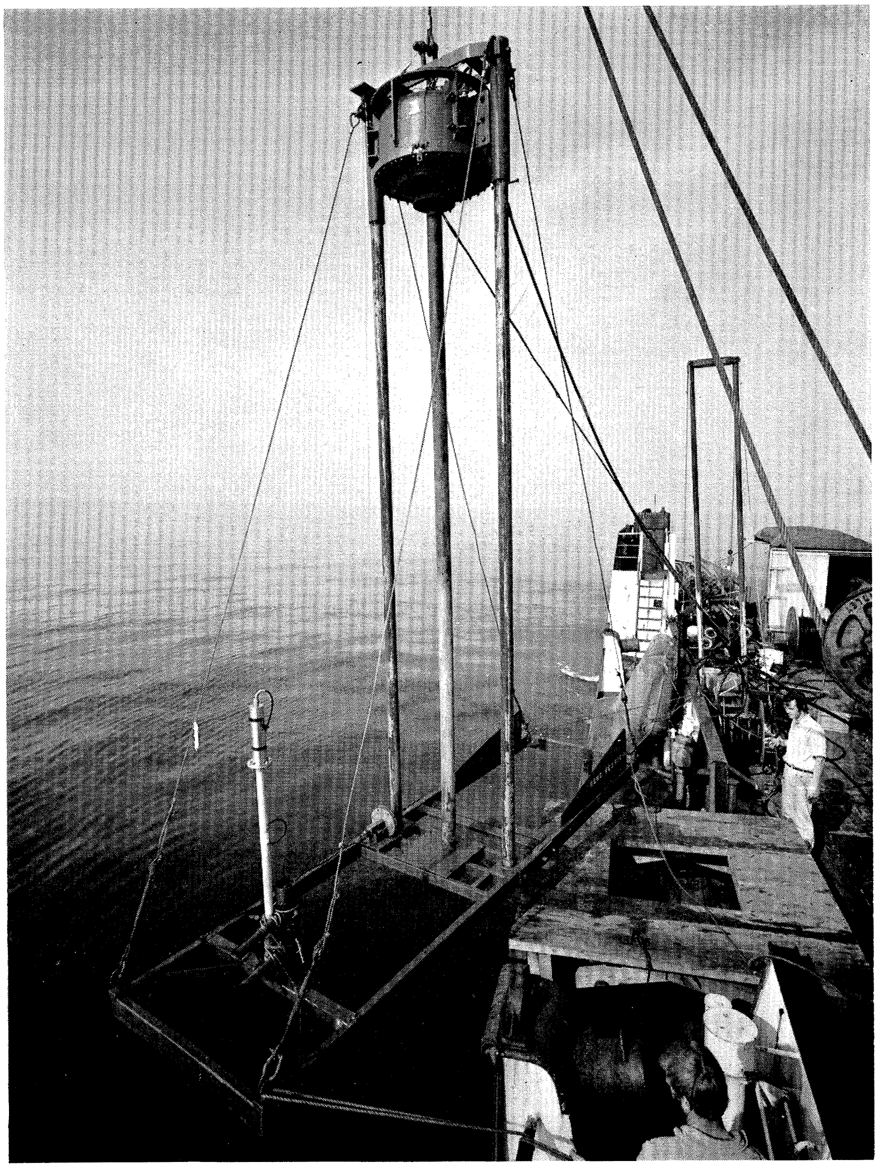

FIGURE 6. IOS (Taunton) vibrocorer used to obtain cores from Start Bay. Photograph by permission of The Netherlands Rijkswaterstaat.

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neighbouring source area to account for the relatively high content of flints in the barrier, relict barrier and buried channel deposits. In fact, the nearest sources are the floor of the English Channel 40 km to the east well beyond the limits of the Start Bay shelf and the chalk cliff at Beer about 58 km to the northeast of the area. Thus, in the light of available evidence, it appears that the barrier deposits have been reworked on several occasions and transported shoreward in response to minor oscillations of sea-level during the latter part of the Holocene transgression and possibly during earlier eustatic changes of sea level. This contention is partly supported by the occurrence of the gravel horizons already mentioned which are considered to be the remnants of former barrier shorelines.

An extensive mineralogical study of about 200 bottom samples, besides the cores, is in progress at the time of writing. This is being completed by the writer mainly to see if diagnostic heavy minerals are present in the lithological units which may assist further the interpretation of the sedimentary history of the area, and to evaluate heavy mineral distribution in terms of energy conditions inside the Bay. So far, excluding the opaques, 25 different minerals have been identified. These include tourmaline, garnet, zircon and andalusite which, on average, constitute 60 % of the non-opaque fraction; with topaz, apatite, hornblende, biotite, epidote, monazite, staurolite, sillimanite and kyanite.

The provenance for most of the minerals is the Dart River catchment and the Devonian Sedimentary rocks (see, for example, Brammell 1928; Shannon 1928) but neither worker has identified staurolite or kyanite, two minerals associated with a medium-grade metamorphic source. It is difficult to say how many times some of the heavy minerals may have been reworked from older unconsolidated shelf sediments which, in turn, originated essentially from the same sources just mentioned.

The sedimentary history of Start Bay has been described in detail elsewhere (Hails 1975). Suffice it to say that the thin veneer of bay deposits, less than 1 m thick, in the nearshore zone probably reflects the winnowing of fine-grained sediments by tidal currents and waves, and perhaps to a lesser extent to terrigenous material from the Dart catchment being trapped in the lower reaches of the river. Certainly, there is no conclusive evidence to suggest that sediment is reaching the coast from offshore or by movement alongshore now, which suggests that Start Bay may be considered as a *closed system* under present-day conditions.

Acton & Dyer (1975) have concluded that the peak tidal currents over the Skerries are not particularly high, being lower than those of the adjacent area seaward of the Bank, and that the residual or *d–c* component of the tidal current is zero along the axis of the Bank. These two factors may explain the relative long-term stability of the Bank.

It is not the purpose here to embark upon a lengthy discourse about the possible age of the superficial sediments. Available evidence suggests that the reworked barrier deposits were probably deposited during lower stands of Pleistocene sea level, and swept shoreward during the Flandrian transgression. The origin of the Skerries Bank is still not known. It might be inferred from the foregoing remarks and the recent conclusions of Acton & Dyer (1975) that the pattern of water movement within the Bay has created the Bank. On the other hand, it can be argued that some of the offshore banks along the English Channel coast may, in fact, pre-date the postglacial rise in sea level. Data pertaining to a lowering of relative sea level by about 6 m have been analysed to ascertain what effect, if any, wave energy dissipation could have on both the orientation and position of barrier beaches within Start Bay. By extrapolation, it has been established that a barrier would have prograded marginally seaward of the modern

Slapton barrier if the Skerries Bank had occupied approximately the same position. But, without an offshore bank, a barrier beach would have been established immediately at the base of the degraded cliffline which is the inner margin of Slapton Ley. At least, this evidence suggests that the Skerries Bank occupied its present position during the latter stages of the Holocene transgression. In conclusion, only information from boreholes will help to resolve the intriguing problem as to whether or not the banks off the south coast of England are much older than has been generally supposed hitherto.

I am indebted to colleagues who have participated in, and contributed to, the Start Bay programme. In particular I would like to thank Mr N. Kelland who undertook the geophysical survey and interpretation, Mrs B. Lees and Mr J. Malcolm for assistance with the analysis of samples, Dr R. Kirby for assistance with vibrocoring and Mr M. Ledgard for preparing the illustrations. Finally, my thanks go to the officers and crews of R.V. *Sarsia* and M.V. *Sara Lena*.

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FIGURE 6. IOS (Taunton) vibrocorer used to obtain cores from Start Bay. Photograph by permission of The Netherlands Rijkswaterstaat.