VII. STUDY ON SUBSTRATE STRATIGRAPHY AND STRUCTURE BY CONTINUOUS SEISMIC REFLECTION PROFILING SURVEY

Kensaku Tamaki

Introduction

A continuous seismic reflection profiling survey was carried out along the ship's tracks shown in Figs. VII-1 and 2. The sound source was a BOLT PAR 1900B air gun with a 120 cubic-inches (1980 cm^3) firing chamber operated at a pressure of 1500–1700 psi (105–120 kg/cm^2) with a firing interval of every 11 seconds. Seismic signals were detected by a Teledyne Hydrostreamer with 50 crystal hydrophones towed 150 meters behind the ship. The signals were processed through a Teledyne Model Au-220 amplifier system with filters passing generally 25–160 Hz and fed into a Raytheon Universal Graphic Recorder Model 196-B employing a 4-seconds sweep rate. The ship's speed was maintained at 9, 10, or 11 knots during the survey.

From the analysis of all the seismic records obtained in the survey area (Fig. VII-9), the acoustic sequence in the survey area is divided into three units: Unit I, Unit II, and acoustic basement in descending order as shown in Figs. VII-3 and 4. The possible correlation between this acoustic stratigraphy and the results of DSDP Leg 17–Holes 165, 166, and 170 around the survey area (Fig. VII-1) can be summarized as shown in

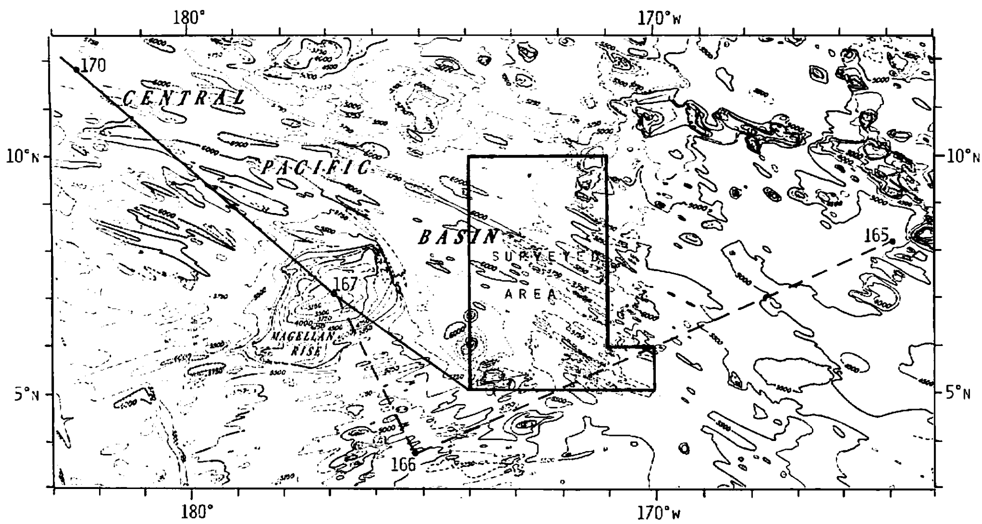


Fig. VII-1 Location map of the survey area and DSDP sites. Solid line shows the ship's track out of the survey area. Dotted line shows the DSDP survey line. Solid circles with numbers represent drilling sites of DSDP Leg 17. Bathymetric map is from the Initial Reports of DSDP, vol. 17 (WINTERER, EWING, *et al.*, 1973)

Table VII-1. The summarized correlation is based on the crossing the tracks of the present cruise with those of DSDP Leg 17 as shown in Fig. VII-1.

Unit I

Unit I is a transparent layer occasionally including coherent reflectors (around St. 406 in Fig. VII-9) or reflective parts (around St. 422 in Fig. VII-9). Three types of Unit I were recognized from the acoustic nature; Type A, Type B, and Type C as shown in the

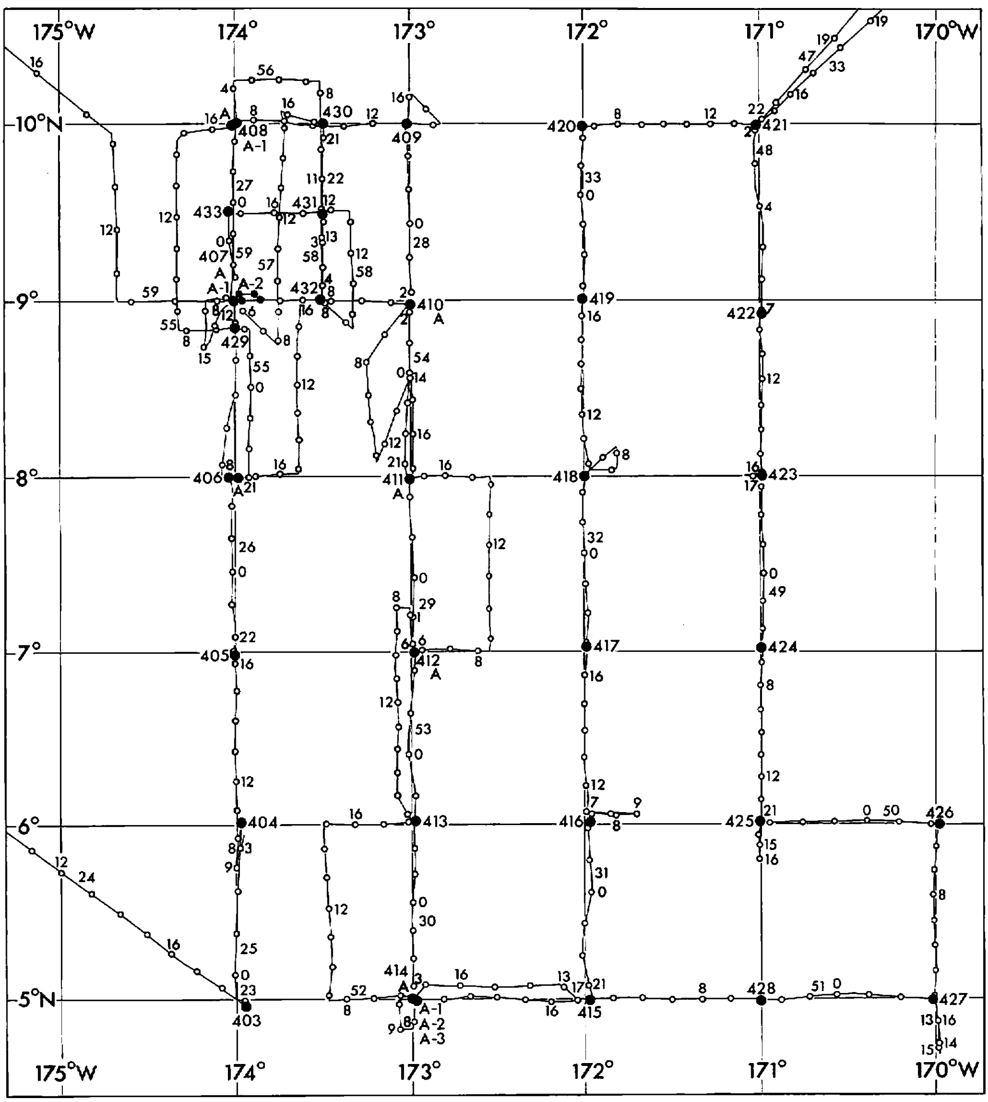


Fig. VII-2 Stations and tracks in the survey area (cited from Fig. I-4). Solid circles with numbers show the locations of stations and the station numbers. Open circles with numbers show ship's position in every hour and the GMT days and hours.

summarized columnar sections of Fig. VII-5. Fig. VII-6 shows the distribution of these three types of Unit I. combined with the isopach map of the whole Unit I.

Type A

Type A is characterized by complete transparency of the whole of Unit I. The transparency is so complete that reflection from the sea floor is often missed on the seismic records. The deposition of such a marked transparent layer is one of the characteristics of the Central Pacific Basin. Type A is distributed predominantly in the survey area (Fig. VII-6), and changes its thickness drastically. The thickness of Unit I shows a marked tendency of thinning northwest from 300 to 20 meters as apparent from the diagram of Fig. VII-4 and also from the isopach map in Fig. VII-6. The thickness of the Type A-Unit I was calculated, assuming that the measurement of the *in-situ* interval sound velocity of the transparent layer in the Central Pacific Basin is equal to that of sea water (1.5 km/sec). This was deduced from the correlation between the drilling results and the seismic records after WINTERER, EWING, *et al.* (1973).

At the Holes DSDP 166 and 170 (Table VII-1), the transparent layer of Type A is composed of clay and ooze respectively, and it is likely that the thicker transparent layer in the southern area mainly consists of ooze according to the results of Hole DSDP 166, and that the thinner transparent layer in the northwestern area corresponds to clay according to the results of Hole DSDP 170.

It is unlikely that the thickness of Type A-Unit I was controlled only by the

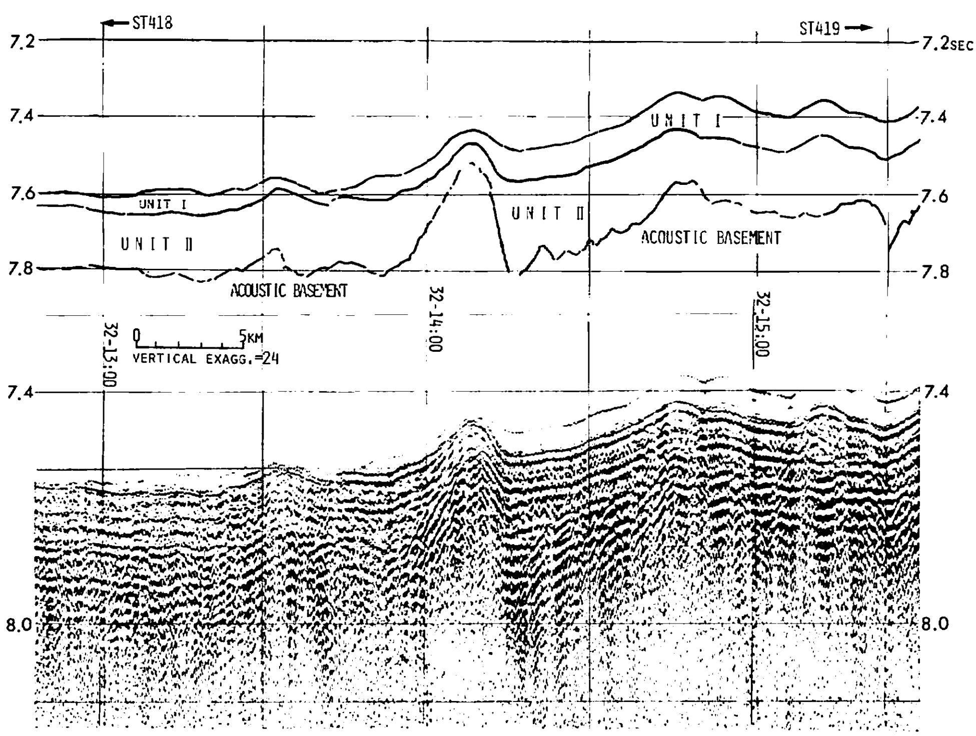


Fig. VII-3 An example of the interpretation of the seismic record. The depth is presented in seconds of two-way acoustic travel time. The location is between St. 418 and St. 419.

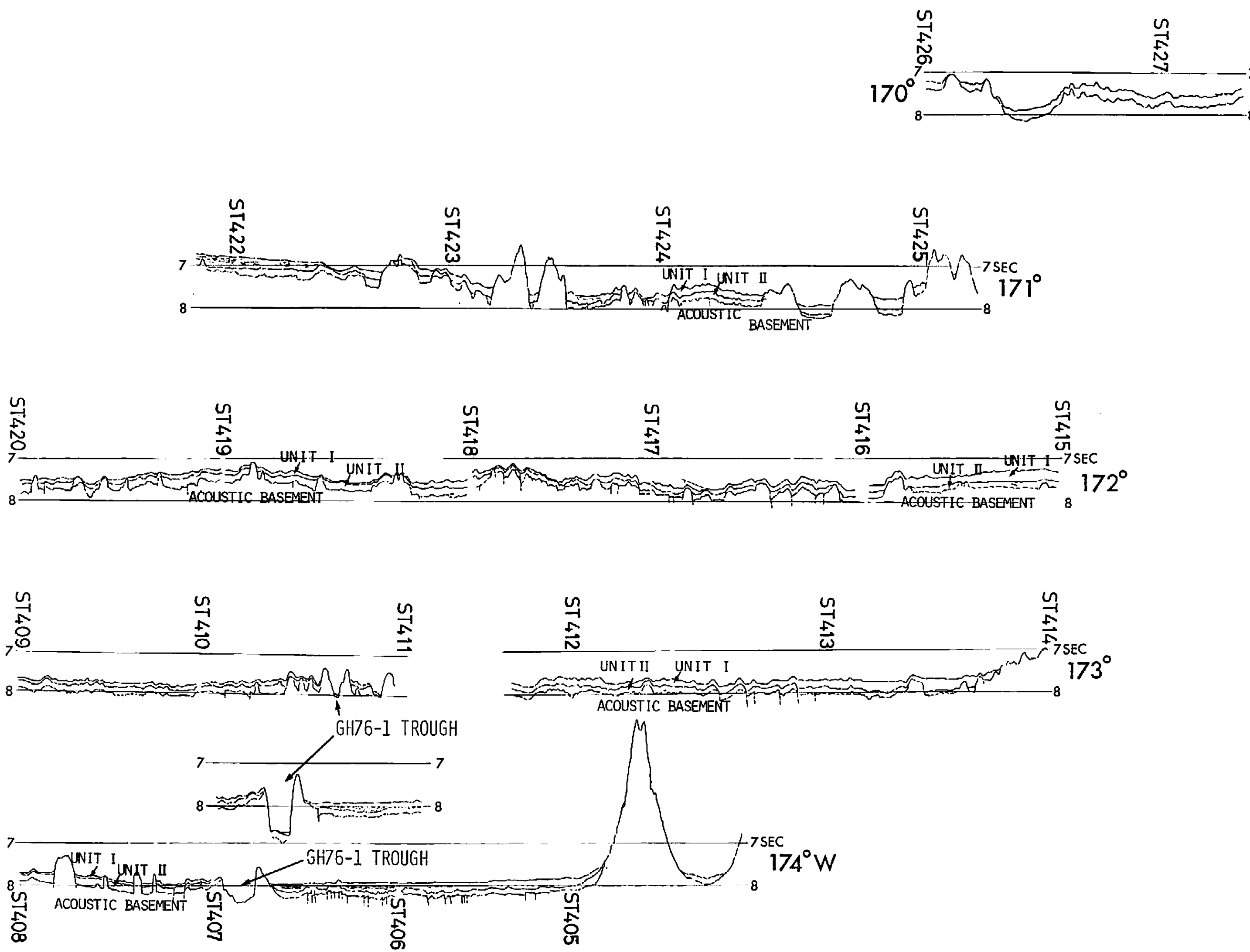


Fig. VII-4 Diagram of seismic record along the ship's tracks.

sedimentation rate during its deposition time, because the age of the bottom of Unit I may vary as the top of Unit II suggests as mentioned later. Besides, incessant movement of the Pacific Plate was occurring as discussed later.

The main depositional feature of Type A is that it was nearly concordant with the topography as shown by the uppermost surface of the underlying unit. However, local variations in the thickness of Unit I shows that it is thinner over the shallower parts than over the deeper parts (for example, see the profile around 49–10:00 in Fig. VII-9). Some special cases are observed within a few troughs where the deposition of transparent layer is very thin as compared with the surrounding area (for example, see the profile around St. 416, 31–08:00 and the profile around 54–11:00 in Fig. VII-9).

Type B

Type B is identified by the presence of the reflective part in Unit I. Its distribution is

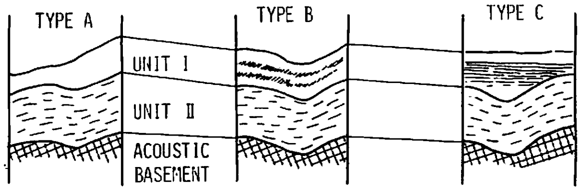


Fig. VII-5 Summarized columnar sections showing Type A, Type B, and Type C.

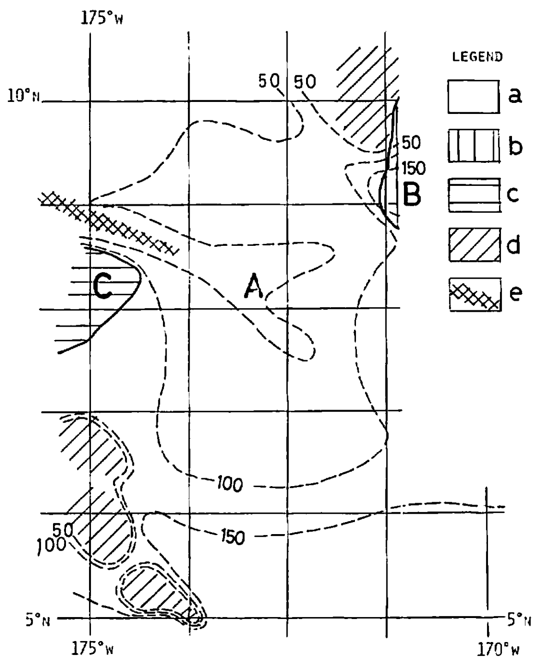


Fig. VII-6 Distribution map of Type A, Type B, and Type C. Dotted lines show contours of the thickness of Unit I in meters. Legend, a: Type A, b: Type B, c: Type C, d: seamounts area and e: GH76-1 Trough.

localized in the northeastern area around St. 422 (the profile between 48–06:00 and 48–12:00 in Fig. VII-9), while its broad distribution is suggested in the eastward adjacent area according to HONZA and TAMAKI (1975).

It is very difficult to estimate the lithological constituents of the reflective part on account of the lack of any drilling data in a Type B area.

Type B is deposited nearly parallel to the topography of the underlying unit and its thickness is almost constant with about 0.2 seconds in two-way acoustic travel time (equal to 150 meters if 1.5 km/sec could be adopted as an interval sound velocity of Type B). Such morphological features of Type B are also observable in the eastward adjacent area.

Type C

The presence of coherent reflectors in Unit I is characteristic of Type C. This type is distributed in the western part of the survey area around St. 406.

The coherent reflectors which are interposed by a certain amount of transparent layer are evenly deposited regardless of the basement topography, and the area where these coherent reflectors is developed forms a topographic abyssal plain (for example on the profile between 54–07:30 and 54–12:30 and the profile between 54–20:35 and 55–01:00 in Fig. VII-9). It is noticeable that this coherent reflector is not deposited on the basement highs but an adjacent to them as seen on the profile around 54–15:00 in Fig. VII-9.

A similar feature is reported from the eastern part of the Central Pacific Basin (HONZA and TAMAKI, 1975), and, there, the coherent reflectors are identified to be turbidite layers with ooze and clay of Late Oligocene to Middle Eocene according to the results of Hole DSDP 165 (Table VII-1).

From these facts, the coherent reflectors of Type C are inferred to be correlated with

Table VII-1 Correlations of acoustic stratigraphy in the survey area and the drilling results by DSDP Leg 17.

Number of site		165	166	170
Position		08°10.7′N 164°51.6′W	03°45.7′N 175°04.8′W	11°48.0′N 177°37.0′E
Water depth		5,053 m	4,962 m	5,792 m
Type of the Unit I		C	A	A
Correlation between the presented acoustic stratigraphy and the results of DSDP	Unit I	Quat. to M. Eocene nanno. and foram. chalk ooze, and rad. ooze including turbidite beds of Late Olig. to M. Eocene (thickness: 240 m)	Quat. to M. Eocene rad. ooze with nannos (thickness: 200 m)	Quat. to Olig. zeolitic brown clay (thickness: 20 m)
	Unit II	M. Eocene to Late Cret. chert limestone, volc. siltstone, breccia, and thin basalt flows (thickness: 240 m)	M. Eocene to E. Cret. chert rad. ooze, volc. claystone and sandstone with some nannos (thickness: 110 m)	Olig., Eocene and Cret(?) cherty ooze and limestone Late Cret. nanno ooze, chalk and limestone, and basalt gravel (thickness: 172 m)
Acoustic basement (age)		Basalt (80 m.y.)	Basalt (120 m.y.)	Basalt (100 m.y.)

the turbidite layer. The thickness of Type C is about 0.2 seconds and the turbidite layer is overlain by a transparent layer with the thickness of 30 meters. The thickness of the turbidite layer is estimated to be 0.1 seconds although this estimation is difficult because of the low resolution of the seismic profiler, and the value is much thinner as compared with the thickness of the turbidite layer in the area around Site 165 where the thickness of more than 0.3 seconds is observed on the seismic records of GH74–5 cruise. The acoustic nature is also different from each other; the coherent reflectors in the present survey area are less reflective than those of the eastern part of the Central Pacific Basin around Site 165.

Unit II and acoustic basement

Unit II consists of a semi-opaque layer and its acoustic nature varies little throughout the survey area. The thickness of Unit II ranges from 0.04 to 0.1 seconds in two-way acoustic travel time, or from 80 to 200 meters if 2.0 km/sec is accepted as an average sound velocity of Unit II according to the data of Holes DSDP 165, 166, and 170.

Based on the DSDP data, Unit II is likely to be composed of various sediments such as chert, ooze, volcanic claystone, volcanic siltstone, limestone, chalk, breccia, and basalt as shown in Table VII-1. Its top seems, without exception, to represent a chert layer, the age of which varies to some extent from Middle Eocene at Sites 165 and 166 to Oligocene at Site 170. This age variation is a great problem in the geological interpretation of the acoustic stratigraphy as discussed later.

The acoustic basement is correlated with Cretaceous basalt as a whole. However, acoustic basement with a smooth surface at some places may possibly includes sills within the sedimentary sequence above the basement basalt as in the case of Hole DSDP 169. All the seamounts and knolls are represented by acoustic basement highs and there is no resoluvable amount of sediments except on the flat top of seamounts and knolls.

Many faults are observable in the acoustic basement and some of them seem to have uplifted Unit II as shown in Fig. VII-4. Unit II is generally concordant with the basement topography except around seamounts and knolls.

The boundary between Unit II and the acoustic basement is rather difficult to detect as shown from many profiles of Fig. VII-9. In the southern area it is almost impossible to recognize the boundary because the thickness of Unit II is less than the resolution of the seismic profiler (0.04 seconds). The presence of thin Unit II can be deduced from the correlation between the results at DSDP site 166 and the seismic records of the present cruise.

GH76–1 Trough

A conspicuous lineated trough flanked by ridges on both sides was observed in the northwestern area (Fig. VII-4 and Fig. VII-7). The trough was tentatively named GH76–1 Trough after the name of the present cruise and its morphological feature is described by A. Mizuno, K. Tamaki, and K. Ishibashi in this report (see Chap. III).

The GH76–1 Trough strikes WNW and has the maximum depth of 6,520 meters which is about 500 meters deeper than the average depth of the surrounding basin floor. The trough is traceable over a distance of approximately 160 kilometers as shown in Fig. VII-6 by hatched portion.

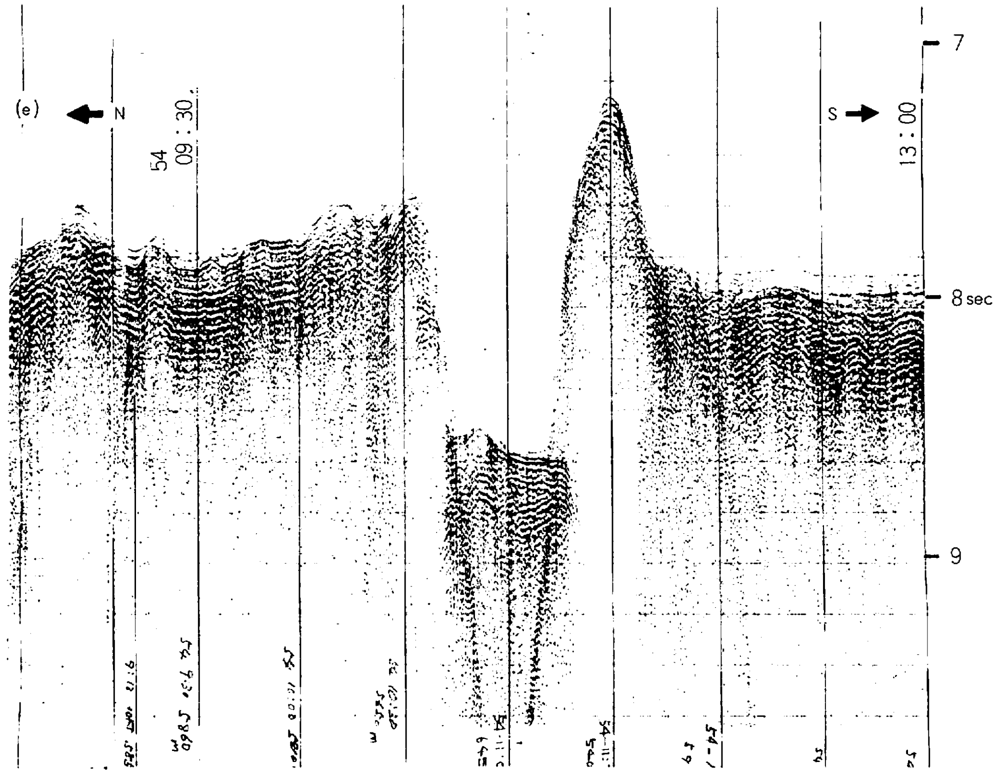
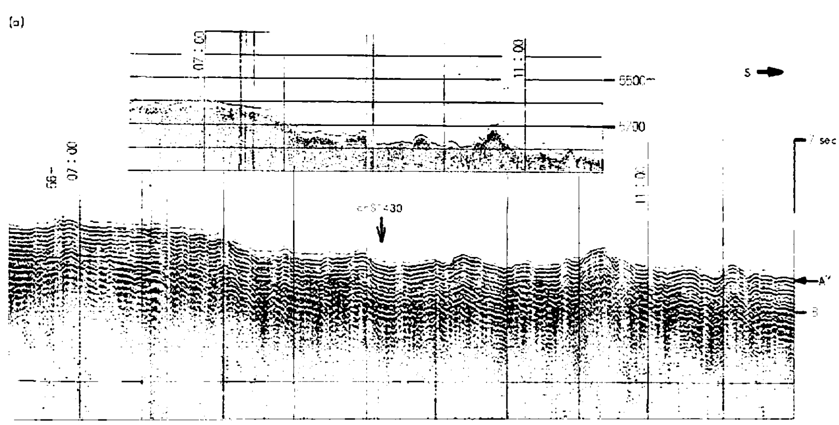


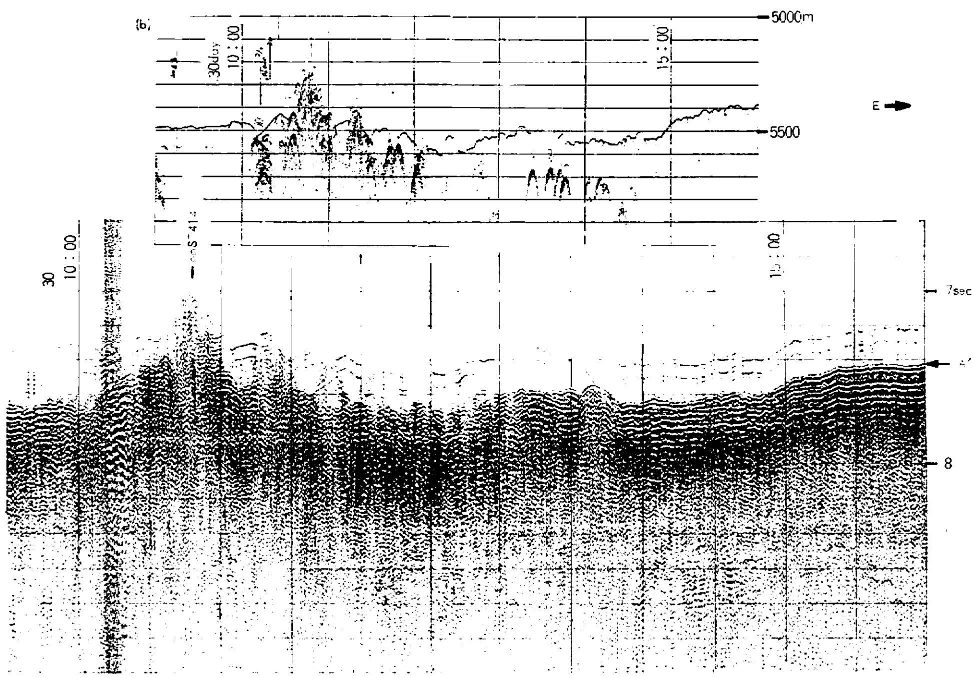
Fig. VII-7 Typical profile of GH76-1 Trough.



(a)

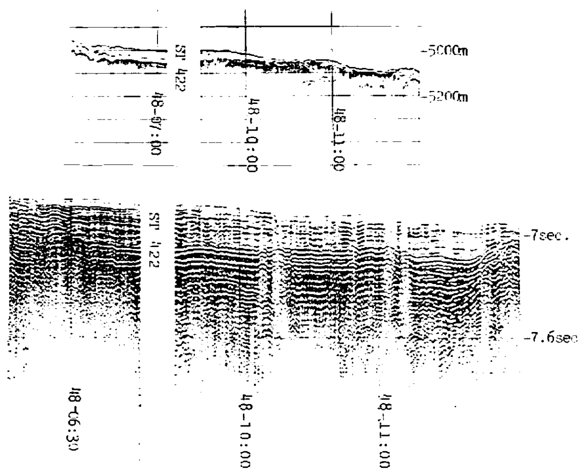
Fig. VII-8a, b, c, and d

3.5 kHz records with seismic records. The upper in each set shows 3.5 kHz record. The depth is presented in uncorrected meters on 3.5 kHz records and in seconds of two-way acoustic travel time on seismic records. The GMT days and hours are also presented. a and b: Type A, c: Type B and, d: Type C.



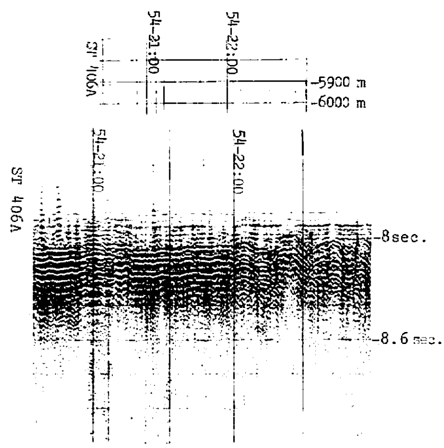
5000m
5500
E
7sec
8
A'

(b)



ST 422
-5000m
-5200m
-7sec.
-7.6sec

(c)



ST 406A
54-21:00
54-22:00
-5900 m
-6000 m
-8sec.
-8.6 sec.

(d)

The most striking feature is that the transparent sediments within the trough show a very limited thickness ranging from nearly zero to 30 meters although the thickness of transparent sediments in the surrounding area is about 70–80 meters. The trend of the trough is quite concordant with that of the magnetic anomaly lineations described by T. ISHIHARA and K. TAMAKI (see Chap. VI).

The ridges on both sides of the trough are composed of acoustic basement. According to M. ARITA (see Chap. X), sampling by piston corer from the trough recovered 1 meter thick deep sea clay possibly of mid-Tertiary age. This clay is underlain by hard volcanic siltstone. There, very little transparent layer is developed and the transparent layer is underlain by semi-opaque layer or an opaque layer. It is probable that the deep sea clay corresponds to the transparent layer and the underlying volcanic claystone represents the semi-opaque layer. From this presumption, the top of the semi-opaque layer within the trough is inferred to be volcanic siltstone instead of chert.

In the area surrounding the GH76–1 Trough, rather strong deformation of Unit II and acoustic basement is observed, and the distribution of the turbidite layer is bordered by the south ridge of the trough (for example, see the profile from 54–22:00 to 55–01:00 in Fig. VII–9).

From the facts mentioned above, it would be reasonable to conclude that the GH76–1 Trough is a very anomalous feature in the survey area.

Relation between the seismic and 3.5kHz records

In the case of Type A, the larger part of Unit I thinner than 150 meters is detectable as the transparent layer in the 3.5 kHz records (Fig. VII-8a) but the thickness of Unit I is often greater than that of the transparent layer detected by the 3.5kHz profiler. A similar situation is reported at Site 169 in DSDP Leg 17 (WINTERER, EWING, *et al.*, 1973, p. 250–251). These authors interpreted that the thickness discrepancy was caused by the nature of the chert beds. They assumed that the top of the opaque layer in the 3.5kHz record is correlated with the top of the shallow chert bed and the most prominent shallow reflector in the seismic record is correlated with either closely spaced, hard chert or a hiatus. The 3.5 kHz profiler cannot detect the whole of Unit I thicker than 150 meters as shown in Fig. VII-8b.

A 3.5 kHz record of Type B is shown in Fig. VII-8c with seismic record. The reflective part in Type B corresponds to the opaque layer in the 3.5 kHz records. The turbidite layer in Type C also corresponds to the opaque layer in the 3.5 kHz record shown in Fig. VII-8d, and the thickness of the transparent layer overlying the turbidite layer is the same in both records.

As mentioned above, the opaque layer in the 3.5 kHz records correlates not only with the chert bed in Unit II but also with the turbidites or reflective part in Unit I.

Discussion

Variation of the thickness of Type A-Unit I

A very good correlation between the acoustic units and the lithologic units is suggested from the results of DSDP drilling as mentioned above. However, the geological interpretation of each unit is rather complicated. The kinematic model of pelagic sedimentation on a moving plate, which was deduced by summarizing all the drilling results in the Pacific Basin, revealed the diachronous nature of lithologic boundaries in deep sea pelagic sediments (HEEZEN *et al.*, 1973). According to this model, chert beds underlying Unit I are formed by the diagenesis of radiolarian ooze which was deposited on the northwestwards moving Pacific Plate when it was passing across the equatorial zone.

The areal variation of the thickness of Type A-Unit I is inferred to have not only depended upon the sedimentation rate and erosion of Unit I, but also the age when the concerned area passed through the equatorial zone from the view point of this model. It also depends upon the diagenesis of radiolarian ooze, because the survey area of Latitude 5° to 10°N is considered to be just going out of the equatorial zone and now undergoing diagenesis of the radiolarian ooze to chert. However, the nearly same age of the top of the chert layer at three DSDP Sites around the survey area may indicate that the thickness of Type A-Unit I depends mainly on its sedimentation rate including hiatus and erosion.

Origin of the GH76–1 Trough

Three facts can be raised as factors in order to deduce the origin of the GH76–1 Trough. The first is that turbidites are distributed only in the southern area of the trough and abut against the south ridge of the trough. The second is that volcanic siltstone overlain by mid-Tertiary thin clay was sampled from the trough. The third is the presence of magnetic anomaly lineations parallel to the strike of the trough.

Two alternatives are possible as a source area of the turbidite beds from the distribution map of Fig. VII-6. One is the south ridge of the trough and another is the Magellan Rise out of the survey area to the west (Fig. VII-1). The absence of turbidites within the trough, however, leads us to suppose that the Magellan Rise might be the source area of the turbidite beds.

The fact that the turbidite layer occupies the lower horizon of Unit I and is overlain by 30 meters of the thick transparent layer may suggest that the age of the turbidite deposition was approximately Eocene to Oligocene as well as in Hole DSDP 165. These features may prove that the ridge along the trough had existed before the turbidites was deposited, i.e., before Eocene.

Two alternatives are also possible as the time when the trough was formed. One is that the trough was formed at the same time as the initiation of the crust or early Cretaceous (100–120 m.y.). Another is that the trough was formed after the initiation of the crust. The remarkable concordance of the trough trend with the magnetic anomaly lineations may suggest that the former alternative is the correct one, i.e., the trough is associated with the initiation of the crust around the trough, because the magnetic anomaly lineations are closely associated with the initiation of the oceanic crust.

The volcanic siltstone sampled within the trough is inferred to be derived by the volcanic activity during the initiation of the trough, and, if the trough was associated with the initiation of the crust, the volcanic siltstone might be included into Unit II and the lack of the chert layer might be plausible. The lack of a chert layer and the presence of a very thin transparent layer within the trough suggest a non-depositional environment or a very low sedimentation rate within the trough during Late Cretaceous and Cenozoic times.

Structural movement

Unit I is free from structural movement and seems to be only a sedimentary cover. The depositional anomalies of Unit I within some troughs and on the profile at 33–07:00 between St. 420 and St. 421 for example would be caused by erosion or non-deposition. Unit II is also almost free from structural disturbance, although some structural movements throughout both Unit II and acoustic basement may be observable around the GH76–1 Trough typically shown in the profile around St. 406.

Structural disturbance in the acoustic basement is prominent around the trough as shown by the presence of many faults (Fig. VII-4). It is inferred that most structural activity in the survey area would be associated with the initiation of the crust at the survey area.

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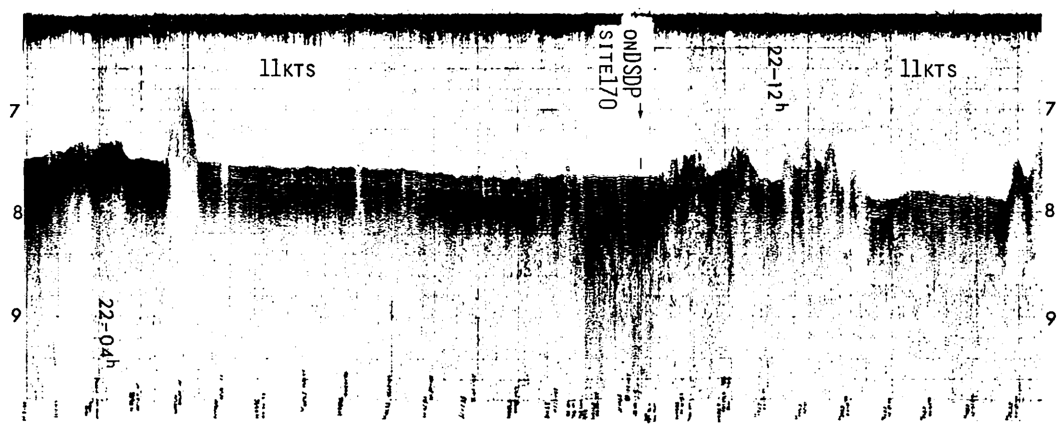
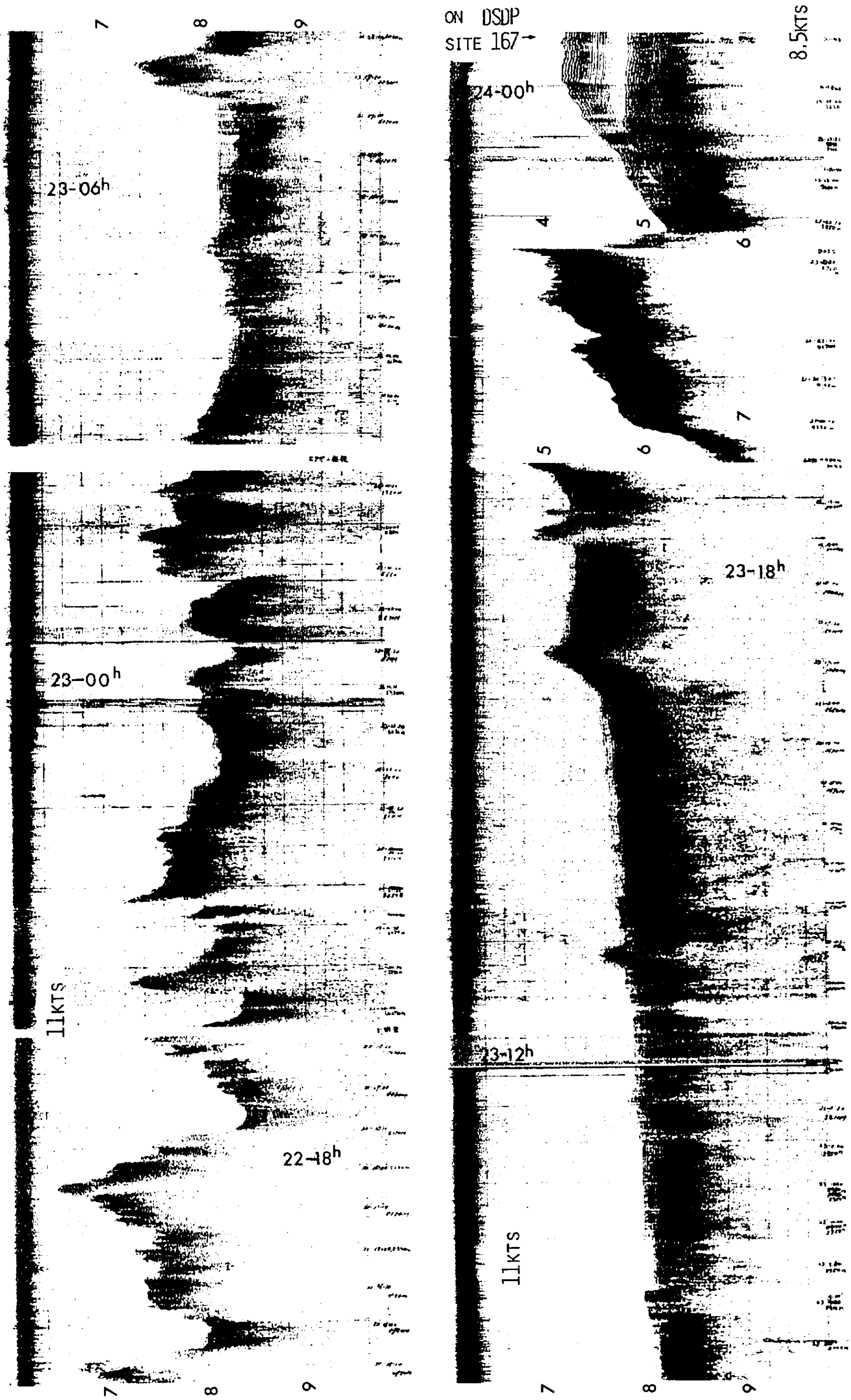
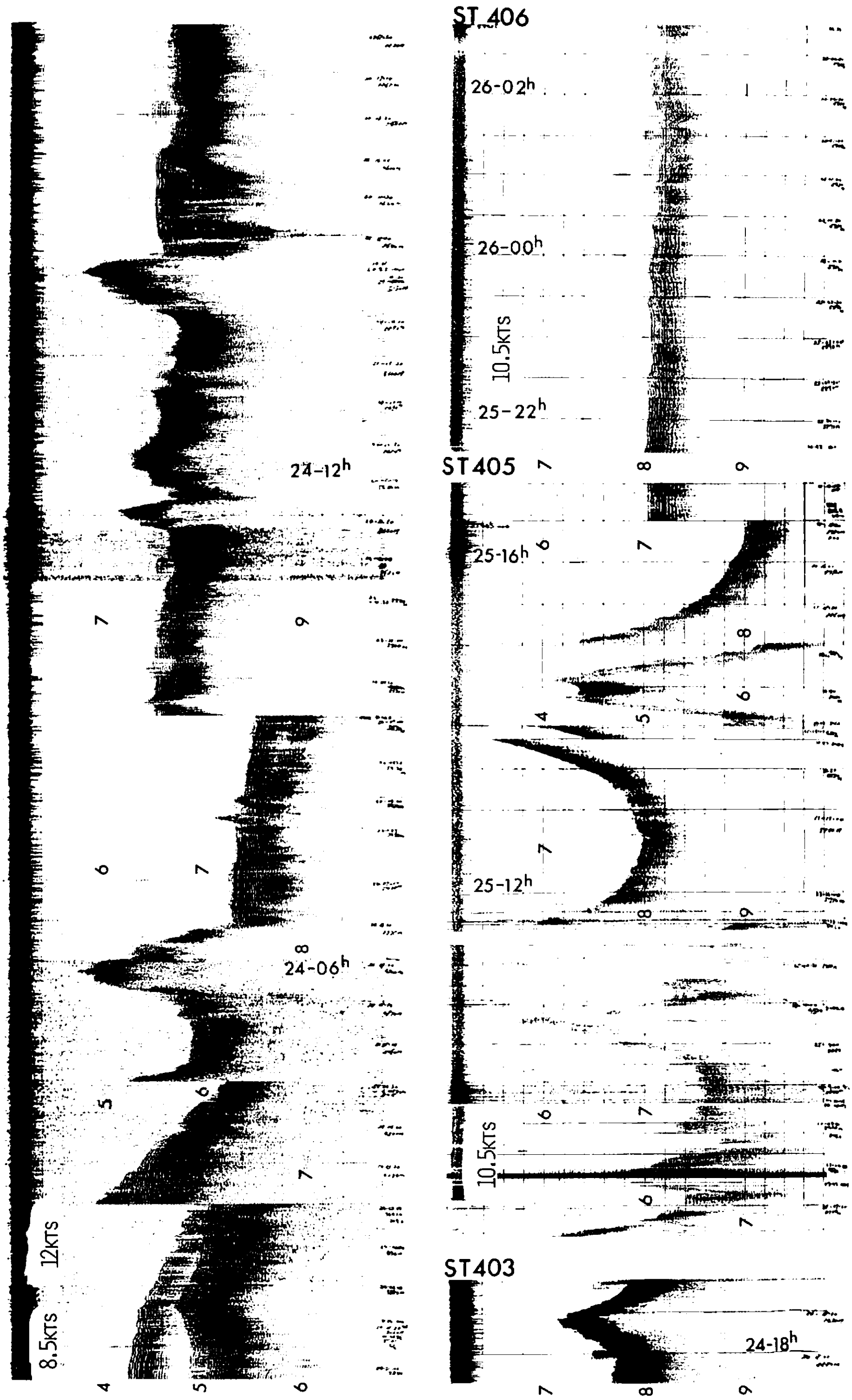
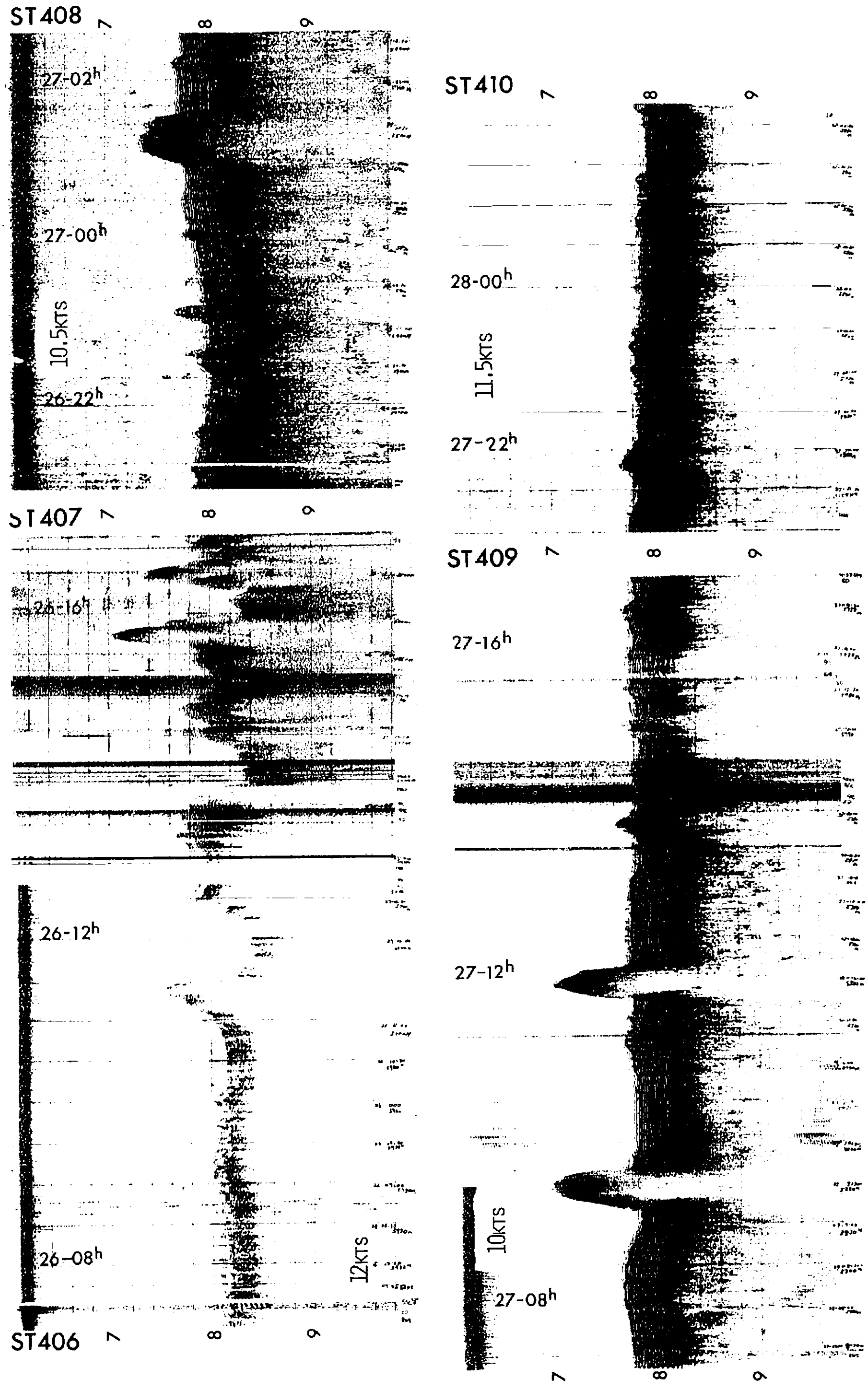
Fig. VII-9 All the seismic records obtained during the survey, with GMT days and hours, two-way acoustic travel time in seconds, and ship's speed. Vertical exaggeration are 24 (8 knots), 27 (9 knots), 30 (10 knots), 33 (11 knots), and 36 (12 knots).

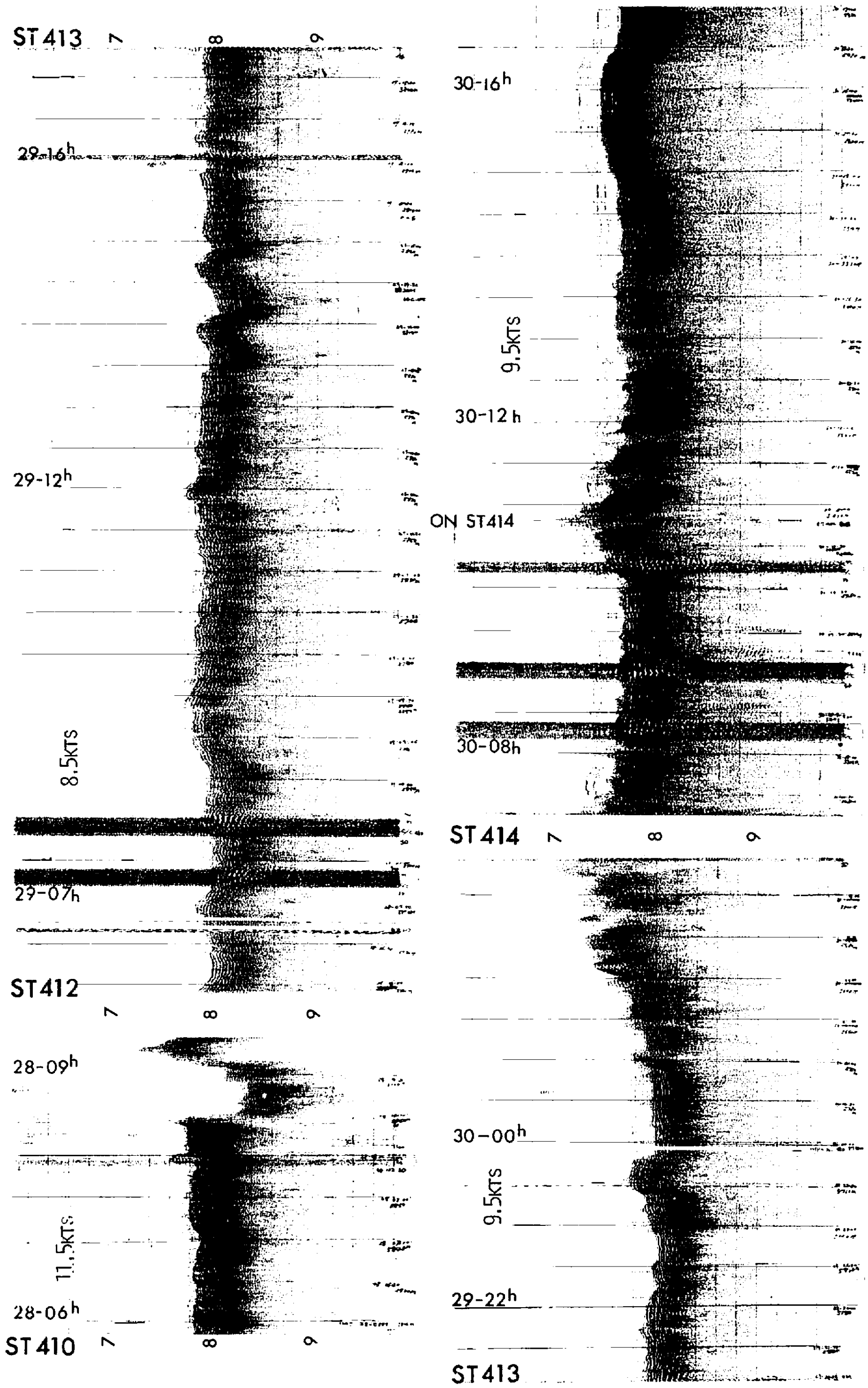



ON DSDP
SITE 167→
8.5KTS
24-00h
23-18h
23-12h
11KTS
23-06h
23-00h
11KTS
22-18h
7
8
9

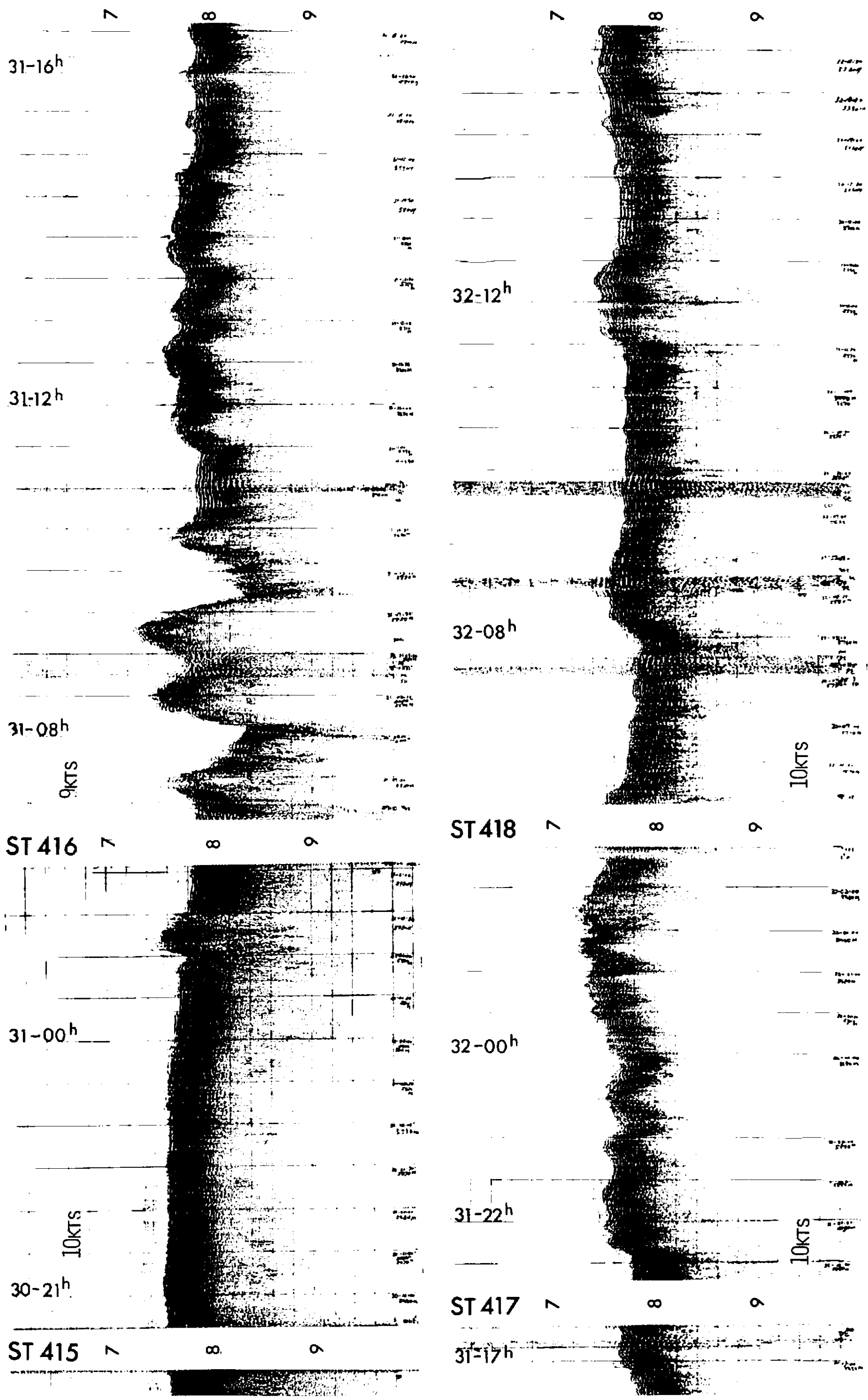


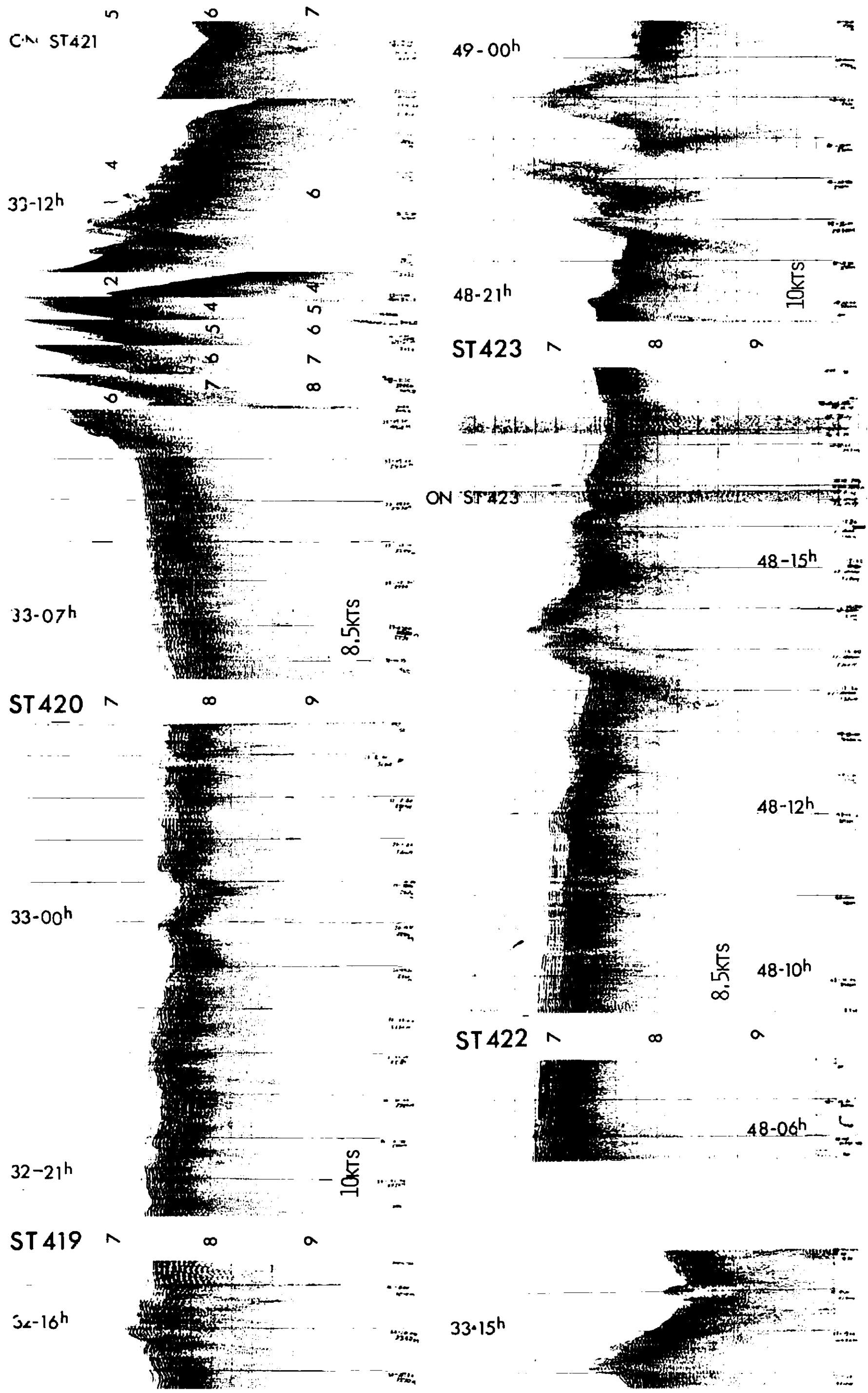
ST 406
26-02h
26-00h
10.5KTS
25-22h
ST405
25-16h
25-12h
10.5KTS
ST403
24-18h
24-12h
24-06h
12KTS
8.5KTS

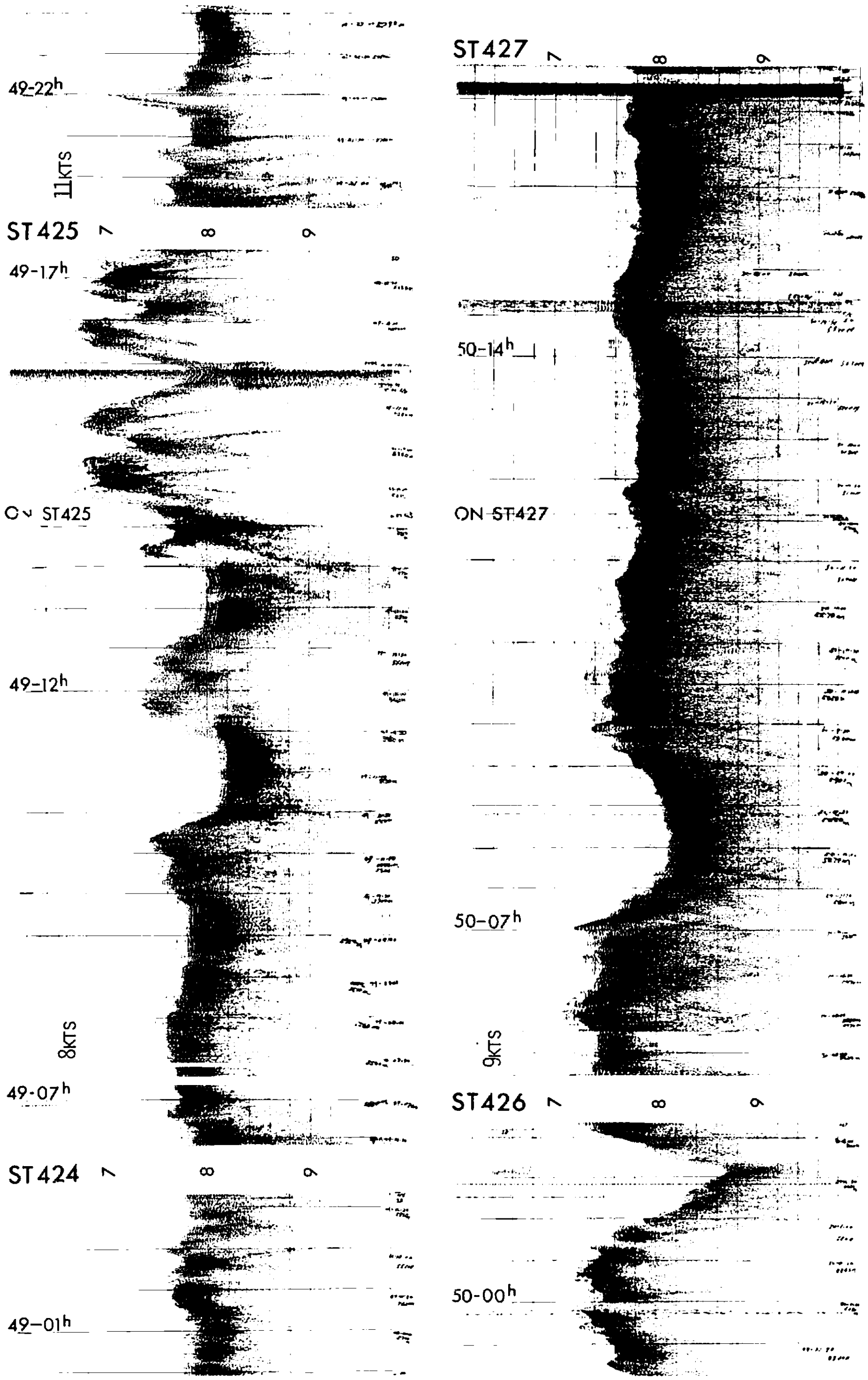

ST408
7
8
9
27-02h
27-00h
10.5KTS
26-22h
ST407
26-16h
26-12h
26-08h
12KTS
ST406
ST410
28-00h
11.5KTS
27-22h
ST409
27-16h
27-12h
10KTS
27-08h

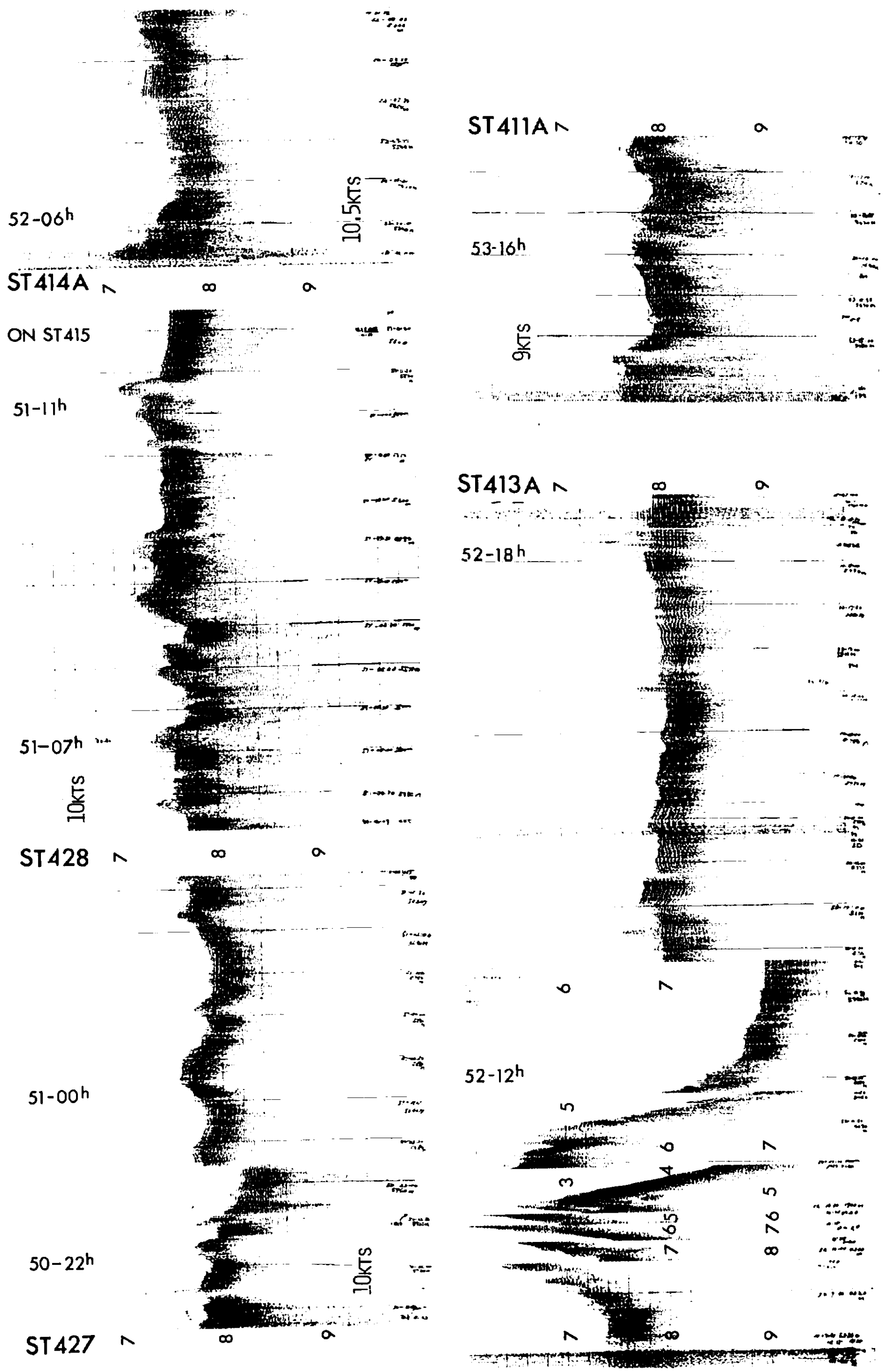


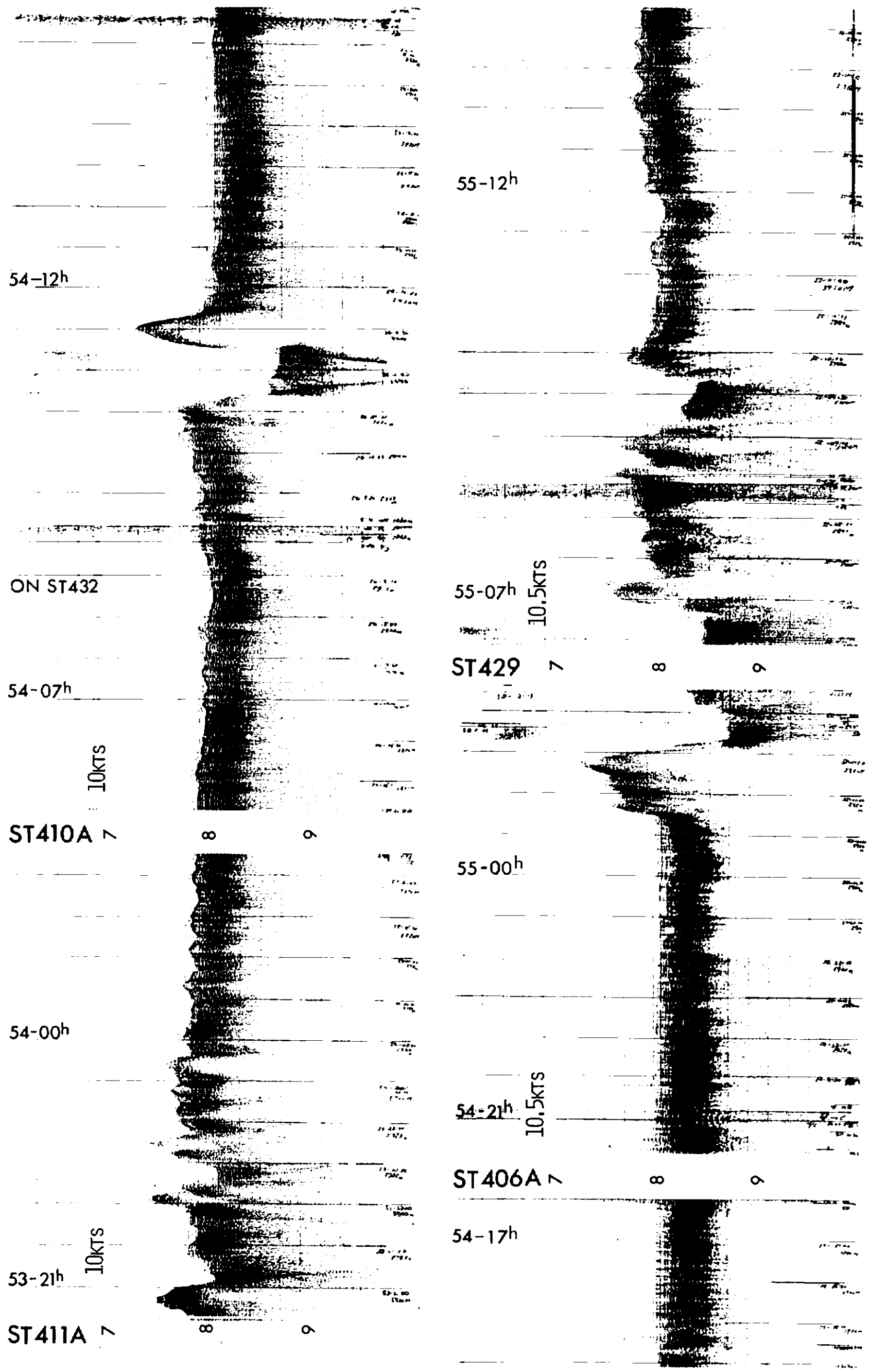
ST413
7
8
9
29-16h
29-12h
8.5KTS
29-07h
ST412
28-09h
11.5KTS
28-06h
ST410
30-16h
9.5KTS
30-12h
ON ST414
30-08h
ST414
30-00h
9.5KTS
29-22h
ST413


7
8
9
31-16h
31-12h
31-08h
9KTS
ST 416
31-00h
10KTS
30-21h
ST 415
32-12h
32-08h
10KTS
ST 418
32-00h
31-22h
10KTS
ST 417
31-17h

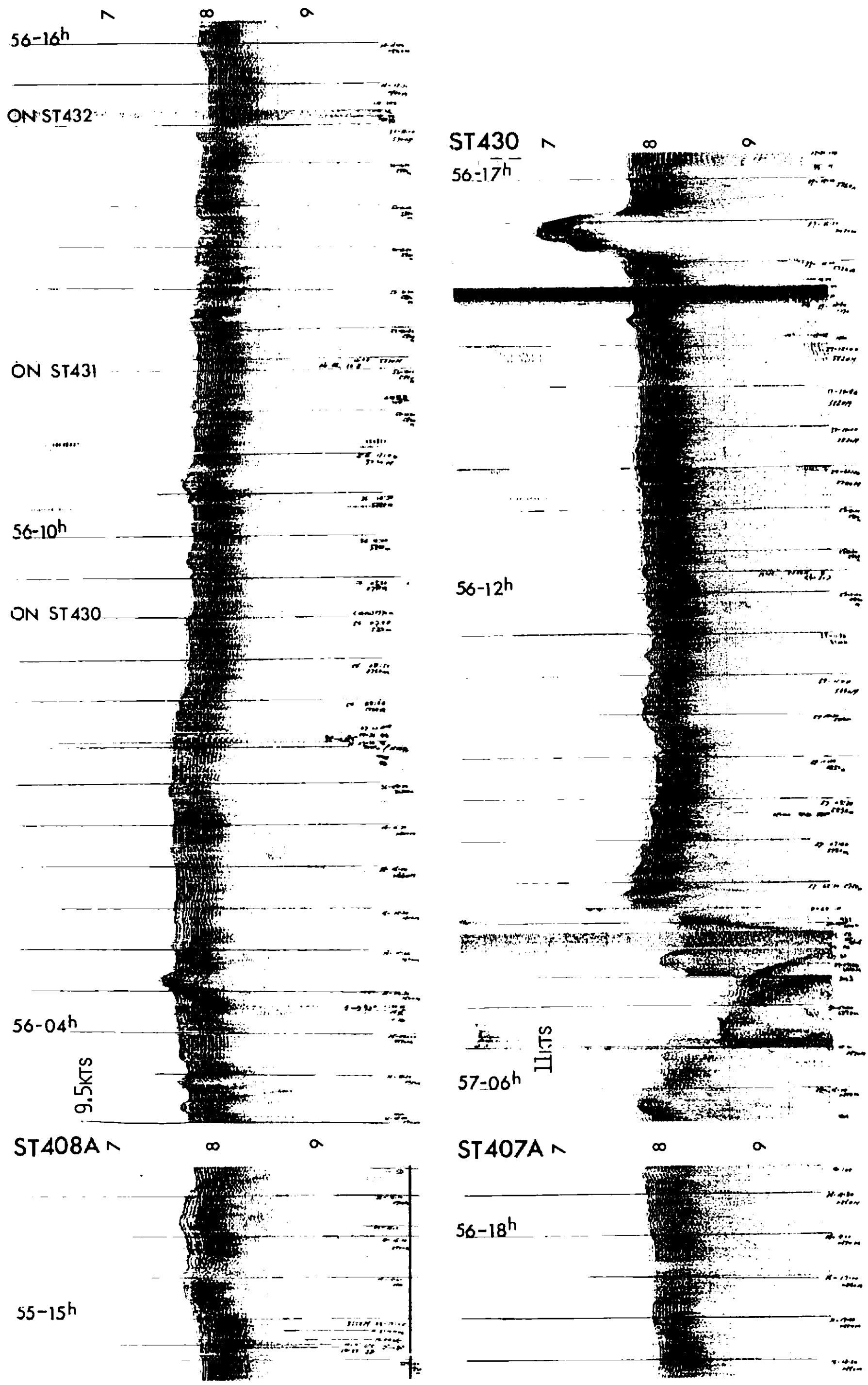

ST421
33-12h
33-07h
8.5KTS
ST420
33-00h
32-21h
10KTS
ST419
32-16h
49-00h
48-21h
10KTS
ST423
ON ST423
48-15h
48-12h
48-10h
8.5KTS
ST422
48-06h
33-15h


49-22h
11KTS
ST425 7 8 9
49-17h
ON ST425
49-12h
8KTS
49-07h
ST424 7 8 9
49-01h
ST427 7 8 9
50-14h
ON ST427
50-07h
9KTS
ST426 7 8 9
50-00h

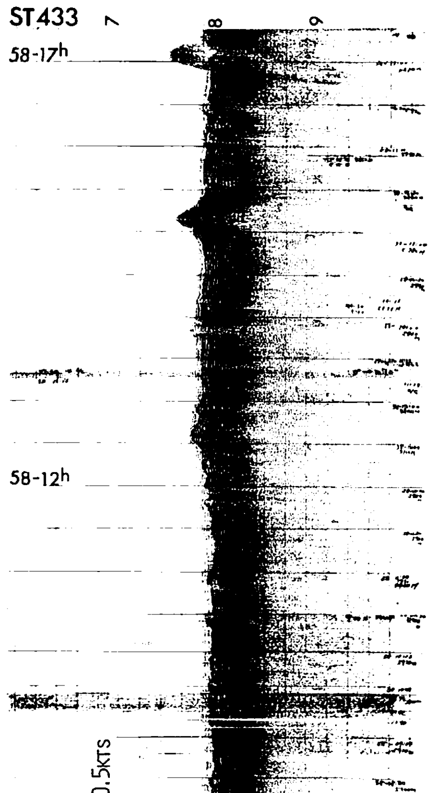

52-06h
10.5KTS
ST414A
ON ST415
51-11h
51-07h
10KTS
ST428
51-00h
50-22h
10KTS
ST427
ST411A
53-16h
9KTS
ST413A
52-18h
52-12h



54-12h
ON ST432
54-07h
10KTS
ST410A 7 8 9
54-00h
53-21h
10KTS
ST411A 7 8 9
55-12h
55-07h
10.5KTS
ST429 7 8 9
55-00h
54-21h
10.5KTS
ST406A 7 8 9
54-17h



56-16h
ON ST432
ON ST431
56-10h
ON ST430
56-04h
9.5KTS
ST430
56-17h
56-12h
11KTS
57-06h
ST408A
55-15h
ST407A
56-18h
7
8
9


ST433
58-17h
58-12h
10.5KTS
58-08h
ST432
7
8
9