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BURIED TUNNEL VALLEYS OFF THE NORTHUMBERLAND COAST, WESTERN NORTH SEA

R.V. DINGLE[1)]

ABSTRACT

A series of deep, steep-sided, probably linear erosion hollows is described from the East Bank area on the northwestern side of the Dogger Bank, off the Northumberland coast of England. These hollows are infilled with bedded sediments and the whole sequence overlain by thick surface sediments with large linear banks. It is concluded, after a comparison with similar features from the western North Sea, that the East Bank hollows are buried tunnel valleys, which were excavated by sub-glacial streams near the edge of the Weichsel ice sheet, which deposited the Dogger Bank terminal moraine.

INTRODUCTION

During 1965-66, the Geology Department in the University of Hull conducted a reconnaissance seismic survey over an area of the North Sea, to the northwest of the Dogger Bank, known as East Bank. The area lies approximately 90 nautical miles east of the Northumberland coast, and about 60 miles south of the Devil's Hole deeps (fig. 1). Reflection seismic studies show a complicated series of buried hollows, and recent publications by F l i n n (1967) on similar, unfilled hollows off the Scottish coast, and W o o d l a n d (1970) on buried tunnel valleys in East Anglia, have provided the background for a satisfactory interpretation of the East Bank data.

The surveys (see fig. 1 for traverse locations) were carried out using Edgerton, Germeshausen & Grier "Boomer" and "Sparker" systems (1 000J), with a hydrophone and receiving circuit built in the Physics Department of Hull University. Navigation was by the Decca Navigator system. All horizontal measurements are given in nautical miles (1 n. mile = 1.85 km).

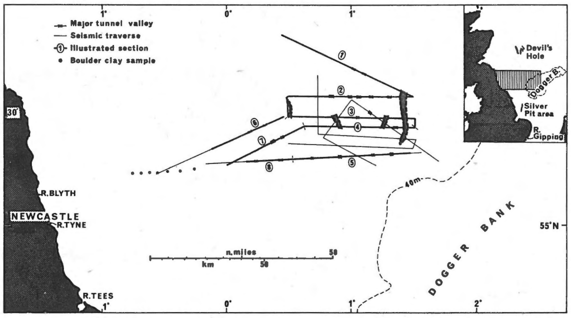

Fig. 1
Location of seismic traverses. Sections shown in figures 2 and 3 are indicated 1 to 8. Position and possible correlation of major erosion features are indicated.

RESULTS

Typically, the seismic records indicate a three-layered succession in the East Bank area consisting of: –

surface sediments
bedded infill
eroded bedrock.

Figures 2 and 3 show simplified sections plotted from the seismic records, and fig. 5 a tracing of actual

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[1)] Institute of Oceanography, University of Cape Town, Rondebosch, Cape, South Africa.

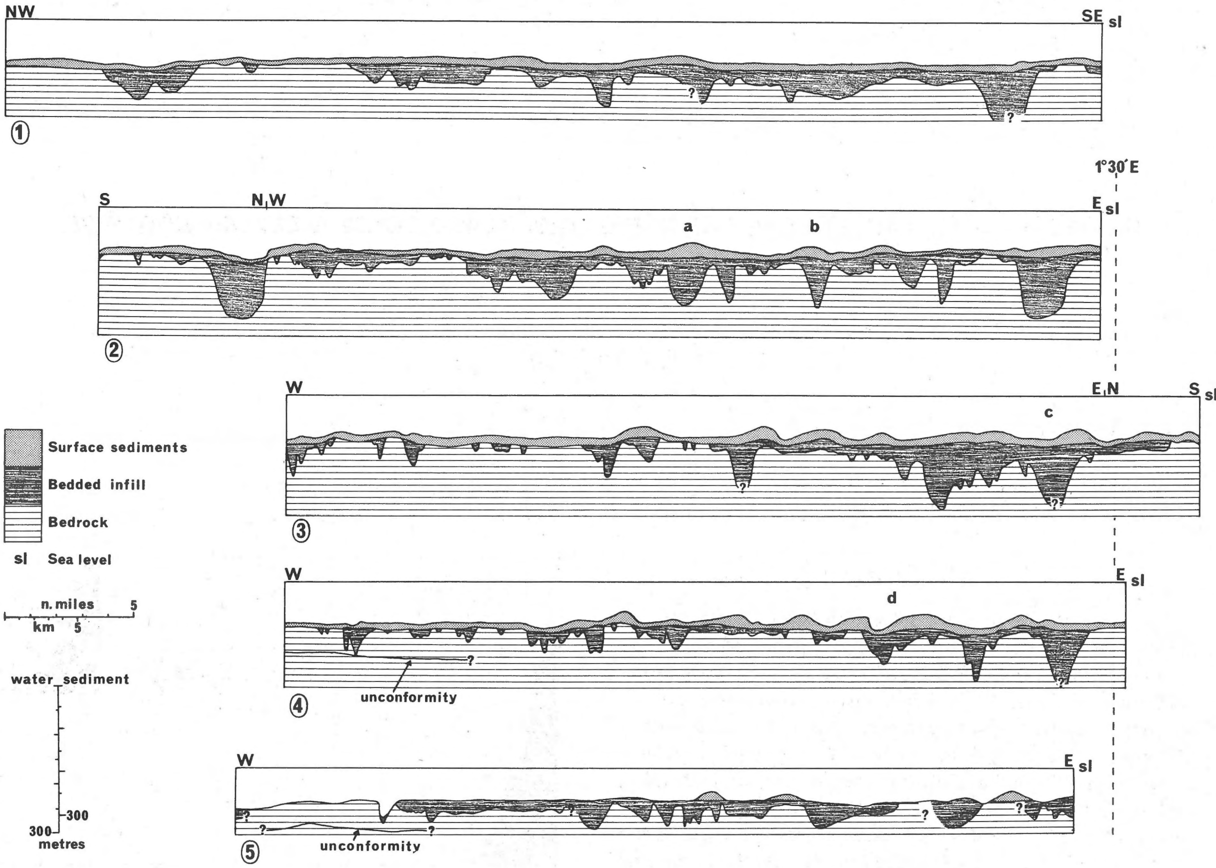

Fig. 2
Sections 1 to 5 plotted from seismic records. See figure 1 for locations. Vertical exagg. approx. x 35.

records. Thickness estimates are made assuming sound velocities of 1 500 m/sec in sea water, and 1 700 m/sec in the upper two sediment layers.

Surface sediments

Except in the south of the area, the sea floor is covered by a continuous blanket of unstratified sediment, which ranges in thickness from 5-15 m. Locally, these surface sediments thicken (up to 30 m) and form long, rounded banks, which rise to 40-50 m beneath sea level. In the southern part, the banks are separated from each other by sea floor which is apparently devoid of surface sediments. A plot of sea floor bathymetry and surface sediment isopachs (fig. 4) indicates that the upper surface of the underlying strata, whilst not being flat, is essentially smooth. No correlation could be observed between the location of the banks and underlying erosion features.

Evidence of the nature of these surface sediments is ambiguous. To the west and south, glacial tills form the sea floor (D i n g l e 1970) (see fig. 1), but the lack of success during coring operations in the East Bank area suggests that at least the top 0.5 m consists of coarse sediments (sands, and/or gravels).

Bedded infill

The irregularities in the bedrock are infilled and smoothed out by sediments which are, typically, sub-horizontally bedded, but which tend to dip more steeply inwards on the flanks of the larger erosion hollows (see fig. 5). Thicknesses of the infill vary considerably from about 150 m in the larger hollows, to nothing where the overlying surface sediments rest

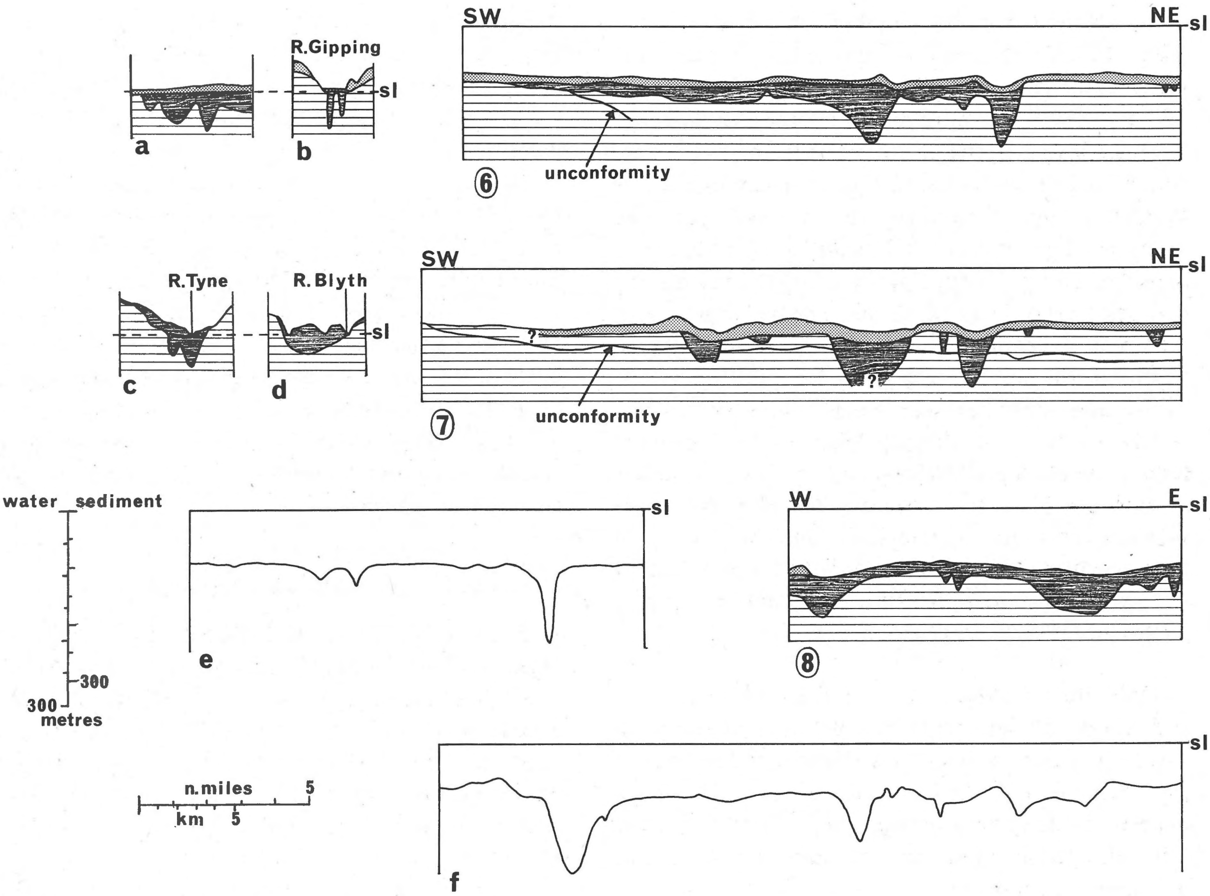

Fig. 3
Sections 6 to 8 plotted from seismic records. See figure 1 for locations and figure 2 for key.
Sections **a** to **f** to same scale; **a** – longitudinal profile, and **b** – cross section of River Gipping at Ipswich, re-plotted from Woodland (1970, fig. 4); c and d, cross sections of buried erosion hollows in Northumberland, re-plotted from Woolacott (1905, fig. 6 & 8 respectively); e and f, re-plotted sections of Devil's Hole and Buchan Deeps, respectively, from Flinn (1967, fig. 1). Vertical exagg. approx. x 35.

directly on the bedrock. As noted above, the upper surface of the bedded sediments is smooth, but not flat; it is frequently depressed over the hollows, and its depth beneath sea-level ranges from 90-110 m, with an average value of about 100 m, although in the southeast of the area it tends to lie somewhat shallower (60-70 m), (see section 5, fig. 2). There is no direct evidence on the lithology of the infill, although the well-developed bedding and strong acoustic reflectors indicate vertical variations in physical characteristics, which are more likely to indicate alternating silts, sands, and gravels etc. than boulder clay.

Eroded bedrock

The strata into which the hollows have been eroded are probably Upper Tertiary in age (D o n o v a n & D i n g l e 1965), and dip eastwards at very low angles (about 1°). Because of the complexity of the erosion pattern, it has not been possible to correlate the mass of smaller features from traverse to traverse, but evidence suggests that the grain is predominantly north to south (see fig. 1). This is particularly well displayed in the case of the large hollow on the eastern end of all the east-west sections shown in fig. 2.

In cross-section, the hollows are narrow, steep-sided, U or V-shaped, and the depth of erosion is variable, being at least 250 m beneath sea-level (about 150 m beneath the surrounding bedrock level) in the larger hollows; depths of 200 m beneath sea level are common. The hollows are either relatively isolated or occur in groups (erosion complexes consisting of one or more large hollows and many smaller features), between which the upper surfaces of the intervening bedrock tend to lie at two levels. The higher level is at 90-110 m beneath sea level, and corresponds to the depth of the upper surface of the infill sediments. This is an important level of erosion, and the bedrock which reaches it is abruptly planed off. The lower level is undulating and less well-defined, and occurs at a depth of 120-130 m beneath sea level (at about 90 m in the south, section 5, fig. 2). There seems to be no regular gradient in the depth of erosion, i.e. if the hollows are linear features then their floors must have many sills and undulations.

Only the westward limit of the erosion hollows and associated sediments was determined from the survey. On approaching to within about 55 miles of the coast the hollows disappear and the bedded-infill deposits wedge out, although on section 6 (fig. 3) at least, the surface sediments maintain their thickness, but do not form banks.

SIMILAR FEATURES IN WESTERN NORTH SEA AREA

In the light of the evidence presented above, the formation of the hollows and deposition of associated sediments are considered to be Quaternary phenomena, and in the following discussion comparison will be made with similar, known Quaternary features from the North Sea area.

Silver Pit tidal scour channel

Donovan (1965) has given an account of the Silver Pit, a narrow, slightly sinuous hollow about 22 miles long, which lies about 20 miles east of the Humber Estuary (fig. 1). It has steep walls and is unfilled. Because the Silver Pit is eroded through boulder clay into Chalk, Donovan concluded that it is a post-glacial feature formed by tidal currents which became funnelled by past coastal configurations (cf. the present-day mouth of The Wash). Subsequently, Donovan has considered the possibility of the Pit being due to subglacial erosion during the retreat stages of the Weichsel glaciation, (Donovan, in press).

Despite its linear form and steep sides, however, the Silver Pit, and the associated smaller Coal Pit, Sole Pit, and Well Hole (shown as "Silver Pit area" in fig. 1) only superficially resemble what is found in the East Bank area. The latter tend to be deeper features comprising a whole erosion complex, in contrast to the shallower, isolated channels of the Silver Pit area, which are separated by as much as 15 miles of hollow-free sea floor. Also, in the East Bank area the evidence is of infilling by glacial deposits, not erosion through them.

Tunnel valleys off North East Scotland

Flinn (1967) has described a large number of linear, unfilled deeps off the coast of Scotland, which occur in groups arranged in an arcuate pattern around a large patch of "late sediments". For comparative purposes, two of Flinn's profiles are reproduced on fig. 3. Features in common with the East Bank hollows include: a long linear form, steep sides, and complexity of erosion pattern. Actual depths of erosion in the Scottish deeps vary greatly from 30 m to over 150 m beneath the local bedrock surface. Flinn (*op. cit.* p. 1152), making use of evidence from NE Aberdeenshire, concluded that "they (the deeps) formed under the front of an ice sheet as siphons through which melt water escaped under pressure". Erosion hollows produced in this way are termed "tunnel valleys". The "late sediments" represent the fine detritus washed out of the stationary glaciers.

Flinn gives no evidence of the stratigraphy or structure of his deeps, but it is interesting to note that Newton (1917) described a block of Pliocene limestone which had been dredged from the walls of the Fladden Ground Deep, east of Orkney.

Tunnel valleys in East Anglia

Tunnel valleys form the subject of a recent persuasive address by Woodland (1970) who compared the buried, sub-glacially eroded valleys of East Anglia with similar unfilled "tunneldale" in Denmark and Schleswig-Holstein. Two of Woodland's

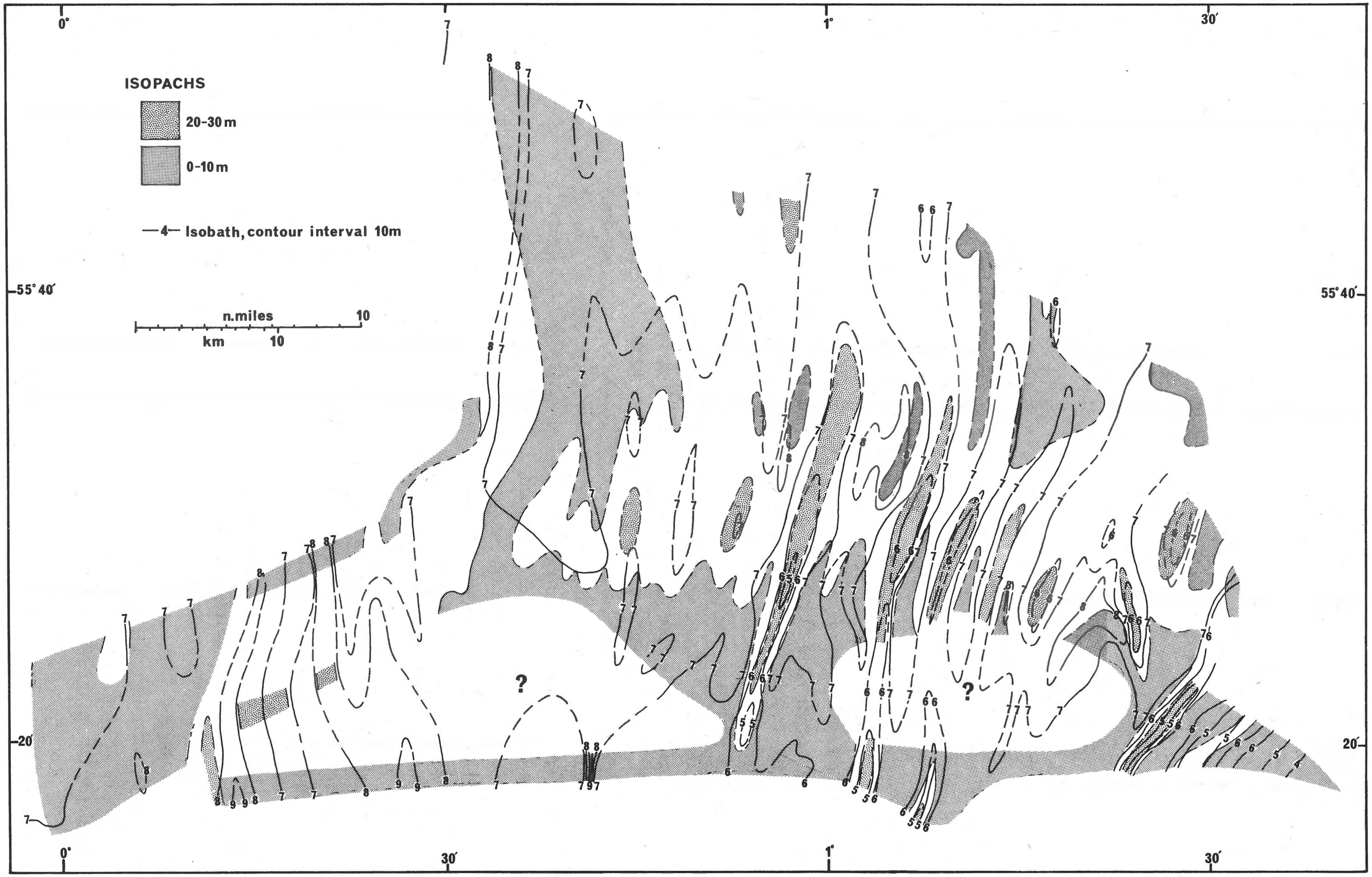

Fig. 4
Bathymetric map of East Bank area, and isopachs for surface sediments. Note that greatest sediment thicknesses coincide with shoaler areas.

profiles from the River Gipping at Ipswich are shown in fig. 3. Here, steep-sided channels filled with bedded sands and silts, and laminated clays are cut into the Chalk. They must have originally been overlain by sands and gravels, and possibly boulder clays (cf. Woodland, *op,cit.* fig. 4c), but post-glacial re-excavation has left the outwash deposits and boulder clays on higher ground above the present-day river valleys.

MODE OF ORIGIN

The possibility of a sub-aerial mode of formation can be considered. The linear form of the East Bank hollows would be in accord with a fluviatile origin, but few other factors seem to favour such a hypothesis. One point in particular, which militates against such processes, is that there appears to be no consistant downslope direction, even in hollows that can be tentatively correlated. If a fluvial origin is postulated, then glacial overdeepening must have occurred. This is a hypothesis which cannot be tested, but even allowing for a certain amount of overdeepening, a sea level at nearly minus 250 m present-day would have been necessary to have produced the larger "river" valleys. One Pleistocene stand of around minus 220 m has been suggested by Boillot (1964), but generally accepted maxima are considerably less (200 m or less). Taken as a whole, the complexity of the erosion pattern, the existence of numerous sills, and the great depths of erosion seem to us to indicate that the East Bank hollows were not produced under sub-aerial conditions.

Despite the superficial similarity of the Silver Pit with the East Bank hollows, a common process of formation is rejected, on the grounds that the widespread and complicated erosion pattern in the latter area is not compatable with localized tidal scour.

The closeness in physiography and associated sediments between the East Bank features, and the tunnel valleys described by Flinn (1967) and Woodland (1970), suggest that common processes were responsible for their formation. These processes of sub-glacial erosion, as described in detail by Woodland (*op.cit.* p. 523-4), offer a ready explanation for the complex erosion pattern and random depths to bedrock.

During a lowering of sea level to at least minus 110 m, an ice sheet lay over the East Bank area. Beneath the glacier, detritus-laden streams (randomly distributed and complexly inter-related) eroded linear hollows into the underlying Tertiary rocks. It is suggested that the undulating level, at about minus 120-130 m, represents wide valleys formed by excessive lateral erosion (meandering and coalescing) by the sub-glacial streams in soft strata. The lower Tertiary rocks may be more consolidated, and would give rise to localized, deep, narrow valleys. Woodland (1970) accounts for the steepness and narrowness of the East Anglian valleys, as compared with the Danish features, by appealing to differences in bedrock hardness (*op. cit.* p. 555-6).

Following erosion of the hollows, they were infilled by strongly bedded material, probably representing the waning sequence of glacial outwash and laminated clays discussed by Woodland (*op. cit.* 557-69). The level of erosion represented by the 90-110 m surface was a later phenomena caused by marine planation following the retreat of the glacier.

Stride (1959), Veenstra (1965), and Houbolt (1968) have postulated that post-glacial erosion of glacial deposits provided the abundant sediments which have given rise to the large banks and sand waves found in the southern North Sea. Likewise, we consider the surface sediments and linear banks in the East Bank area to have been formed by tidal and

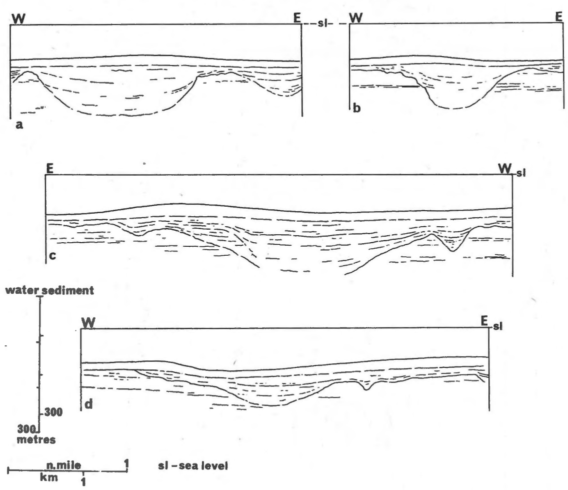

Fig. 5
Tracings of seismic records. Locations shown on figure 2. Vertical exagg. approx. x 6.5.

current, erosion and movement of glacial sediments: although the present-day tidal streams indicated on the Admiralty charts of the area seem unlikely to possess the required strength.

The major differences between the deeps described by Flinn (1967) and the East Bank tunnel valleys, namely, that the latter are filled and the former not, could be explained by postulating dirty ice in the East Bank area, and relatively clean ice off Scotland (cf. Woodland 1970, p. 557). This is not an altogether satisfactory explanation, however, as sub-glacial streams capable of deep down cutting (as in the Devil's Hole) would, presumably, need to be highly detritus-charged. Flinn does not discuss the problem, and we can see no obvious explanation.

AGE OF THE EAST BANK TUNNEL VALLEYS

No direct evidence is at hand for the age of the East Bank tunnel valleys. Flinn (1967) and Woodland (1970) put forward strong arguments for Weichsel ages for their features, both postulating an association with ice-sheet fronts.

In the East Bank area, the postulation of a nearby glacier margin immediately suggests an association with the adjacent Dogger Bank, which both Valentin (1955) and Stride (1959) concluded is, basically, a Weichsel terminal moraine. A long standing ice front over the Dogger Bank area would accord very conveniently with the postulated mode of formation of the East Bank erosion hollows. In this respect, the East Bank area differs from East Anglia, where no terminal moraines are associated with the Gipping Boulder Clay ice, which appears to have melted *in situ* and not to have had a lengthy stand at its maximum extent (Woodland *op. cit.* p. 561)[1].

The nearest comparable erosion features on land to the East Bank area occur in Northumberland, where Woolacott (1905) described the buried "pre-glacial" valleys of the Tyne and upper Wear areas. Two of his cross sections have been plotted on fig. 3, and it is suggested that some at least of these features, which Woolacott was convinced were sub-aerially eroded, may be tunnel valleys. Their age is uncertain, as the age of the Durham boulder clays, with which they are associated, is not established. Catt and Penny (1966) suggest that the earliest Durham tills (the Scandinavian Drift) are Gipping (Saale), and they favour a Weichsel age for both the Upper and Lower Boulder Clays which overlie the Scandinavian Drift. However, these datings are not universally accepted (Smith 1966), and the precise relationship between the tills and the buried valleys has yet to be described.

In conclusion, a Weichsel age for the East Bank tunnel valleys is postulated by virtue of their proximity to the Dogger Bank, but direct evidence may prove this to be a fortuitous association, although Weichsel boulder clays are widely distributed on the sea floor within 30 miles (Dingle 1970).

[1] It should be noted that Woodland considers the Gipping Boulder clay to be Weichsel in age, not "Gipping" (Saale).

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