Geol. Soc. Malaysia, Bulletin 35, July 1994; pp. 61-68

Seismic and borehole analysis of Pantai Kundor, Melaka

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Abstract: Twenty boring logs were studied in conjunction with four shallow seismic reflection data. The boreholes located close to the seismic lines were drilled at depths ranging from 12 to 40 metres. By comparing the borehole data with the seismic record, empirical relationships between the character of the seismic records and the corresponding lithology was established. The seismic data were analysed using a velocity of 1,600 m/sec to convert the two way travel times into depth. Four distinct lithological units were recognized and classified into units A, B, C, and D.

The uppermost unit, D representing soft clay with some coarse sand is characterized by strong horizontal stratification on seismic profiles. Unit C which is made up of medium to coarse sand with some clay and shell fragments is recognized by a chaotic reflection pattern in seismic records. Unit B is represented by dense silty sand with numerous mica flakes and it is interpreted as weathered granite. The lower most unit, A comprises lowly weathered to fresh coarse grained granites or bedrock and shows up as a domed reflection pattern on seismic sections. Using these empirical relationships, all the four seismic profiles were interpreted and analysed.

INTRODUCTION

This paper presents the results of seismic sub-bottom profiling interpretation and borehole analysis performed to provide subsurface information of a proposed Petronas marine facilities site at Pantai Kundor Melaka (UKM, 1990). The marine facilities contain several major components, one of which is the export jetty capable of accommodating up to 120,000 DWT tankers. The export jetty extending 1.0 to 1.5 km offshore requires the construction of a dredged approach channel and a berthing basin with depth levels at 19 m below chart datum (CD). However, the offshore depth in the proposed area is rather shallow varying from –10 m CD to –14 m CD. It is therefore necessary to dredge the approach channel and the berthing area to –19 m CD to allow a passage way and berthing of 120,000 DWT tankers.

Prior to the dredging activity, Sepakat Setia Perunding, acting as a consultant to Petronas authority had conducted a high resolution shallow seismic reflection study as well as subsea soil investigation in the proposed area. The EG & G uniboom sub-bottom profiling system was used to provide continuous shallow seismic profiling along the trestle area and across the proposed jetty site. The equipment was operated with filter settings of 600 Hz for low-cut and 3,000 Hz for high-cut, firing interval of 375 ms (millisecond) using a sweep speed of 125 ms (millisecond). The seismic records and borehole data submitted to Petronas were then used in this study to interpret the subsurface lithology and structure of the unconsolidated sediments as well as the nature of the bedrock in the study area.

SURFACE AND SUBSURFACE GEOLOGY

The geology of the coast adjacent to the proposed site of the jetty, adapted from the Preliminary Petronas Melaka Refinery EIA report (UKM, 1988) is shown in Figure 1.

In general, there are only two main rock types in the area i.e. granites and quartz mica schist. The granites cover the northern part of the area whilst the schists occupy the southern area.

Topographically, the granite forms a relatively flatter terrain than schists. It is the coarse grained phorphyritic type of which the phorphyritic biotite granite is the dominant variety. Large phenocrysts are a common feature of this granite. The phenocrysts are mainly microcline feldspar measuring up to 5 cm in length. Biotite on the other hand, has a much smaller size ranging from 0.02 mm to 0.8 mm. The age of the granite is estimated to be either Upper Triassic or middle Lower Jurassic.

Generally, the granites are severely weathered. However, relatively less weathered granite outcrops are found along parts of the shoreline as well as offshore. The seaward extension of granitic bedrock is covered by overburden which consists of unconsolidated, stratified young sediments. A few tiny islands of granite exposures are found off the coast of Pantai Tanah Merah. Other than

Paper presented at GSM Annual Geological Conference '92.

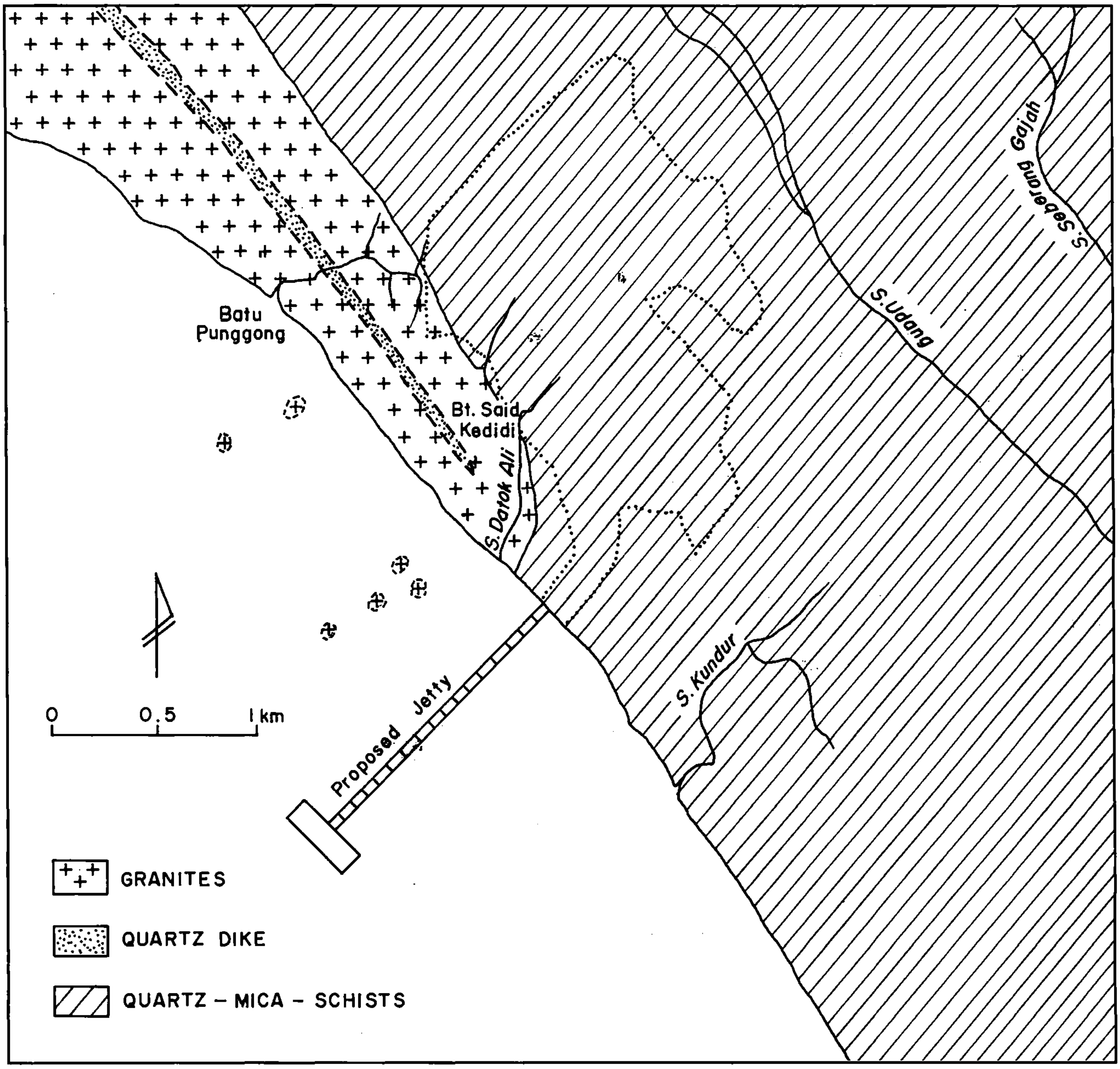

Figure 1. Geology of Pantai Kundor, Melaka.

weathering features, the granites also show several sets of joints and some of the joints are filled by quartz. A big quartz dyke trending northwest is found in the middle of the granite area and this is as a result of late filling of an open joint or fissure. The granite is of Upper Triassic to Middle Jurassic age (Gobbett and Hutchison, 1973).

The schists have been described to display more rolling and jagged landform as compared to that of the granites (UKM, 1988). It is interpreted to be of Lower Palaeozoic age and as quartz-mica-schist type. Their colour ranges from pinkish to greyish black. This colour reflects the iron content of the rocks. Most of the rocks are found to be weathered and changed to laterite at the top. The laterites are found only in the schist area. The laterite is derived as a result of weathering of iron-rich schists and it is found in the form of huge blocks. These blocks of laterite are found along the shore near the site of the proposed jetty.

In the offshore area, subsurface soil formations encountered were mainly 5 m to 20 m thick soft alluvial clays, overlying firm to stiff clayey silts with significant mica contents, probably a result of decomposition of hornfelses, which in turn overlies medium dense silty coarse sand from the weathering of rocks of granitic origin. With depth, the decomposition of granite reduces in intensity resulting in progressively denser and harder soil/ rock horizons. The hornfelses are likely a result of contact metamorphic processes around the fringes of granite intrusives.

SEISMIC AND BOREHOLE ANALYSIS

A total of twenty borehole logs were studied in conjunction with four seismic sub-bottom profiling data. These raw data were available from the consultancy report (Sepakat Setia Perunding, 1988 and 1989) submitted to Petronas Penapisan (Melaka) Sdn. Bhd.

Most of the boreholes were located along or very close to the seismic reflection profiles. The exact location of the boreholes and the seismic lines are shown in Figure 2. The boreholes have depths varying from 11.96 to 38.8 m below sea bed. The borehole logs were studied and their results were superimposed onto the relevant seismic records. In this way, the empirical relationship between the character of the seismic records and the corresponding lithology was established. The seismic data were analysed using a velocity of 1,600 m/sec to convert two way time to depth. From the borehole logs, four distinct lithological units were recognized and their description are given below:

Unit D: The uppermost unit immediately underlying the sea bed is characterized by sediments of soft greenish grey clay (D2) and in part intermixed with light grey coarse sand (D1). On the seismic profiles, these sediments are characterized by a fine texture and weak to strong stratification which is generally horizontal. A coarser texture with relatively weak stratification generally occurs where the sediments are dominantly sandy. This type of material frequently have very low mechanical strength and form very poor foundations for offshore structures.

Unit C: This unit is characterized by yellowish grey sediments of medium to coarse sand. It is loose to medium dense with clay seams and shell fragments. Coarse grained sediments are normally characterized by a chaotic reflection pattern (line 4) in seismic data.

Unit B: This unit is represented by samples of light grey and brownish yellow silty fine to coarse sand. The samples are very dense and in some parts it is high and moderately dense with numerous mica flakes. It is interpreted either as decomposed or weathered granite. This weathered layer is shown as relatively reflection free areas in seismic records.

Unit A: The lowermost unit which comprises lowly weathered to fresh strong coarse grained granite (bedrock). This unit is found in several boreholes and is seen as a 'domed' overlapping reflection pattern on seismic section.

Using the above empirical relationships, all the four seismic profiles (Fig. 3) were interpreted and their results are presented in Figure 4.

The resulting geophysical profiles are described individually below:

Line 1 (Figure 3a and 4a):

Line 1 comprises units D (1 and 2), C, B and A. The surface of the lowly weathered bedrock (Unit A) in this section lies at about 35 to 40 meters. It is overlain by a thick layer of weathered bedrock (Unit B). A thin wedge of Unit C lies above Unit B. The top most Unit D is characterized by parallel and relatively weak dipping layers.

Line 2 (Figure 2b and 4b):

Line 2 profile is very similar to that as interpreted for line 1. The only difference to note is that Unit C is relatively thicker than Unit B and that the topography of Unit A appears to be more undulating.

Line 3 (Figure 3c and 4c):

Unit D is the uppermost unit in this section. This unit is relatively thick (> 10 meters) and is overlying Unit B. The unit underlying Unit B is designated Unit A. Unit C being absent at this particular location.

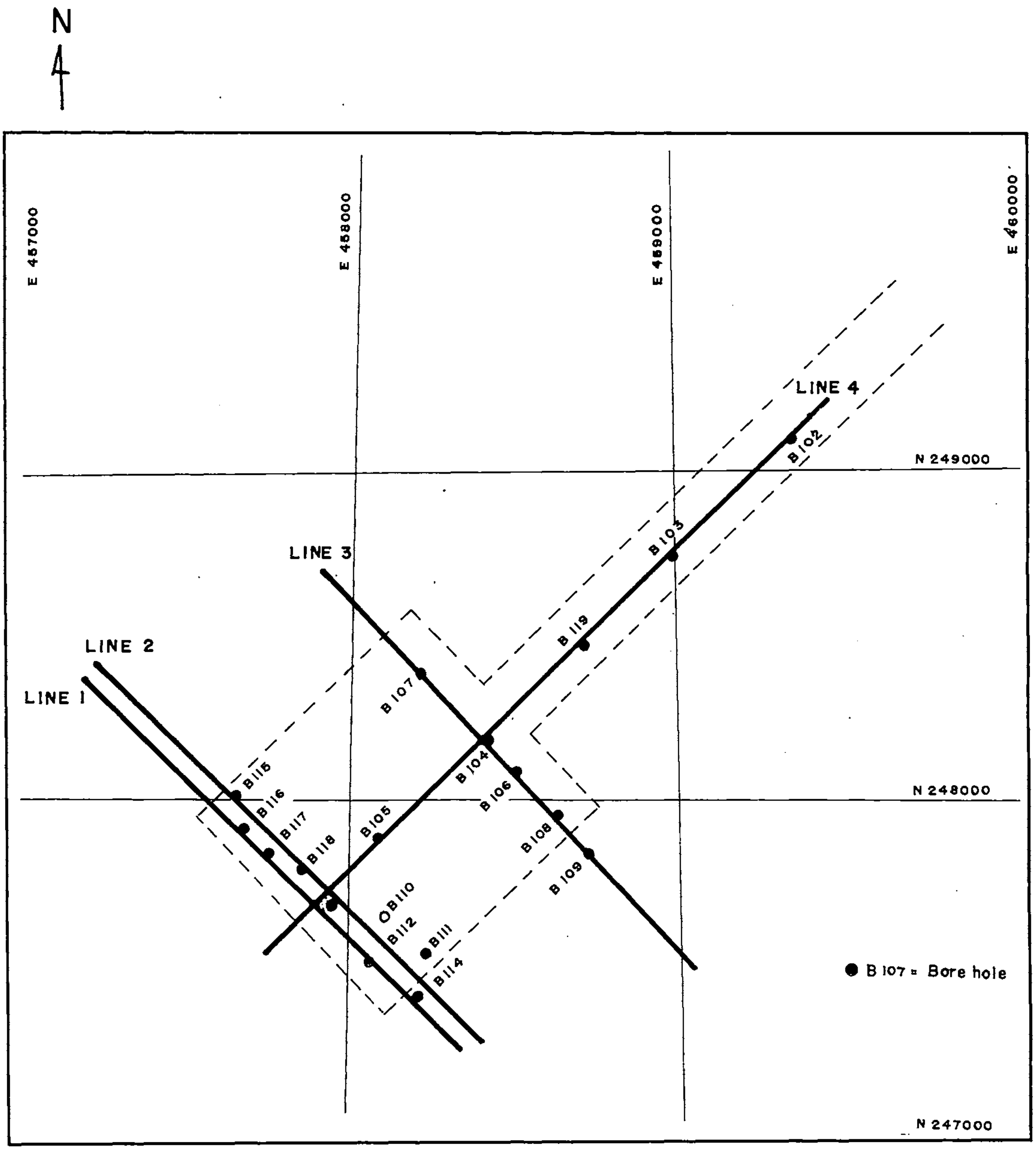

Figure 2. Seismic lines and location of the boreholes.

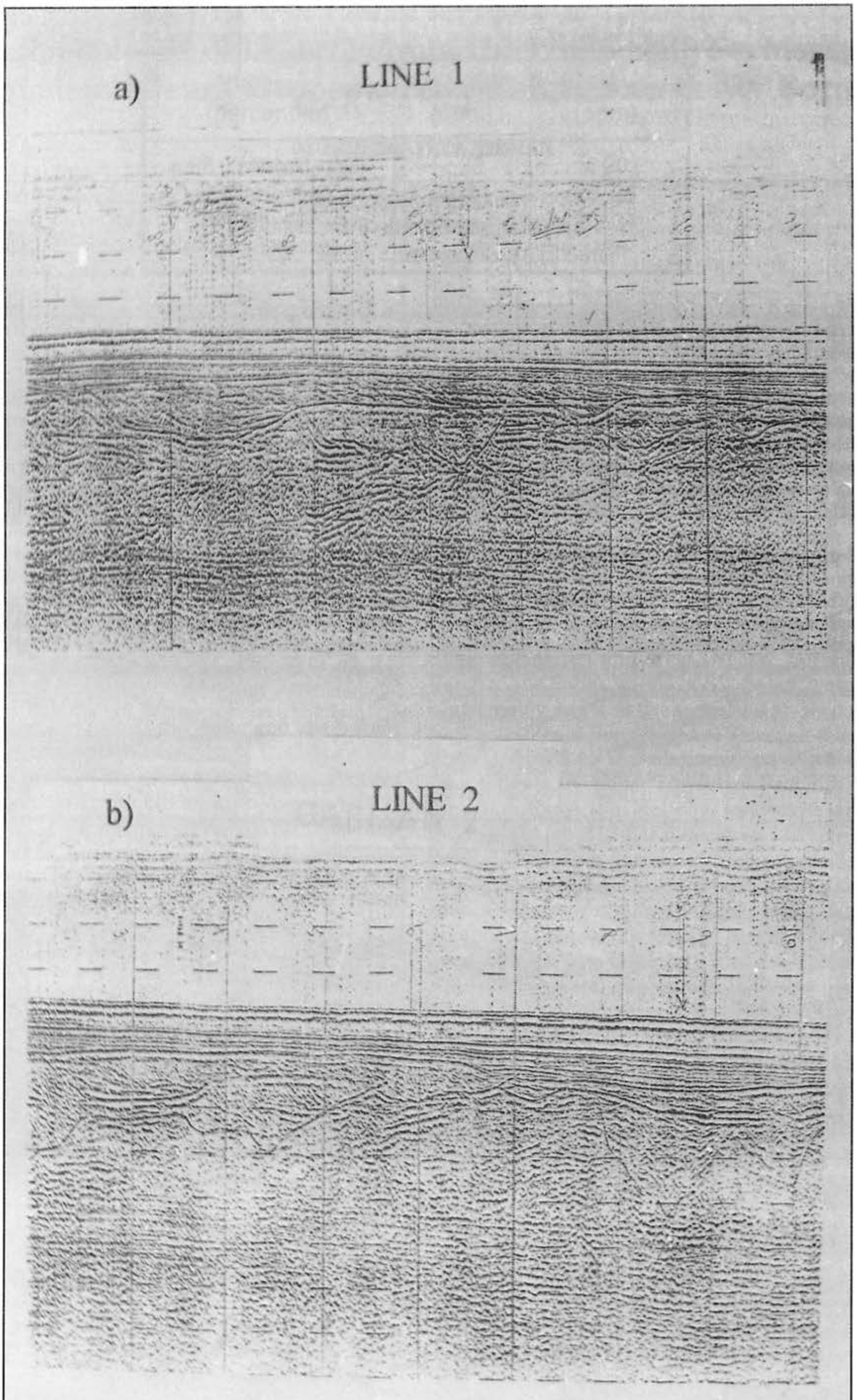

Figure 3a. Seismic sections of line 1(a), and line 2(b).

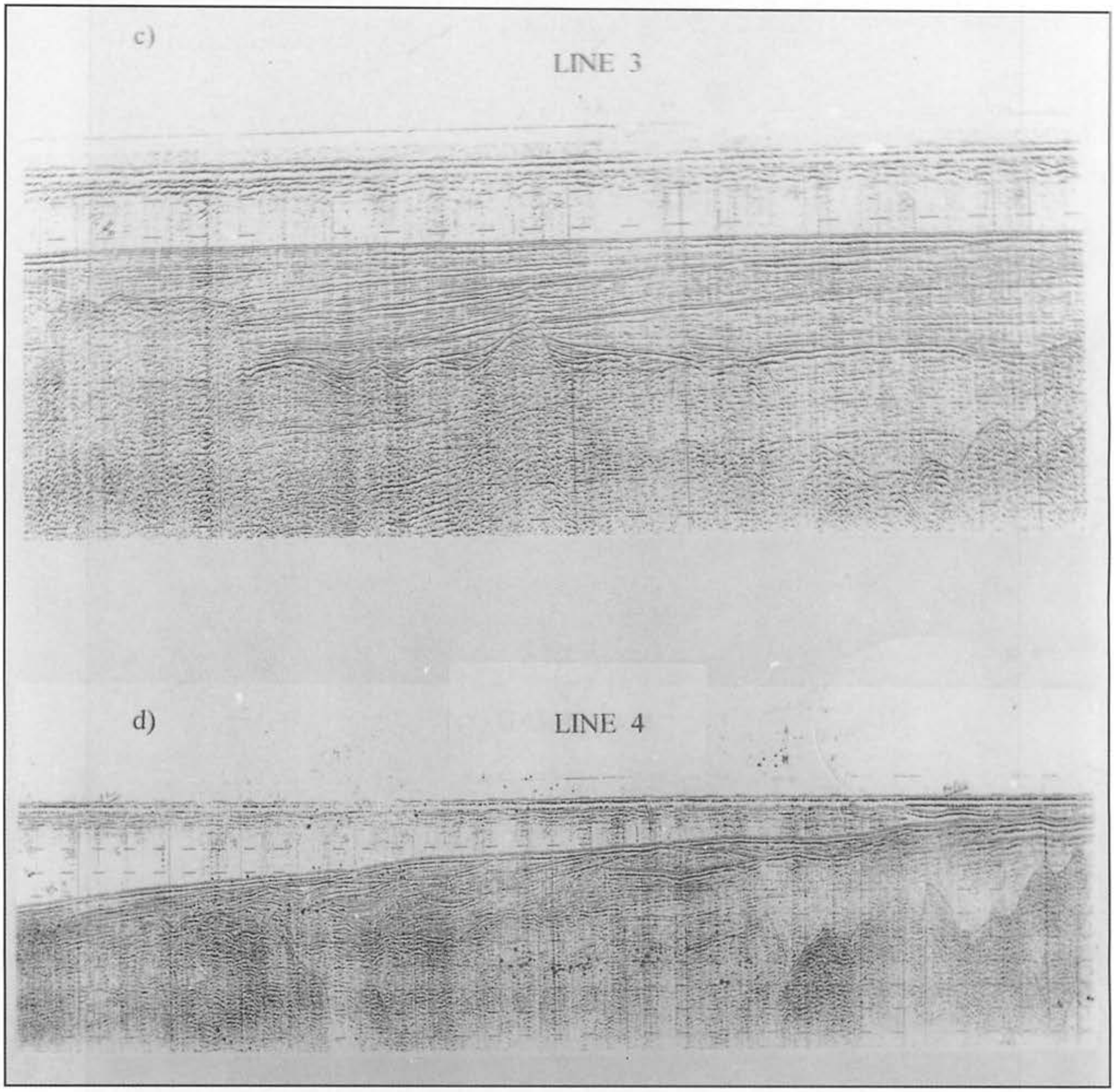

Figure 3b. Seismic sections of line 3(c) and line 4(d).

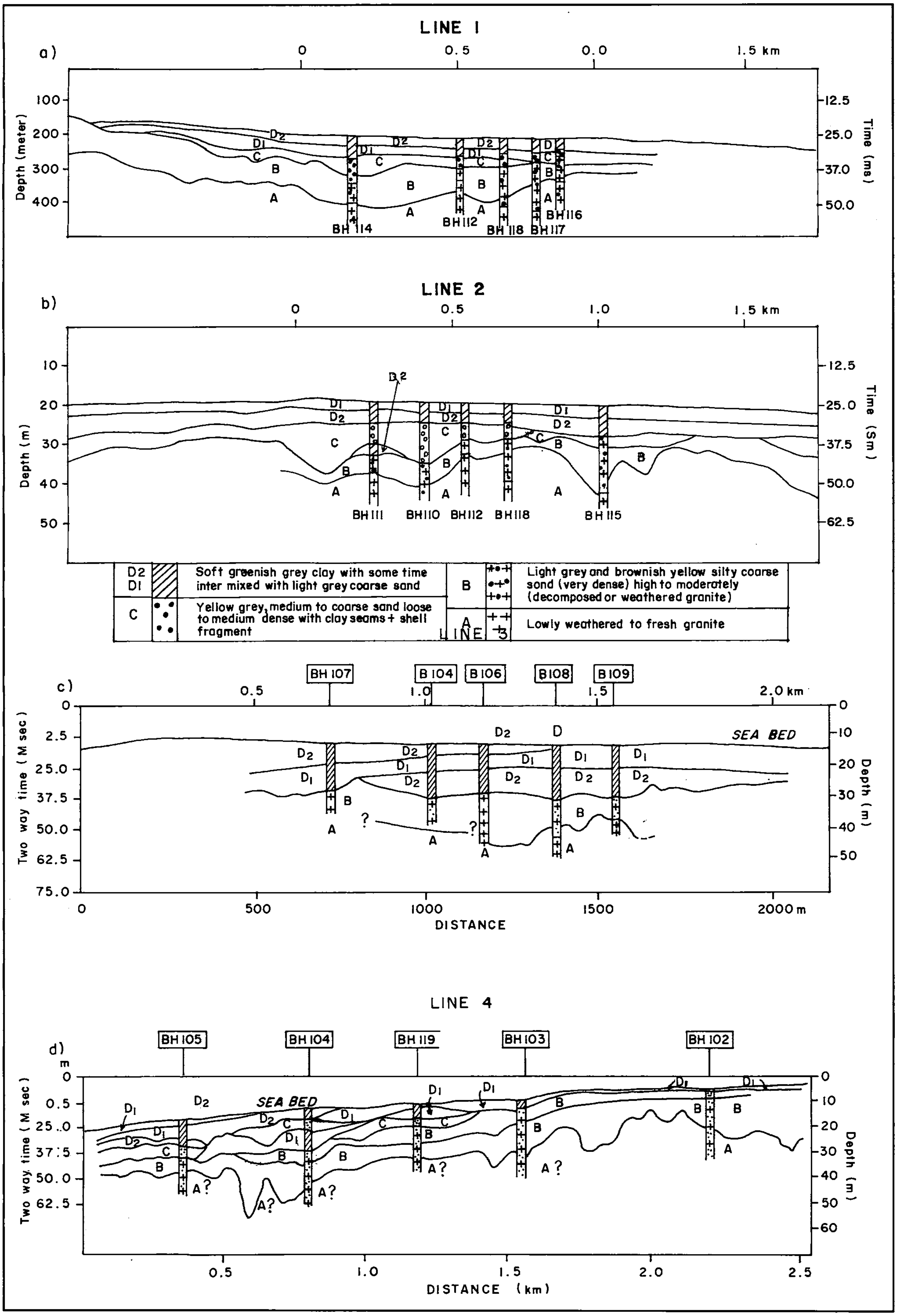

Figure 4. Depth sections and geological interpretation of line 1(a), line 2(b), line 3(c) and line 4(d).

Line 4 (Figure 3d and 4d):

All the four units are present in this section. Unit D is the uppermost unit which appears to be thicker to the south-west. Unit C appears as lenses. All other units show strongly eroded surfaces and some parts are truncated. A predominant dip towards the south-west is shown by the sediments section, an indication of sediment supply from the north-east. The units in the south-west section appear to exhibit evidence of reworking. The highly chaotic and internal structure and extreme variation in unit thickness also tends to indicate that the sediments were deposited in a highly active fluvial environment.

CONCLUSION

The subsurface geological sections along the four seismic lines were successfully obtained by establishing the empirical relationship between the character of the seismic records and the corresponding lithology of the borehole data. A complete geological section of the proposed site is well represented by the interpreted seismic profile of line 4 which shows the presence of all the four lithological units A, B, C and D. In average, the maximum depth to which granite bedrock (Unit A) could be reliably mapped is about 30 to 40 m below sea level. The granite bedrock surface offshore is characterized by steep slopes and high relief and an overall relatively gentle slope towards the southwest. The 40 m depth of bedrock below sea level occurs at about 1.5 km from the coastline. The topography of the bedrock parallels the shoreline is relatively undulating with no apparent change of slope in that direction.

Penetration of seismic data in this area was limited, probably in the most part of high sand content in the upper soils but also by the quartz sands and micas of the weathered granite. Borehole records indicate that this material type is prevalent beneath the clays and silty sands deposited from elsewhere. Due to the lack of internal structure exhibited by the weathered igneous rocks it has been difficult from this survey, to indicate the depth to bedrock and the maximum depth of soft sediments. The seismic data in conjunction with borehole data does, however indicate the extreme variability in thickness of the soft sediments.

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Manuscript received 1 April 1993