SURFICIAL GEOLOGY OF THE AREA NEAR THE TITANIC WRECK

Steven Haysom

Atlantic Geoscience Centre, Geological Survey of Canada, Bedford Institute of Oceanography,
P.O. Box 1006, Dartmouth N.S. B2Y 4A2

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ABSTRACT

The Atlantic Geoscience Centre has collected seismic and sample data in the region surrounding the Titanic wreck as part of a study of geological evolution and sedimentary processes on the continental rise. This report describes and interprets new 40 cu in sleeve gun seismic profiles, 3.5 kHz profiles, and samples collected in 1991. The seismic data shows two major Pleistocene erosion surfaces resulting from erosion by the Western Boundary Undercurrent, that separate sediments on the rise principally deposited by turbidity currents and slides. Surficial sediment near the Titanic wreck is commonly sandy, partly as a result of deposition from a recent turbidity current down Titanic Valley and partly as a result of winnowing by the Western Boundary Undercurrent.

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INTRODUCTION

The "Titanic area" is the name informally used for the area near the wreck of the Titanic, located on the rise south of the Grand Banks of Newfoundland in about 3700 m of water (Fig. 1). As a result of the search for the wreck, an unusual amount of deep-water geological information was obtained by various groups (Ryan, 1983; Cochonat et al., 1989; Uchupi et al., 1988). This data showed that although the Titanic wreck is swept by the Western Boundary Undercurrent, nearby areas of the continental rise have been affected by late Quaternary slides and turbidity currents.

Two cruises on CSS Hudson have collected additional seismic and core data from the Titanic area, with the intention of using it as a case study of processes affecting the continental rise off eastern Canada. The issues addressed include the frequency and extent of sediment failure on the margin and the risk from both turbidity currents and bottom currents to deep-sea cables. Results from cruise 87-008 are described by Savoye et al. (1990). This present report describes the results from data collected on cruise 91-020 and some resulting re-interpretation of 87-008. It also incorporates some information from the Keldysh 1991 cruise to the Titanic wreck. Grab and core samples were taken from the Keldysh and submersible short core samples were obtained from the MIR submersibles.

On cruise 91-020, detailed study took place up the continental rise to the northwest of Titanic valley and southeast of the valley on the plateau on which the Titanic wreck is located. 6 cores were attempted and 90 km of 40 cu in compressed air sleeve gun seismic and 150 km of 3.5 kHz data were collected on the 1991 cruise (Fig. 2). Weather and water surface conditions were not ideal, thus effecting the quality of both data types.

BATHYMETRY

The continental slope north of the study area off the Tail of the Grand Banks of Newfoundland is steep and highly dissected by canyons (Skene, 1991). Canyons on the slope coalesce into a few valleys on the rise, the largest of which is Titanic valley (Uchupi et al., 1988). [This feature has recently been termed, misleadingly, Titanic Canyon]. The continental rise is ponded behind the J-Anomaly ridge and broken by the southeastern Fogo Seamounts.

The area can be divided into three bathymetric regions (Fig. 3): the continental rise southeast of Titanic valley, Titanic valley and the continental rise northwest of Titanic valley. Southeast of the valley, the seafloor relief is low and gently rises to the south from Titanic valley. In the study area, Titanic valley is a broad valley with a 60 to 100-m deep central erosional channel with a U-shaped cross profile, that becomes more deeply incised down-slope. There is a low levee on the southern side of the valley. The continental rise northwest of Titanic Valley is cut by several south-trending channels and has higher relief than the area south of Titanic valley.

The new bathymetric map (Fig. 3) has provided more detail on features originally identified by Ryan et al. (1983), Uchupi et al. (1988) and Cochonat et al. (1989), but has not provided any new scientific insights.

CORES

Gravity core 87008-5 from the seismically-detected major slide was described by Savoye et al. (1990). This showed an alternation of foram ooze, thin sand beds, and mud with gravel and shale clasts (interpreted as ice-rafted or debris flow deposits). A foraminiferal ooze at a subbottom depth of 1 m yielded a C-14 age of 4250 a. A fine sand was found at the top of the core. Core 91020-59 at a nearby site recovered a surface sandy mud resting on a sharp sand lamina at 10 cm subbottom.

Several cores in the region either showed a surface layer of sand (87-008/005, 91-020/059 and 062 trigger weight cores) or were washed out (87-008/009, 91-020/060, 064 and 065; Keldysh 2460, 2479 & 2470).

3.5KHz REFLECTION PROFILE DATA

Description and method

Through studying reflection type and relief a classification system of the 3.5KHz reflection data was set up. Relief was identified as either slightly irregular (A) or irregular (B). Reflection type was based on degree of acoustic penetration, with the following categories distinguished: (1) very good penetration with many clear subbottom reflectors; (2) good penetration with several clear subbottom reflectors; (3) rare evidence of subbottom reflections; (4) high reflectivity with no subbottom reflections; (5) and areas with many hyperbolic diffractions and side echoes. Type examples of these categories are illustrated in Appendix 1. Each of the above mentioned categories was mapped along track lines, except where reflection type was indeterminate due to poor record quality as a result of bad weather. Probably because of weather conditions, reflector type was not always consistent from one survey to another. Therefore the map in Figure 4 represents some degree of generalisation.

Interpretation

3.5 kHz reflection types were classified according to relief and/or reflectivity. High relief might be a result of slump blocks, eroded seafloor, scouring, or any form of mass movement downslope. High reflectivity probably results from surface sand or indurated mud, whereas deep acoustic penetration (non-reflective) characterised soft mud.

The more reflective types (3 and 4) correspond to several types of bottom sampled in the cores:

(a) outcrops of indurated mud sampled in piston core 62 and seen from submersible work around the Titanic wreck.

(b) areas of winnowed foraminiferal ooze (cores 65, 2489, and possibly 61) that correspond to sand waves imaged by SAR sidescan (Cochonat et al., 1989).

(c) terrigenous silty sand bed near the surface in cores 60, 64, and 59TWC.

Correlation of the 3.5 kHz data (Fig. 4) with the SAR sidescan imagery of the "Zone Titanic" (IFREMER, 1986) can also be used to groundtruth the 3.5 kHz reflection types. The area to the southwest of Titanic valley is of low relief, save for the bedforms which have formed on this plateau. Barchan dunes, sand ribbons and sediment waves are all crossed by tracks which have been interpreted to be category (4), highly reflective. This whole area is probably underlain at depths of less than a metre by indurated mud. This mud is overlain locally by soft mud (as at the Titanic wreck) and in other places by sand and/or gravel (as evidenced by the bedforms imaged by the SAR).

The reflection character of the floor of Titanic Valley is obscured by hyperbolic diffractions from the walls. The SAR data (IFREMER, 1986; Cochonat et al., 1989) suggest that it is flat floored and highly reflective. Airgun data also suggest that the floor of the valley is reflective. The levees within 2 km of the valley show surface sand in core and hence reflectivity close to the valley.

The area to the northwest, bathymetrically, is a steep continental rise, containing a large instability corridor. Thus relief is very high due to slump blocks and mass movement scars. Most tracks in this area show reflector types (3) and (2). This tends to indicate a mix of sandy and soft muddy sediments. Cores indicate alternating near surface sands and muds, with a surface sand in places. Very pronounced lineations run downslope to Titanic valley showing near-surface turbidity current erosion (Savoye et al., 1990). The high area north of the Titanic wreck and east of the valley has acoustically highly penetrable sediments.

SEISMIC REFLECTION PROFILES

Definition of key reflectors

A grid of seismic reflection profiles is available in the Titanic area from approximately 41 30'N 49 30'W to 42 30'N 51 00'W. Quality varied depending upon weather conditions. Most seismic data were recorded around Titanic valley and up the continental rise.

Three reflections were used to follow the key horizons from a type section at the crossover of 1987 and 1991 data at 116/0024 and 180/0625 (Fig. 5).

(X) to surface interval - This unit occurs between the (X) reflector and the seafloor. It contains mounded and irregular reflectors, some of which represent slump blocks (Savoye et al. 1990).

(X) reflector - The (X) reflector is the prominent reflector below the seafloor. It dips toward the Titanic valley from the continental rise and is cut by the valley; it cannot be traced with confidence on the SE side of the valley.

(Y) to (X) interval - This interval has a variety of reflectors from parallel to sub-parallel and dipping to irregular. Top lap on the (X) surface and irregular reflectors are typical of the section near the Titanic valley as for example in the type section.

(Y) reflector - The (Y) reflector is continuous to discontinuous throughout the seismic records. Frequent toplap indicates that it is an erosional surface. This reflector outcrops at the bottom of Titanic valley and can be traced throughout the area. This reflector was termed A by Savoye et al. (1990).

(Z) to (Y) interval - This interval has parallel to sub-parallel reflectors which are locally cut out by the (Y) unconformity.

(Z) reflector - This is the deepest continuous reflector detectable in the 40 cu in seismic profiles. Despite its depth, which results in a rather low amplitude reflection in places, it appears more continuous than the (Y) and (X) reflectors.

Description of the acoustic stratigraphy

The top unit, between the (X) reflector and the seafloor, is of rather variable character throughout the region. On line 87-9, which is a dip line north of the Titanic Valley through the "instability corridor" of Cochonat et al. (1989), the unit is very irregular and mounded, with a series of blocks or wedges that are imbricated and dip upslope. Three stratigraphic divisions occur above the (X) reflector. The lowest is a series of apparently stratified sediments that dip gently northward and are terminated upslope by more steeply dipping reflections, resulting in an appearance like a series of steps (1 in Fig. 5a) Above these well stratified "steps" is an acoustically amorphous area (2 in Fig. 5a). This is overlain by further stratified sediment, generally dipping northward (3 in Fig. 5a), that appears to form a series of blocks at the sea floor. These layers are parallel to sub-parallel, however continuity is lost near the seabed due to hyperbolic diffractions. These imbricated blocks were identified as the distal part of slide by Savoye et al. (1990).

The shallowest key reflector, (X), is fairly continuous on the northwestern side of Titanic valley. Numerous down laps and top laps (4 in Fig. 5a) indicate that (X) is an erosional surface or slide plane. The reflector is visible in only a few places on the southeastern side of Titanic Valley (1 in Fig. 5b) but is generally near the seabed and obscured by sea bed reflections. In places, the (X) reflector may correspond to the erosional surface of the seabed. At the western end of profile 3 (Fig. 5c), Savoye et al. (1990) interpreted reflector (X) as rising to the surface at the western end of profile 3 (3 in Fig. 5c). Although there does appear to be an oblique reflection that rises to the surface (perhaps the trace of a slide plane, as suggested by Savoye et al.), regional correlation indicates that (X) continues as an essentially planar subbottom reflection.

The sequence between the (X) and (Y) reflectors varies throughout the area.

In places it contains continuous reflections, but there are areas in which reflectors are of low amplitude and become discontinuous. The unit thins toward the southeast. A large channel (5 in Fig. 5a) and levee (6 in Fig. 5a) could be a result of large scale erosion by downslope-flowing turbidity currents: its dimensions are similar to the modern Titanic valley. Elsewhere in the unit are examples of smaller channels (1 in Fig. 5c) and top lap and down lap relationships between individual reflections.

The sequence between (Z) and (Y) shows parallel to sub-parallel reflectors. This unit dips approximately due south and runs under Titanic Valley where (Z) outcrops on the valley floor. It becomes thicker to the southwest away from the continental rise. Throughout the study area, the top of this sequence top laps against the (Y) reflector (e.g. 8 in Fig. 5a), which regionally has an undulatory character. This suggests that the (Y) reflector is a major erosional surface. Below the (Y) reflectors, reflectors are sub-parallel, with small depressions at irregular intervals (e.g. 9 in Fig. 5a). The bottom of the unit is acoustically amorphous except for small areas of wavy reflectors.

The (Z) reflector is continuous and uniform throughout the study area. It remains rather flat, shows no evidence of being another erosional surface and tends to dip slightly to the SW. The unit under this reflector is generally acoustically amorphous.

<u>Correlation with industry seismic lines</u>

Regional industry multichannel seismic data (GSI lines 116 and 119, fig. 6) cross the study area. The seismic stratigraphy cannot be tied directly to any dated wells. Four units are recognised:

(A) A series of high amplitude reflectors, the lowest of which corresponds to the (Z) reflector of the sleeve gun profiles described above.

(B) A more transparent section with some continuous reflections and some rather irregular reflections.

(C) A pronounced erosion surface, M, marks the top of a rather transparent interval with a few continuous low frequency reflections.

(D) A series of high amplitude reflections

Unit D unconformably overlies basement of the J-anomaly ridge and a sequence of irregular reflections.

INTERPRETATION

Surficial geology

The area to the NW of Titanic valley is mainly composed of surficial muds, with thin coarser interbeds, giving relatively good acoustic penetration. These sediments are derived from downslope sediment transport on the continental rise, consistent with evidence in the SAR sidescan data for downslope sediment movement (IFREMER, 1986; Cochonat et al., 1989).

There is a poorly constrained sandy area around the Titanic Valley (Fig. 4). Titanic valley itself is not well documented as far as surficial sediment is concerned, but probably contains surficial sand overlying outcrops of indurated mudstone. Cores close to the valley contain surficial very fine sand (cores 60, 64) and a similar sand occurs at the top of the trigger weight core in core 5 (Fig. 10 of Savoye et al. 1990). In the trigger weight core of piston core 59, there is a 10 cm thick sandy mud with sandy laminae at the base. This widespread distribution of a surface sand layer may indicate that a turbidity current has recently flowed down the Titanic valley.

The area to the SW of Titanic Valley is the area that has been studied in most detail, particularly around the wreck of the Titanic. SAR sidescan data show bedforms (barchan dunes, sand ribbons and sediment waves) occur in areas where surface samples consist of fine to coarse sand. The two sections of the Titanic, few hundred meters apart, rest in two different sediments, fine-grained sand and silty mud. Other sediments in the immediate area include sandy silt, what appears to be a gravelly band, and other mixed sediments. To the south of the Titanic area, sand ribbons and barchan dunes can be observed in SAR data (IFREMER, 1986). This is an area of fine to coarse-grained sand swept by the Western Boundary Undercurrent and should thus be void of finer grained muddy sediments.

Core 62 near the Titanic wreck penetrated stiff grey muds underlying the surficial muddy and sandy sediments. Radiocarbon dating of foraminifera yielded an age of 53 ka, interpreted as an infinite age (TO-3278). This stiff mud outcrops at the present seabed erosional surface and is probably responsible for the low ridges observed near the Titanic wreck.

Subsurface geology

The regional industry seismic data illustrated in Figure 6 cannot be tied directly to any dated wells. However, we propose a correlation of seismic character with data from the Sohm Basin and Scotian Rise illustrated by Ebinger and Tucholke (1988). The high amplitude reflectors of unit A are similar to the section above the mid-Pliocene reflector L on the Scotian margin. The more transparent section of unit B resembles the lower Pliocene - upper Miocene section on the Scotian margin. The pronounced erosion surface M at the top of unit C resembles the middle Miocene "Merlin" unconformity of Tucholke and Mountain (1975). The high amplitude reflections of unit D resemble the package of A^*, A^c and A^u reflectors of uppermost Cretaceous to Eocene age on the Scotian margin.

The seismic section above reflector Z shows two prominent planar erosion surfaces, Y and X. In their lack of pronounced relief, they resemble erosion surfaces produced by the Western Boundary Undercurrent (e.g. Tucholke and Mountain, 1975; Myers and Piper, 1988). They contrast with the irregular relief produced by turbidity current erosion and slides.

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Table 1. Surficial sediment recovered in cores and grabs

Core no.	Length (cm)	Type of sediment, or notes if washed out
Hudson 87008		
005	122	Medium grained sand.
009	0	Washed out, one pebble recovered.
Hudson 91020		
059	450	Dark brown sandy mud.
060	0	No recovery; veneer of fine green sand on out-side of corer.
061	60	Muddy foram ooze, with some red and grey matter in burrows.
062	165	Olive sandy mud with rare gravel.
064	0	No recovery; washed out; light green very fine sand, coarse silt on outside.
065	0	Silty sample removed from bolt holes on barrel.
Keldysh 1991 Titanic Cores		
2448	0	Grab was empty.
2449-1	7	Metal corrosion. Sand, fine grained with admixture of silt grains.
2449-2	6	Sand, fine grained.
2451	7	Clayey mud with admixture of sand and silt.
2452	0	Core arrived empty.
2453	0	Trace of gravel.
2454	0	Grab arrived empty.
2457	0	Core tube arrived empty.
2458	0	Trace of dark grey silt-clay.
2459	60	Silt-clay mud, brownish-grey to light grey.
2460	0	Trace of grey fine-grained sand.
2461	0	Mixed gravel and pebbles in sandy-silty mud, with an admixture of clay material.

2462	10	Silt-clay with an admixture of sand size grains
2466	394	Sandy-silt sediment. Dark brown.
2467	16	Silt-clay. Dark grey.
2468	178	Silt-clay. Dark grey.
2469	10	Fine-grained sand. Dark grey.
2470	0	Traces of fine-grained sand. Grey.
2471	10	Sandy-silt with an admixture of clay sized fragments. Brown-grey.
2472	18	Sandy-silt. Grey with brown tints.
2477	23	Silt-clay mud. Brown-grey.
2479	0	Trace of coarse-grained sands and gravel.
2480	17	Silt-clay. Brownish-grey.
2481	30	Silt-clay. Dark grey with yellow/green tints.
2482-2	?	Upper part of core not recovered.
2485-2	?	Silt-clay. Dark grey.
2485-3	?	Silt-clay. dark grey.
2485-4	16	Fine-grained sand. Dark grey.
2489	?	Coarse-grained sediment. Light grey.
2490	218	Silt-clay to clay mud. Dark grey to black.

Table 2. Classification scheme for 3.5 kHz reflection type.

TYPE	COLOUR*/NUMBER	TYPE SECTION
Very good penetration with several many subbottom reflectors	green/(1)	179/0725
Good penetration with several clear bottom reflectors	blue/(2)	179/1120
Rare evidence of sub-bottom reflections	brown/(3)	179/0910
Good reflectivity with no subbottom reflections	orange/(4)	180/2320
Many hyperbolic diffractions and side echoes	Black/(5)	116/0630

* colours are those used on original working charts

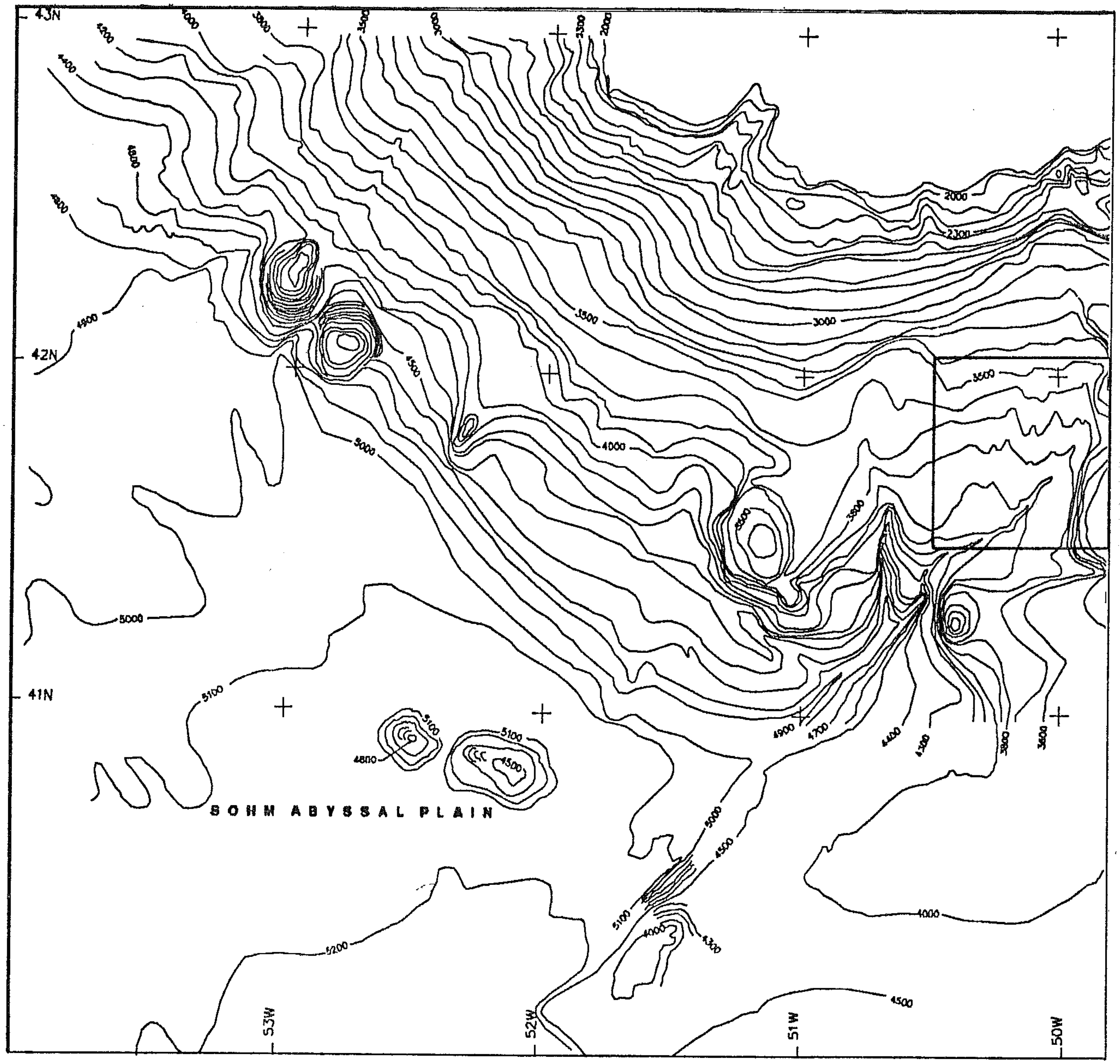


Figure 1. Map showing location of the Titanic study area (solid box)

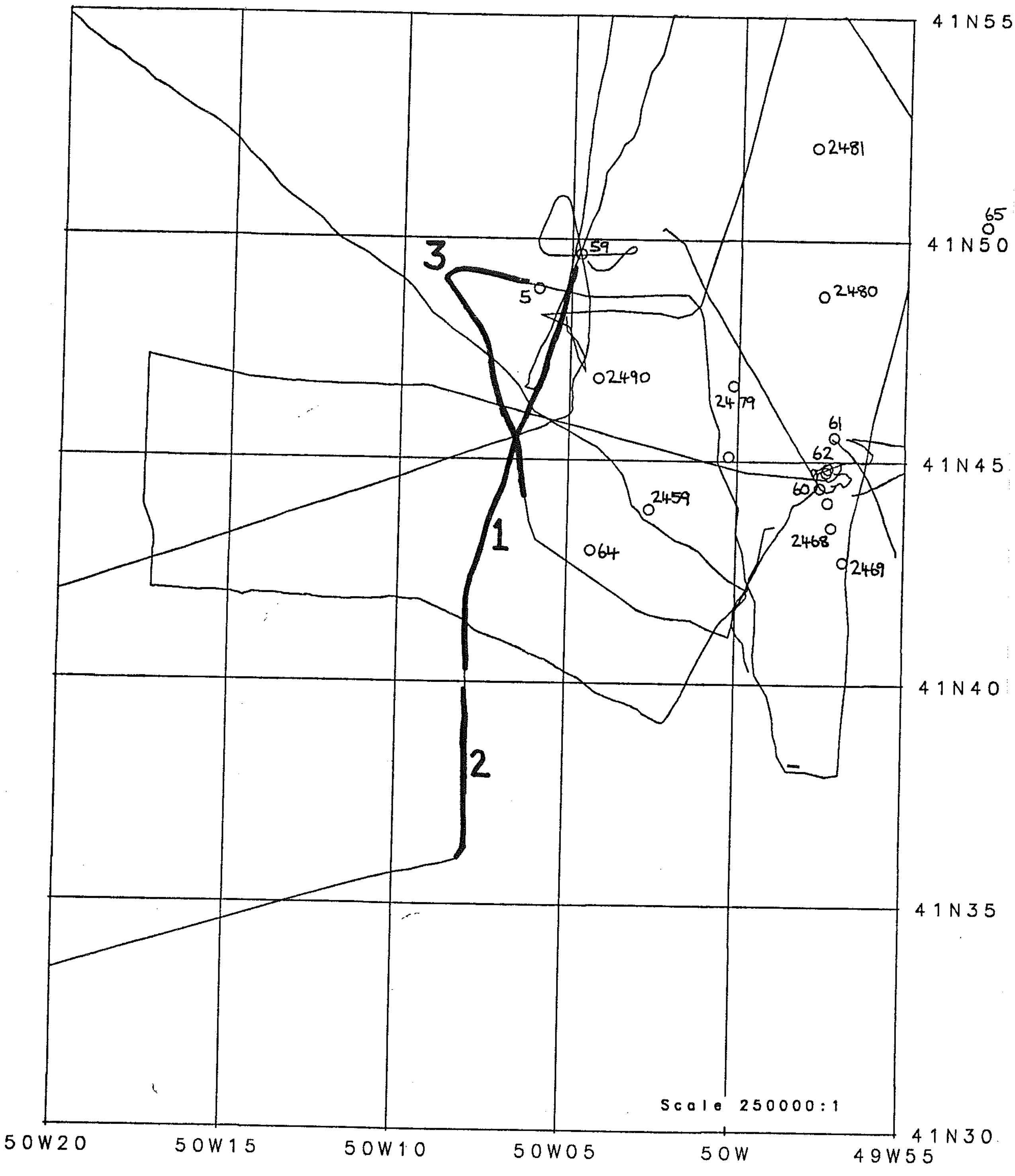
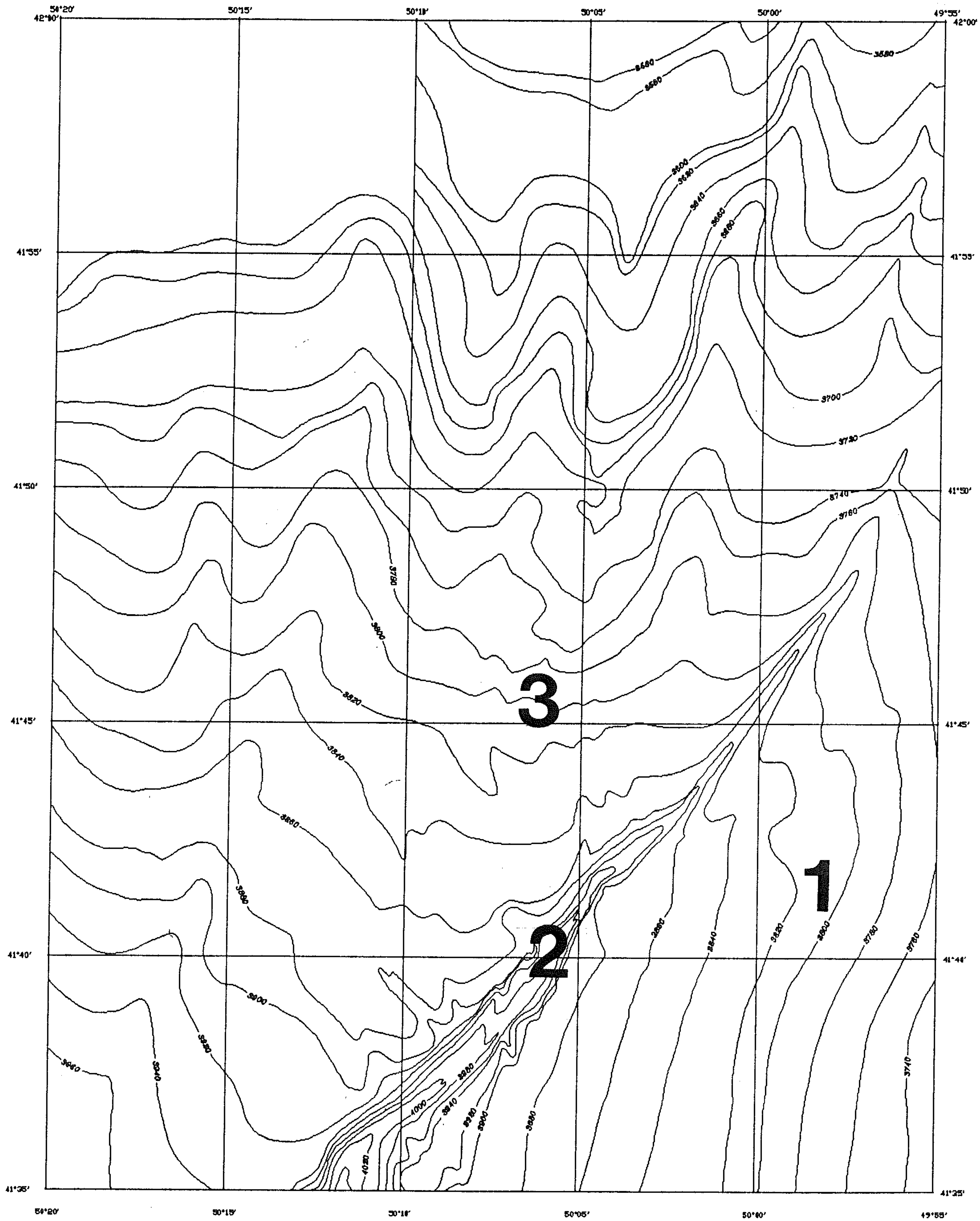


Figure 2. Map of Titanic area showing available cores and tracks with acoustic data

Figure 3. Bathymetric map of the Titanic area. Based on Ryan (1983) and new AGC data.



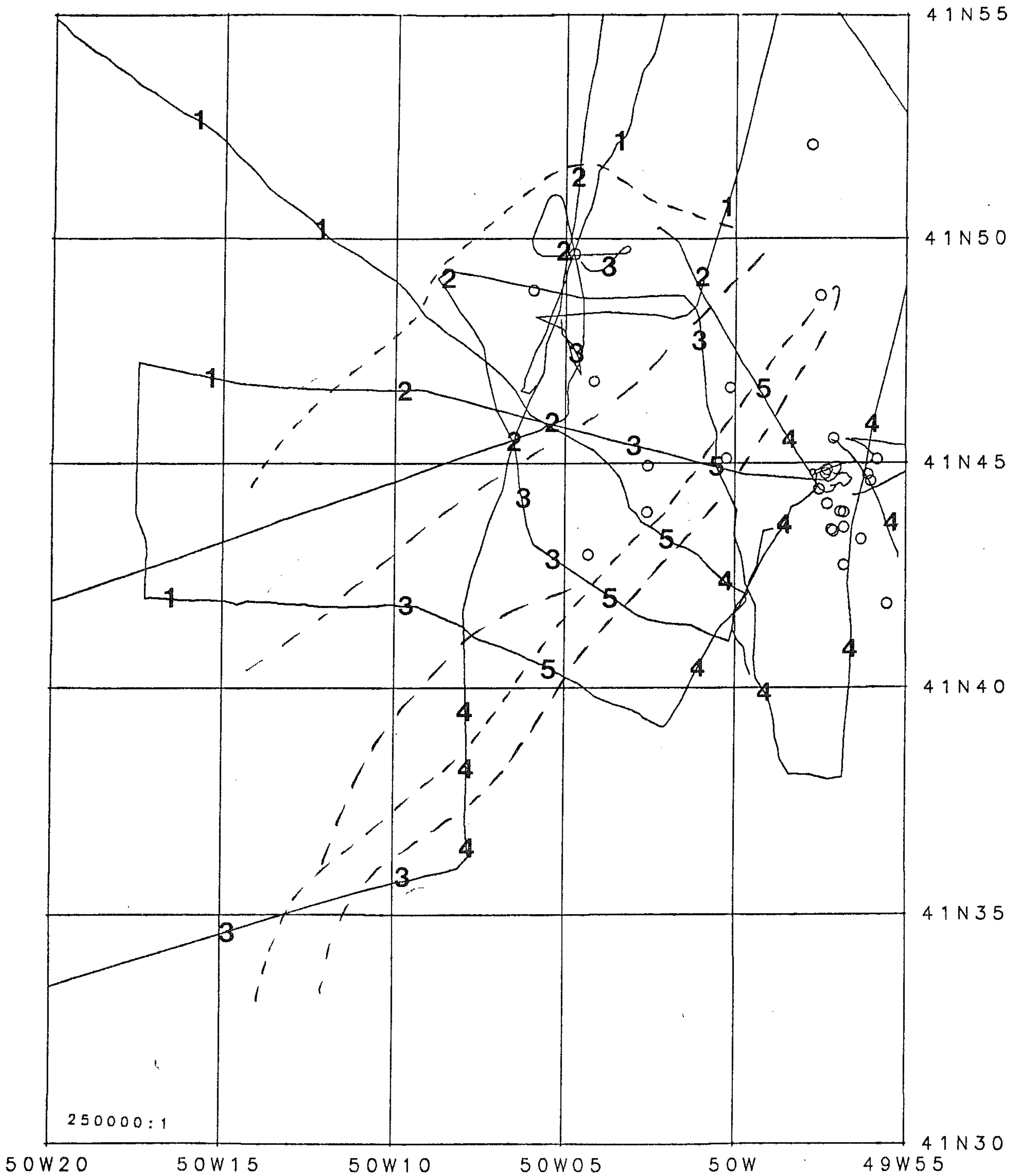


Figure 4. Map showing distribution of 3.5 kHz reflection types (cf. Table 2)

Fig. 5A. Seismic profile north of Titanic valley over the slide described by Cochonat et al. (1989), showing key seismic reflectors. Numbered features are described in text. Profile located on Figure 2.

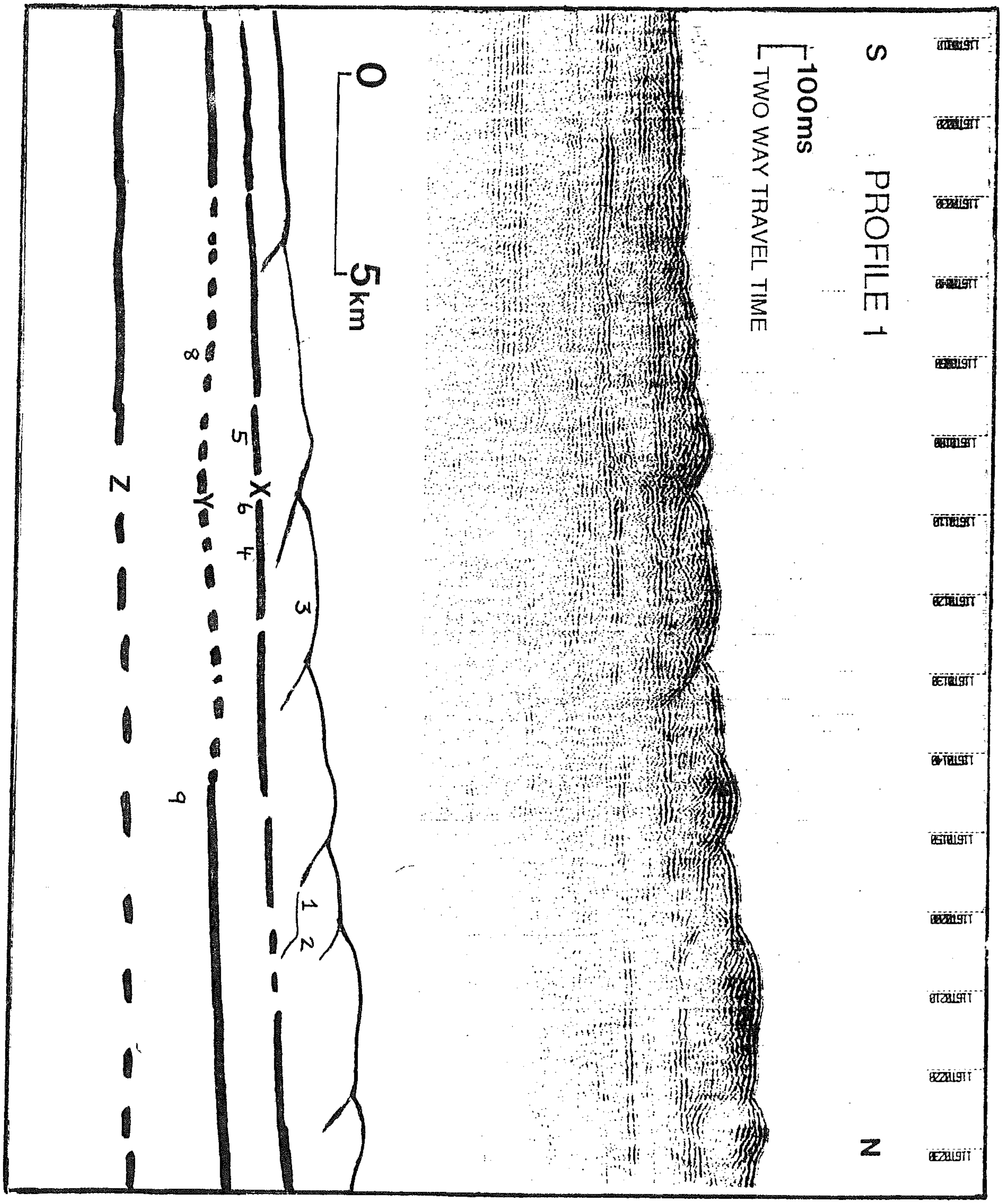
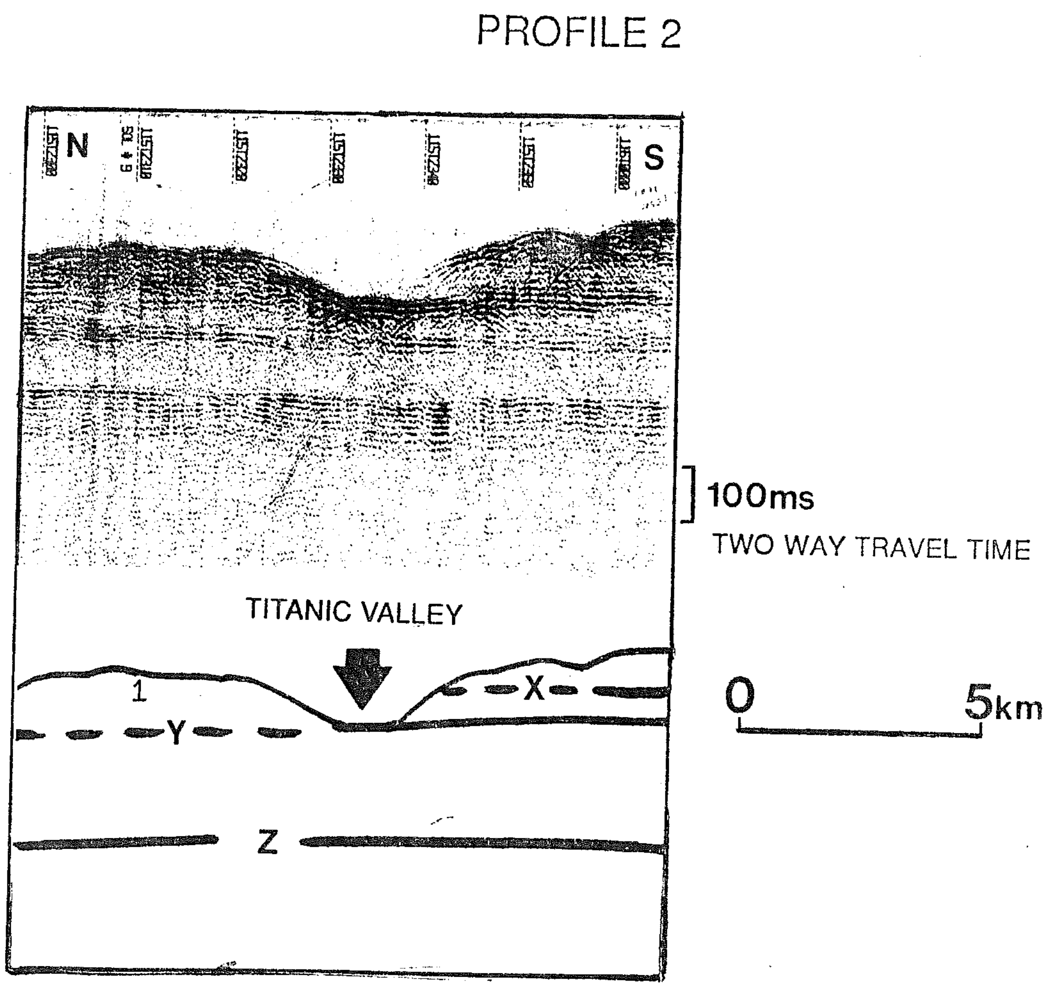


Fig. 5B. Seismic profile across the central channel of Titanic valley showing key seismic reflectors. Feature 1 is described in text. Profile located on Figure 2.



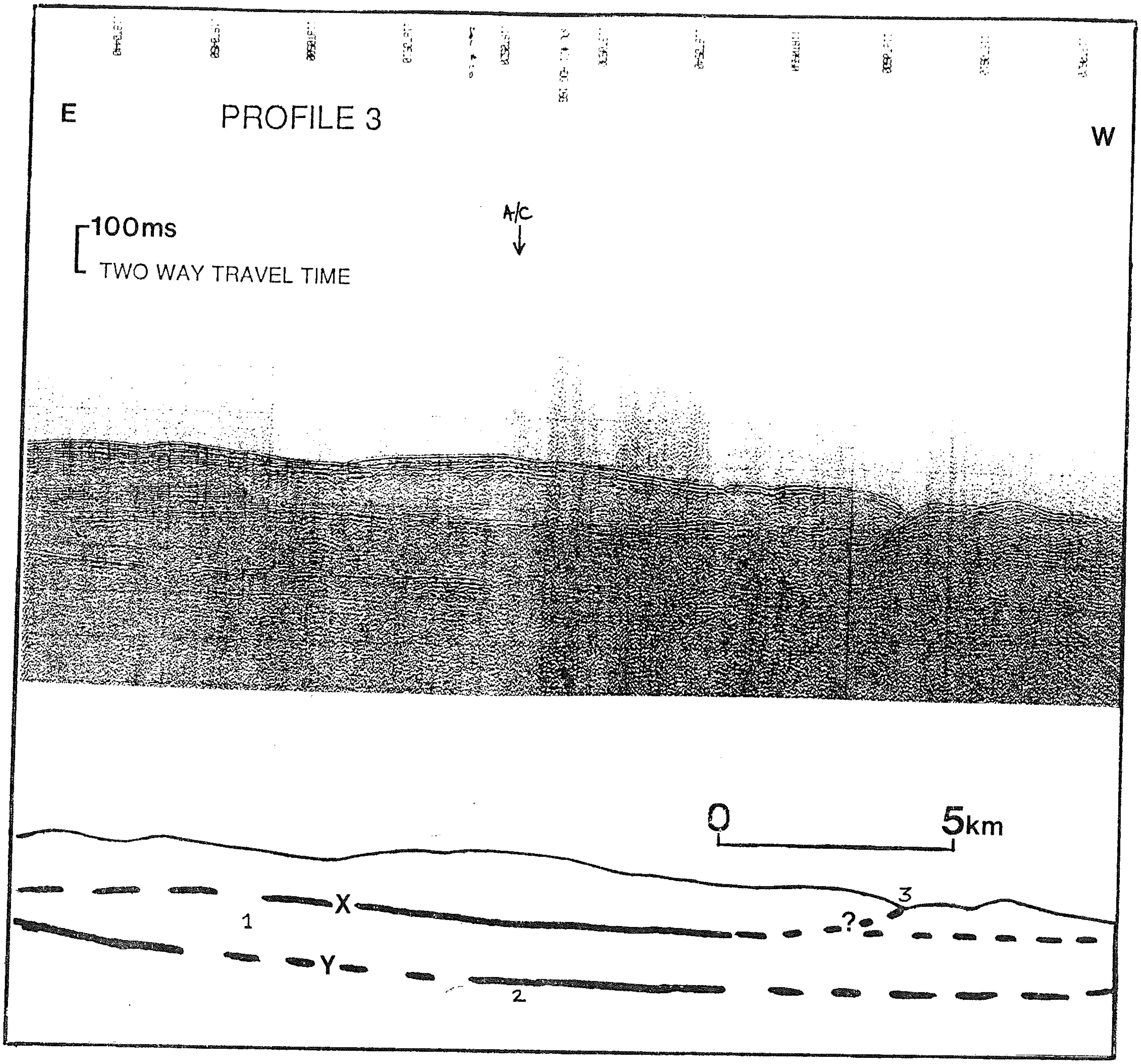
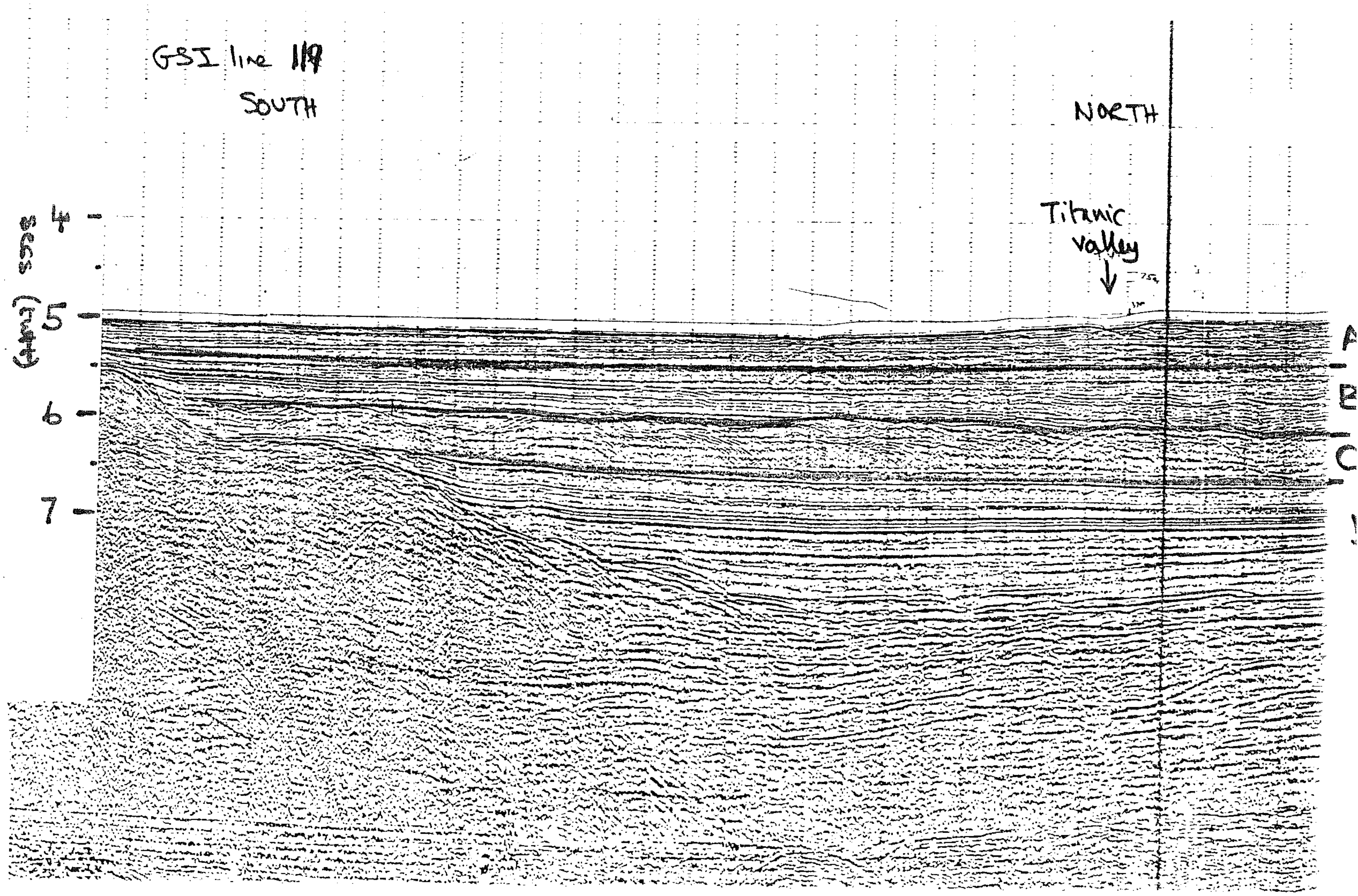


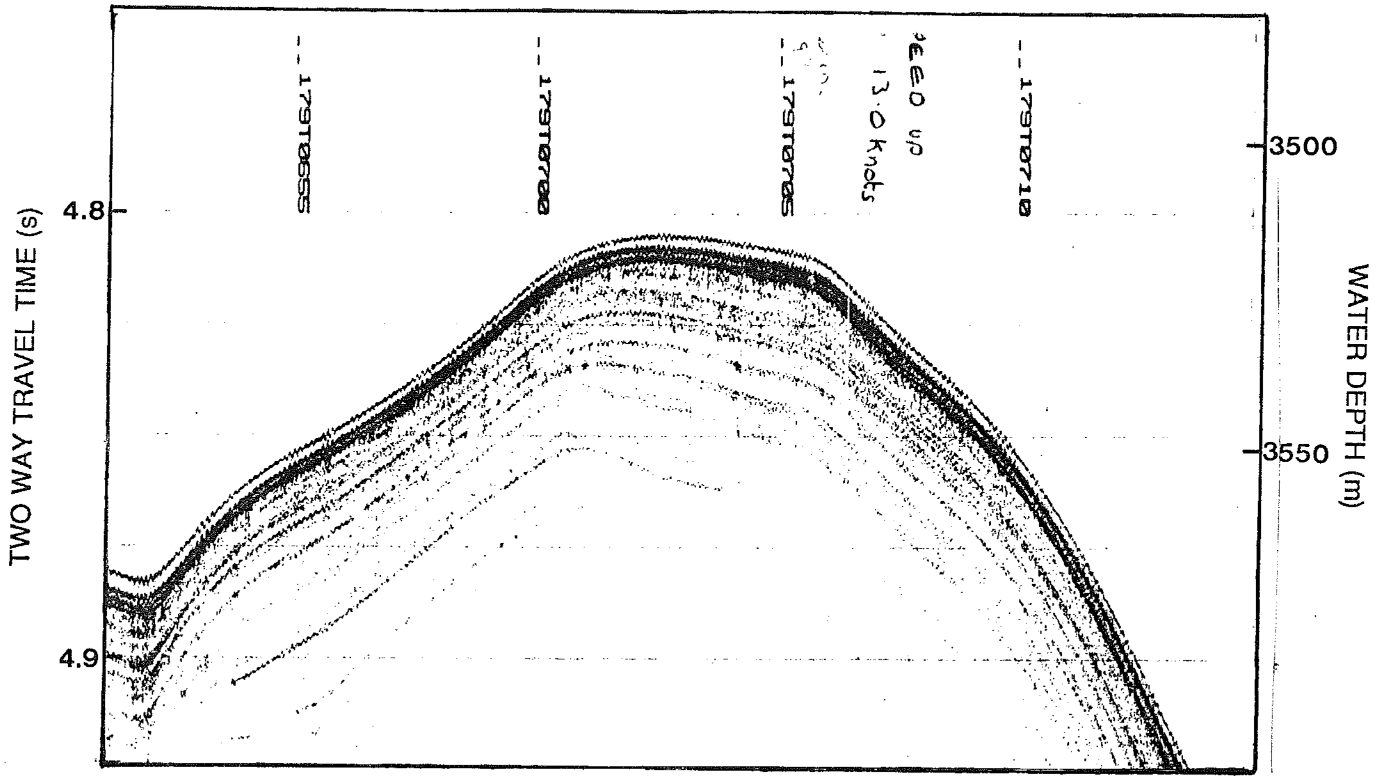
Fig. 5C. Seismic profile north of Titanic valley west of the slide described by Cochonat et al. (1989), showing key seismic reflectors. Numbered features are described in text. Profile located on Figure 2.

Fig. 6. Industry multichannel line GSI 119 showing seismic stratigraphy beneath the Titanic valley. Units A to D are explained in text.

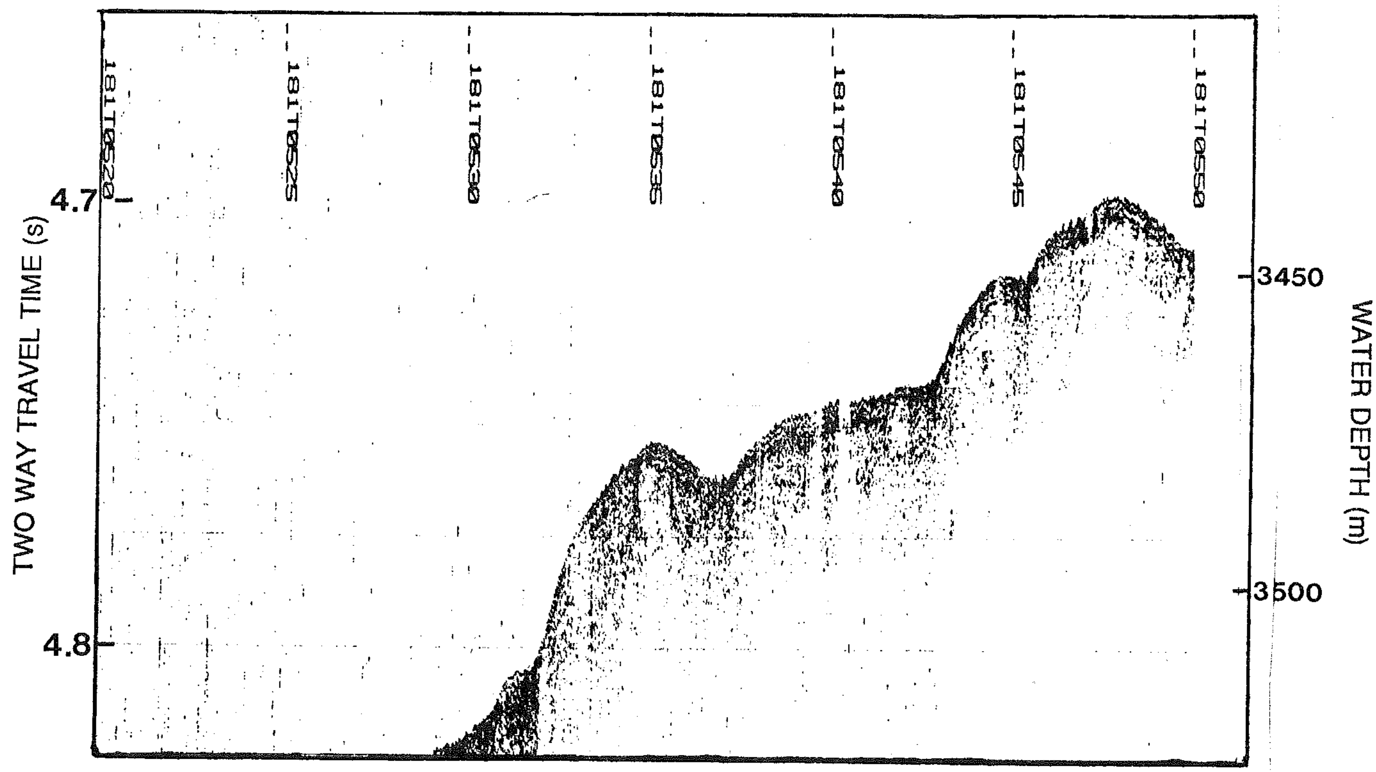


APPENDIX: Examples of reflector types in 3.5 kHz profiles

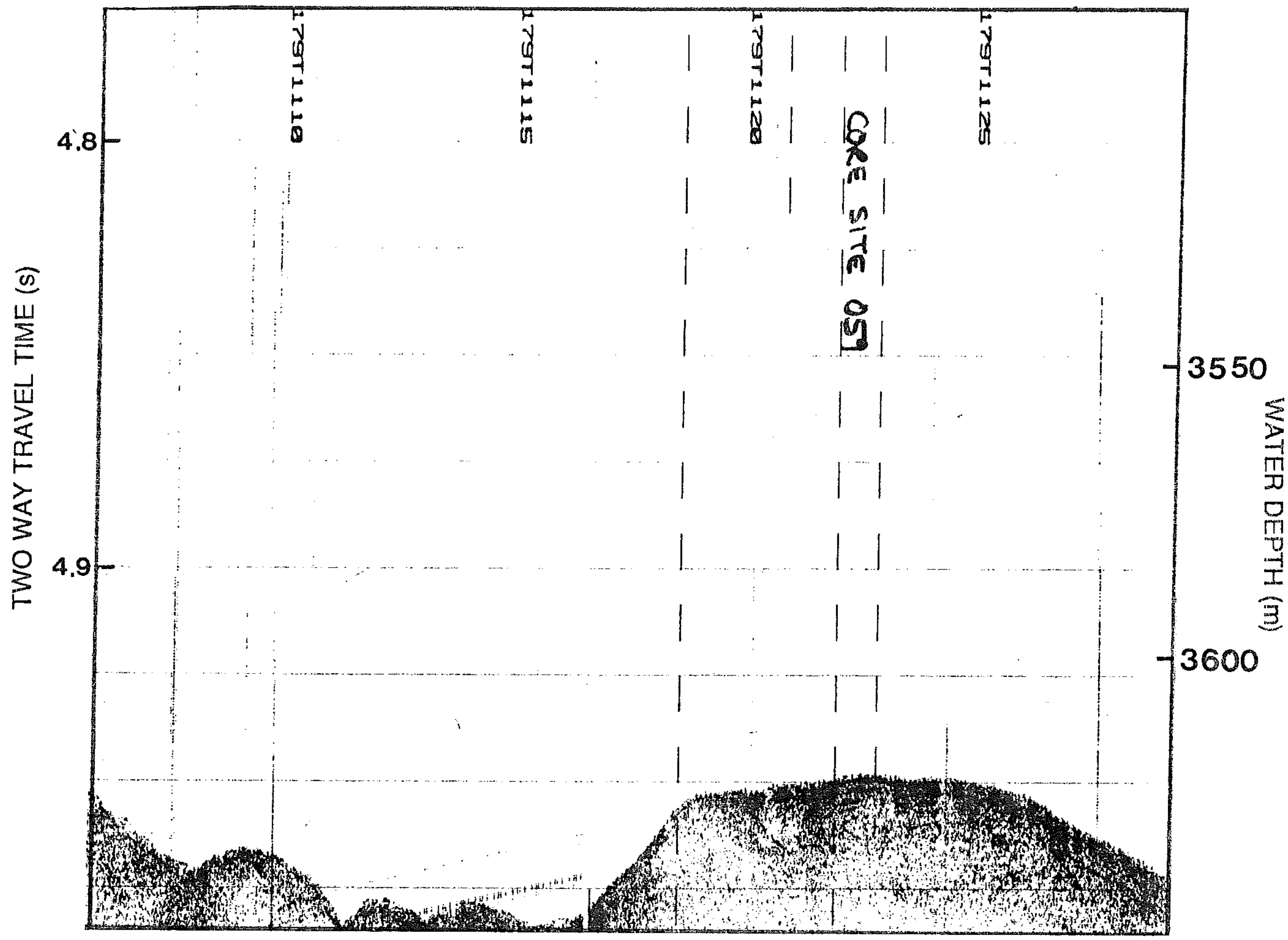
TYPE #1



TYPE #2

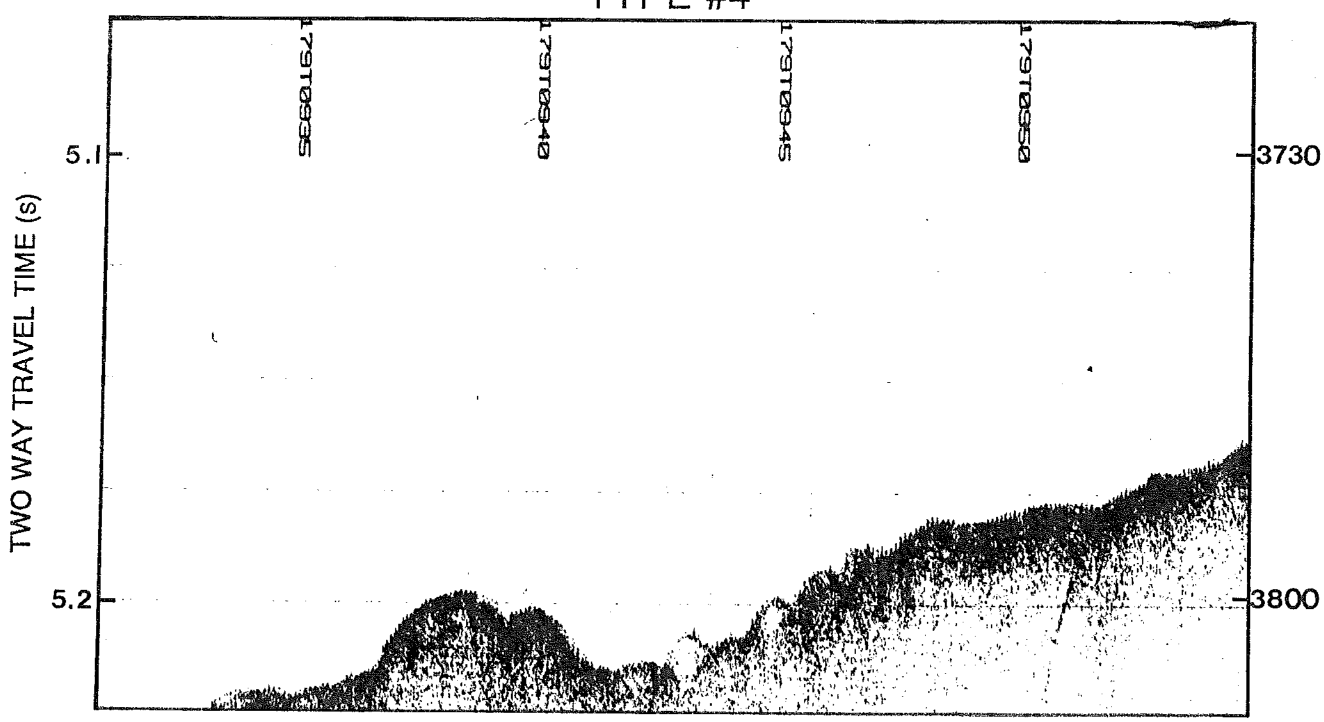


TYPE #3



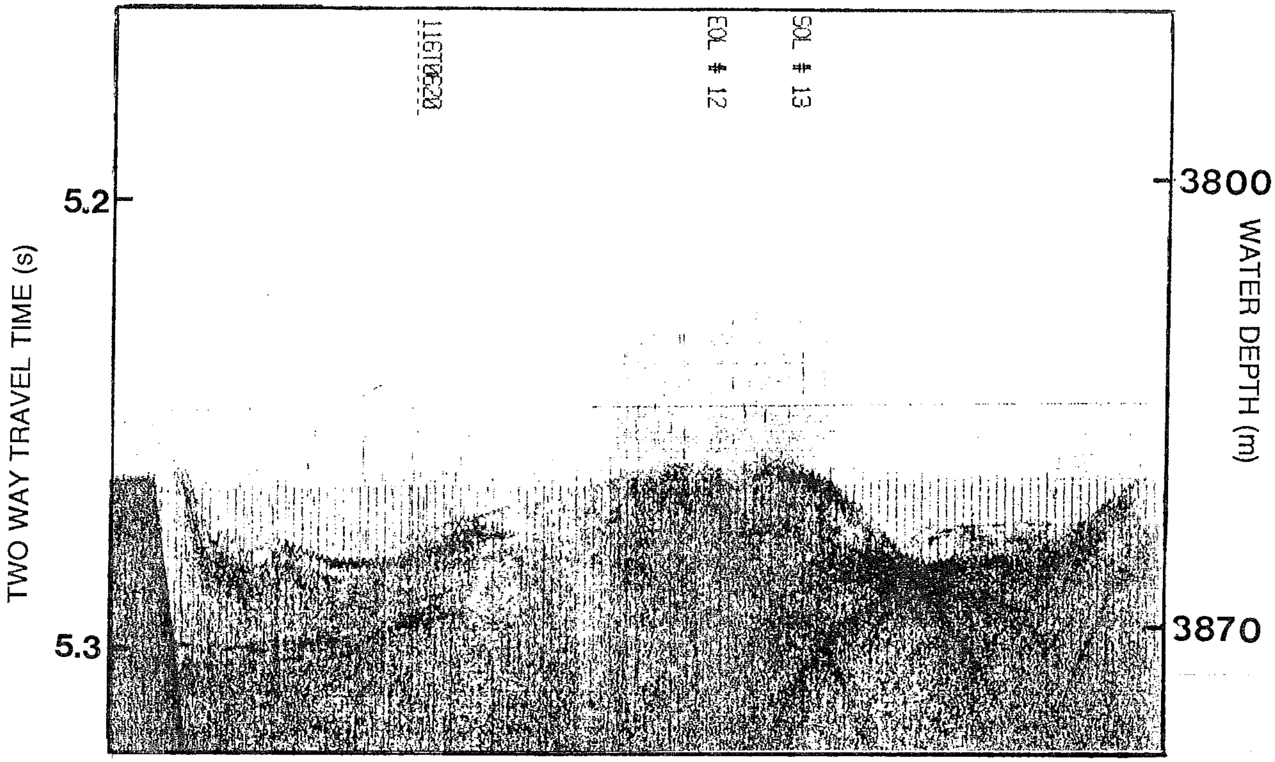
179T1110
179T1115
179T1120
179T1125
CORE SITE
4.8
4.9
TWO WAY TRAVEL TIME (s)
3550
3600
WATER DEPTH (m)

TYPE #4



179T0935
179T0940
179T0945
179T0950
5.1
5.2
TWO WAY TRAVEL TIME (s)
3730
3800

TYPE #5



Note: all examples are shown with high relief