VII. SEISMIC REFLECTION SURVEY IN THE NORTHEASTERN MARGIN OF THE CENTRAL PACIFIC BASIN

Kensaku Tamaki and Manabu Tanahashi

Seismic reflection survey with an air gun sound source was carried out along the ship's tracks shown in Figs. VII-1, 2. Equipments and conditions of the seismic reflection survey are listed in Tables VII-1, 2. We obtained high resolution records in the detailed survey area south of the Cross Trend seamount chain under the conditions of relatively low ship speed, short shot interval, high air pressure, and smaller guns. These high resolution records, together with the results of DSDP Leg 17, improved our work on the seismic stratigraphy in the northern Central Pacific Basin. All the profiler records obtained are shown in Fig. VII-8.

Previous works

Four research cruises including seismic reflection survey, GH74–5, GH76–1, GH77–1, and GH78–1, were previously carried out in the northern Central Pacific Basin by the Geological Survey of Japan. TAMAKI (1977) divided the acoustic sequence in the basin northeast of the Magellan Rise into three units; Unit I, Unit II, and acoustic basement. Unit I is a transparent layer occasionally intercalating coherent reflectors or reflective parts. He subdivided Unit I into three types; Type A which is completely transparent, Type B which intercalates reflective horizons in a transparent layer, and Type C which intercalates coherent reflectors caused by turbidity deposits. Unit II is a semi-opaque layer underlain by acoustic basement. TAMAKI (1977) correlated the acoustic sequence to the results of DSDP Sites 165, 166, and 170 by WINTERER, EWING, *et al.*

Table VII-1 Equipments of seismic reflection survey.

Air Gun	Bolt PAR Air Gun 1900C
Compressor	Norwalk APS-120
Hydrostreamer	GSJ type hydrostreamer with 100 to 200 hydrophones
Hydrophone	T-1 (Teledyne) or MP-18-200 (Geospace)
Amplifier	Ithaco 451 and Ithaco 3171
Recorder	Raytheon UGR 196B and LSR 1811

Table VII-2 Conditions of seismic reflection survey.

	Normal survey	Detailed survey
Ship speed	10–12 kts	7–8 kts
Shot interval	11 sec	5 sec
Pop interval	57–68 m	18–20 m
Vertical exaggeration	30.5–36.7	9.7–11.1
Air gun	BOLT 1900C × 1	BOLT 600B × 2
Chamber of air gun	150 in^3	40 in^3 × 2
Pressure	1500 psi	1800 psi
Filter	25–100 Hz	40–160 Hz

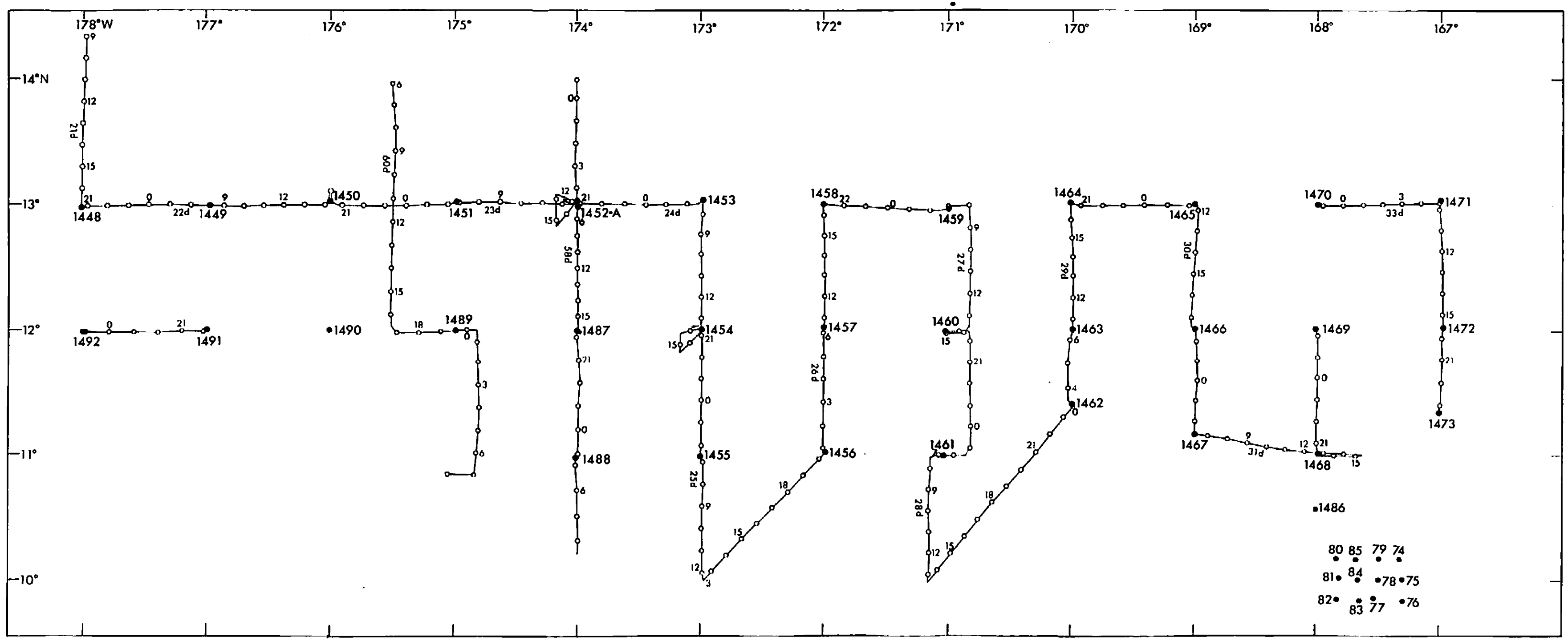


Fig. VII-1 Tracks for seismic reflection survey in the main survey area. Solid circles with numbers show the locations of sampling stations and the station numbers. Open circles with numbers show ship's position in every hour and the GMT days and hours.

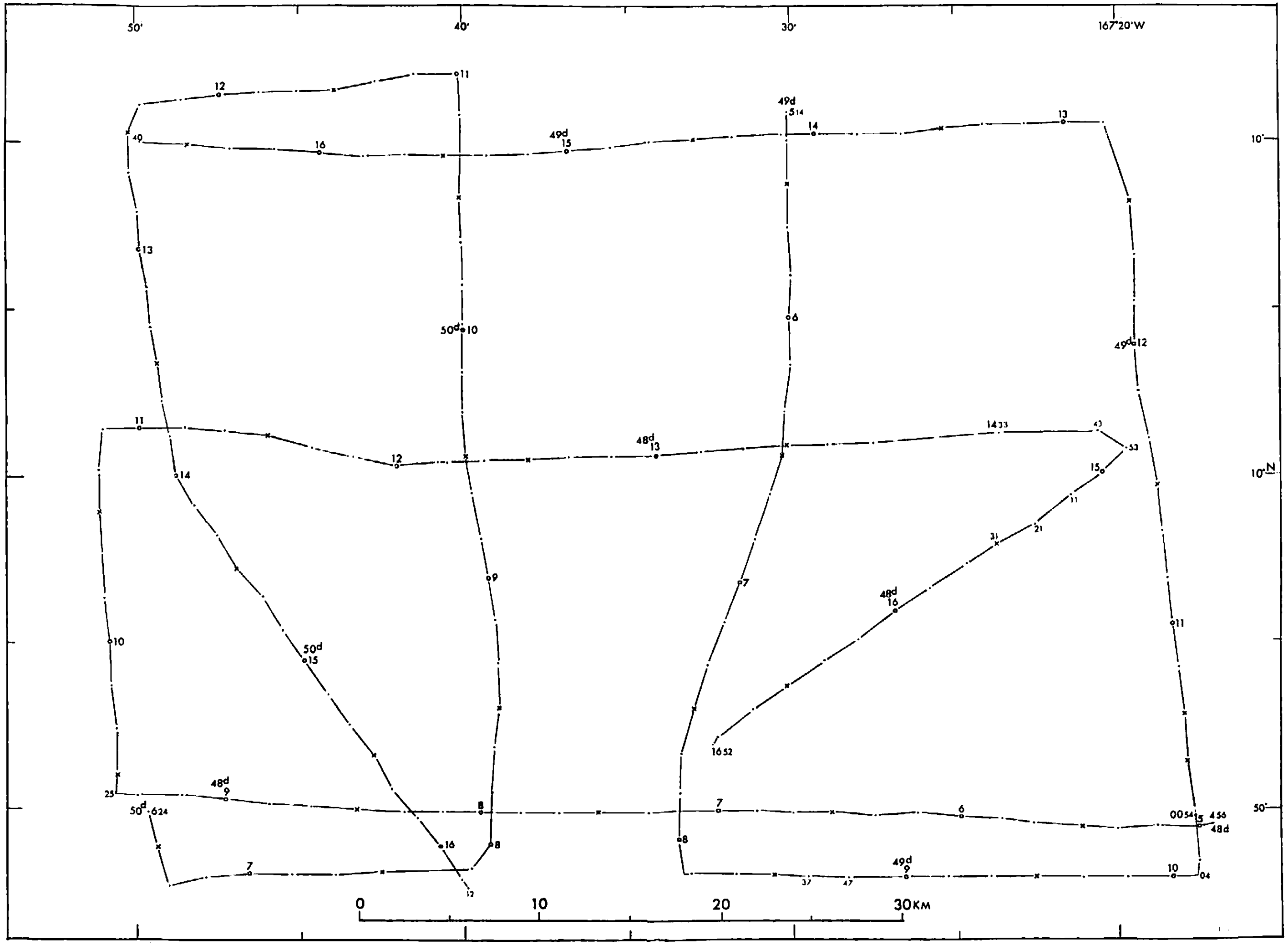


Fig. VII-2 Tracks for seismic reflection survey in the detailed survey area. Ship's tracks are fixed every 10 minutes and annotated with the GMT days and hours.

(1973). MURAKAMI and MORITANI (1979) apply these acoustic units to the acoustic sequence in the basin north and northeast of the Magellan Rise.

Acoustic sequence in the GH79–1 survey area

Two prominent reflective horizons occur above basement arrivals at the places where a complete acoustic sequence is developed. These two horizons have been observed in many places in the northern Pacific and called reflector A′ for the upper one and reflector B′ for the lower one (EWING, 1966). Profiles of the detailed survey area present a good case for a complete acoustic sequence (Fig. VII-3).

Reflector A′ is very common and continuous throughout the main and detailed survey areas, whereas reflector B′ is poor in the former area but occurs continuously in the latter area. Reflector B′ is distinguished from acoustic basement by its characteristically smooth upper surface. The strong reflection of reflector B′ occasionally reduces acoustic penetration and hides basement arrivals because of an acoustical impedance not greatly different from that of acoustic basement.

Reflector B′ has been poorly known in the previous survey areas. It may have been missed and interpreted as acoustic basement. Good profiler record of the detailed survey area clearly shows the difference between reflector B′ and acoustic basement. Then we divide Unit II into two subunits; upper Unit IIA and lower Unit IIB. Reflector A′ is the top of Unit IIA and reflector B′ is the top of Unit IIB.

The acoustic sequence in the GH79–1 area is summarized as follows; Unit I, Unit IIA, Unit IIB, and acoustic basement in descending order.

Main survey area

Unit I is transparent to semi-transparent in the main survey area and is confirmedly identified in many cases by recognizing the underlying reflector A′. Transparency of Unit I is low in the present area as compared with the previous survey areas (GH74–5, GH76–1, and GH77–1) south of the present survey area. Sea bottom is often missed in the previous survey area because of its very little reflectivity, while sea bottom is clearly detected in the GH79–1 survey area. The tendency that the transparency of Unit I increase toward the south may depend on active sedimentation of ooze in the southern area close to the equator and diagenesis mainly by compaction in the northern area. The ooze which was rapidly deposited with high water content in the southern area is dehydrated and compacted during moving to the west-northwest since about 40 Ma ago. The compacted and dehydrated ooze (Unit I in the northern area) may represent semi-transparency. Unit I is not uniformly semi-transparent, but changes the semi-transparency with the subbottom depth. This vertical variation of transparency also may depend on the compaction and dehydration with the subbottom depth. The gradual change from transparent to semi-transparent is well observed on the 3.5 kHz subbottom profiler record (Fig. VII-4-a). Semi-opaque Unit I is exceptionally observed in the basin north of the Cross Trend chain (around St. 1462, Fig. VII-8-v and around St. 1467, Fig. VII-8-vi). The semi-opaque Unit I is sculptured by several minor deep-sea channels. The occurrence of the semi-opaque Unit I is likely related to the development of the deep-sea channels.

The thickness of Unit I varies from 0 to 200 meters in the main survey area, assuming

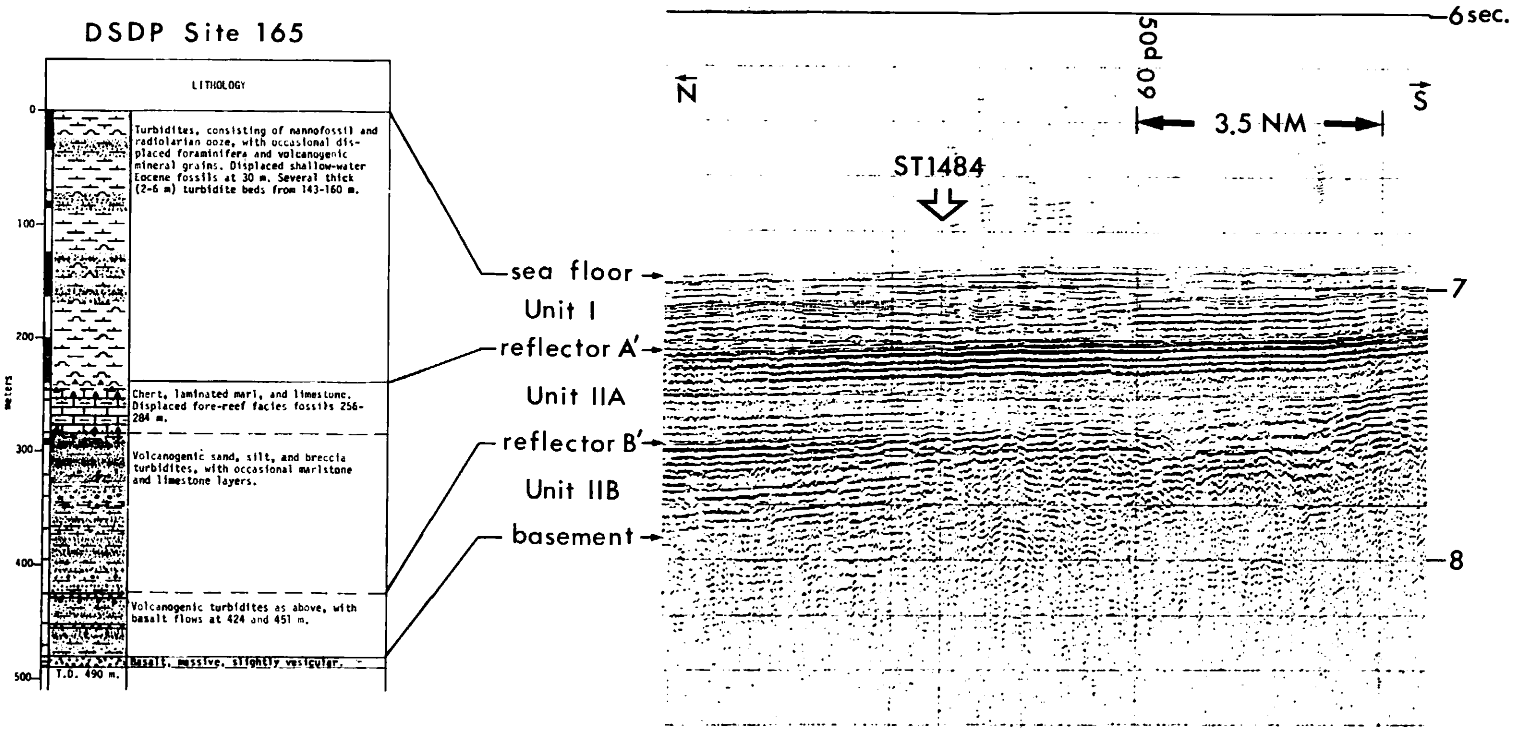
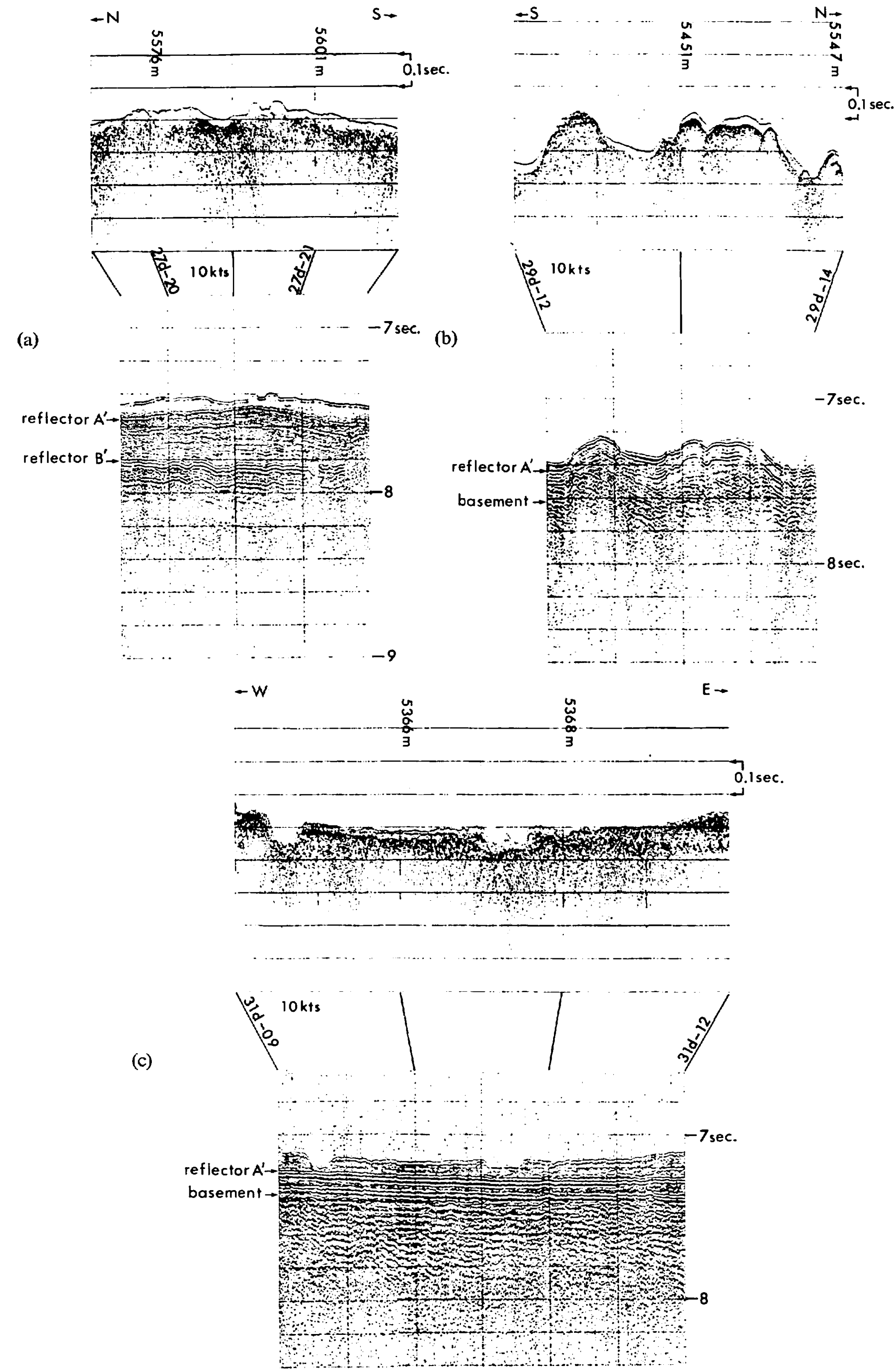


Fig. VII-3 Typical record in the detailed survey area showing the correlation with the results of DSDP Site 165.



Figs. VII-4-a, b, and c 3.5 kHz records and seismic profiler records. The upper in each set shows 3.5 kHz record. The depth is indicated in uncorrected meters on 3.5 kHz records and in seconds of two-way acoustic travel time on seismic profiler records. The GMT days and hours are also presented.

that the sound velocity of the transparent layer in the Central Pacific Basin is equal to that of sea water (1.5 km/sec) based on the results of DSDP Leg 17. Unit I is thick in the eastern area in general. The maximum thickness of Unit I, 200 m, is observed on the easternmost track of the present survey (around St. 1468, Fig. VII-8-vi). Unit I is thin (less than 50 m) or lacks in the western part where rise-like topographic features occur. Generally, Unit I lacks on the topographic highs such as knolls, seamounts, and rises.

Figure VII-4 shows the correlation between the 3.5 kHz subbottom profiler and seismic profiler records. A transparent layer on the 3.5 kHz record, which is commonly observed in the main survey area, is mostly not identical with Unit I of the seismic profiler record. The transparent layer is correlated to the upper-half of Unit I (Fig. VII-4-a). The transparent layer gradually changes to opaque layer downward on the 3.5 kHz record. Reflector A′ cannot be detected on the 3.5 kHz record in many cases. Figure VII-4-b shows a rare case: the transparent layer of 3.5 kHz record can be correlated to the whole Unit I, and reflector A′ corresponds to the uppermost part of underlying opaque layer on the 3.5 kHz record. The boundary between the transparent and the opaque layer is clear in this case. The semi-opaque Unit I observed in the basin north of the Cross Trend chain appears as a semi-opaque to opaque pattern on the 3.5 kHz record (Fig. VII-4-c).

Unit I in the main survey area belongs to Type A according to the TAMAKI (1977)'s subdibision of Unit I, excluding semi-opaque Unit I which have never been observed in the previous survey areas.

Reflector B′ is poorly developed in the main survey area: it is not continuous over 60 km and hides underlying acoustic basement in many cases (for instance, Fig. VII-8-ii, around St. 1451 and Fig. VII-8-iv, 27d 19:00–21:00). Acoustic basement of rough surface underlies Unit IIA in the places where reflector B′ lacks. Unit IIA crops out widely in the western rise area where Unit I lacks.

The thickness of Unit IIA ranges from 0.2 to 0.4 second in two way acoustic travel time, or 200 to 400 meters if 2.0 km/sec is accepted as an average sound velocity of Unit II according to the data of DSDP sites 165, 166, and 170. The thickness of Unit II in the GH79–1 area is thicker than that in the GH76–1 and GH77–1 areas to the south, where the thickness of Unit II is between 0.04 to 0.2 second. Unit IIA represents semi-opaque pattern beneath reflector A′ and occasionally intercalates weak reflectors. Thick Unit IIA shows semi-transparency in its lower part (for instance, Fig. VII-8-iv, around St. 1458).

Acoustic basement is identified by its rough surface, while reflector B′ represents smooth surface and strong reflectivity. Acoustic basement is difficult to identify in the places where reflector B′ is developed. Then, the thickness of Unit IIB is hard to detect in the present survey area. The reflectivity of acoustic basement is not so strong as that of reflector B′. Unit IIB appears to have deposited in the depressions of acoustic basement in many cases.

Detailed survey area

The seismic reflection survey in the detailed survey area is carried out along mesh pattern tracks of 10 nautical miles interval (Fig. VII-2). Seismic profiling by small airguns with high pressure air, short shot interval, and low ship speed (Tables VII-1 and

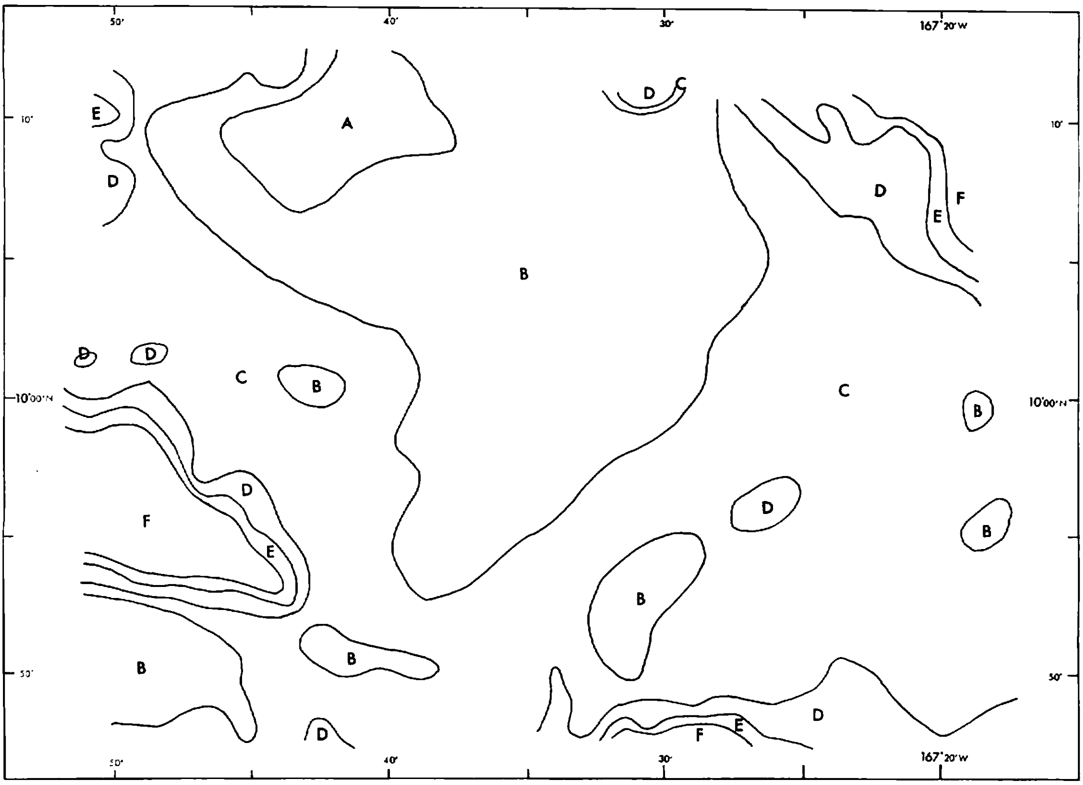


Fig. VII-5 Isopachous map of Unit I in the detailed survey area. A: 280–240 m, B: 240–200 m, C: 200–160 m, D: 160–120 m, E: 120–80 m, and F: 80–0 m (assumed velocity = 1.5 km/sec).

2) enabled to obtain high resolution records (Fig. VII-3). Figures VII-5 and 6 shows isopachous map of Units I and IIA in the detailed survey area.

The two reflective horizons, reflectors A′ and B′, are well developed in the detailed survey area, although some knolls interrupt the continuation. The knolls are mostly composed of acoustic basements.

Unit I in the detailed survey area intercalates many weak reflectors of high frequency. These reflectors are generally evenly stratified, but occasionally show weak hyperboral pattern and rolled feature. The reflectors appear as densely stratified opaque layer on the 3.5 kHz record (Fig. VII-7). The thickness of Unit I ranges from 0 to 265 meters with the average value of about 200 m if the sound velocity of Unit I is 1.5 km/sec. Figure VII-5 shows that the area is dominated by Unit I of 150 to 250 meters thick and that the distribution of Unit I has no correlation with bathymetric contours. The tendency of northward thickening of Unit I is observable from the isopachous map. Some disconformable features occur in Unit I. Strongly reverberant horizon is observed at the bottom of Unit I or just above reflector A′. The reverberant horizon makes well developed hyperboral arrivals.

Unit IIA generally shows well-stratified, semi-opaque pattern although it changes to

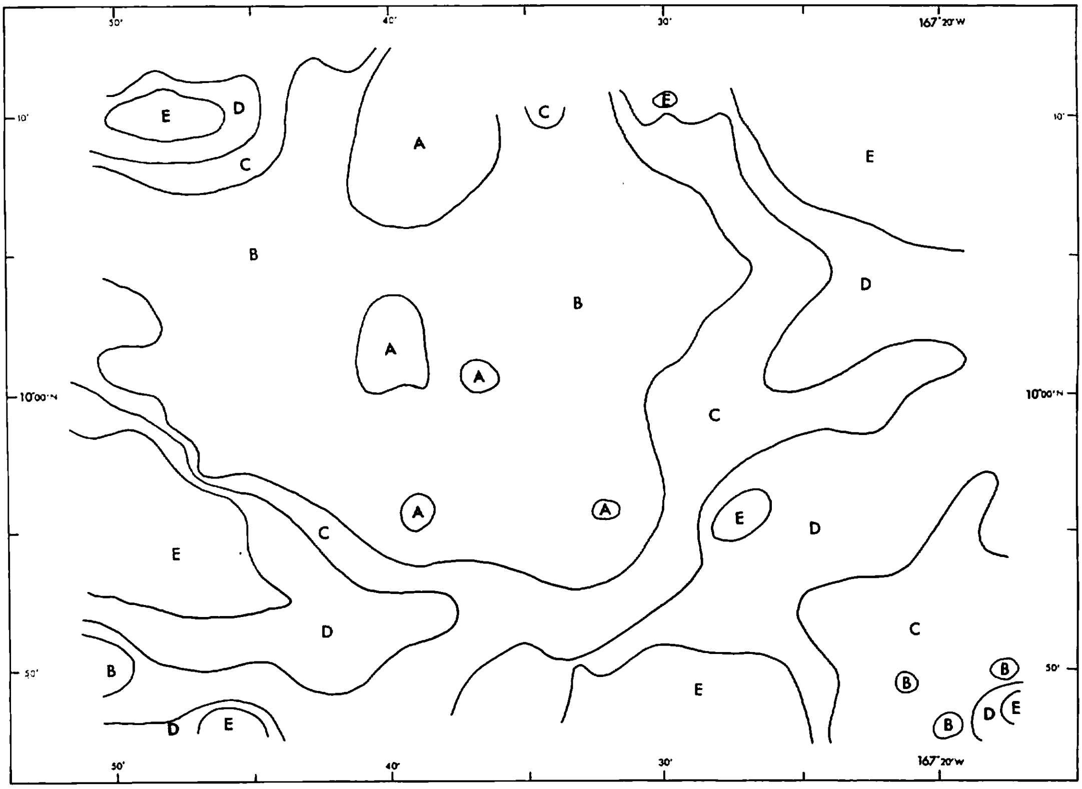


Fig. VII-6 Isopachous map of Unit IIA in the detailed survey area. A: 400–350 m, B: 350–300 m, C: 300–250 m, D: 250–200 m, E: 200–0 m (assumed velocity = 2.0 km/sec).

transparent pattern in its lower part at some places. The thickness of Unit IIA varies from 0 to 400 meters (assuming that the sound velocity of Unit IIA is 2 km/sec) (Fig. VII-6). The thickness between 250 and 350 meters is predominant. The average thickness 300 m, is larger than that of Unit I. The thickness distribution of Unit IIA appears to show a similar pattern with that of Unit I and shows no correlation with the bathymetric contours.

Acoustic basement is distinguished by its rough surface and assemblage of hyperbolas, although it is often difficult to detect the basement arrivals because of strong reflectivity of reflector B′. Unit IIB and reflector B′ appear to lack around the basement high.

Correlation of seismic sequence with DSDP and GH79–1 sampling results

Correlation between the seismic sequence of the present survey area and the results of DSDP drilling is summarized in Fig. VII-3 and Table VII-3. Transparent and semi-transparent Unit I is correlated to clay or ooze of the Quaternary to middle Eocene at Sites 166 or 170. The weak reflectors in Unit I in the detailed survey area are correlated to turbidites consisting of ooze and occasional volcanogenic mineral grains of the Quaternary to middle Eocene. Some internal hyperbolas and discontinuity in Unit I

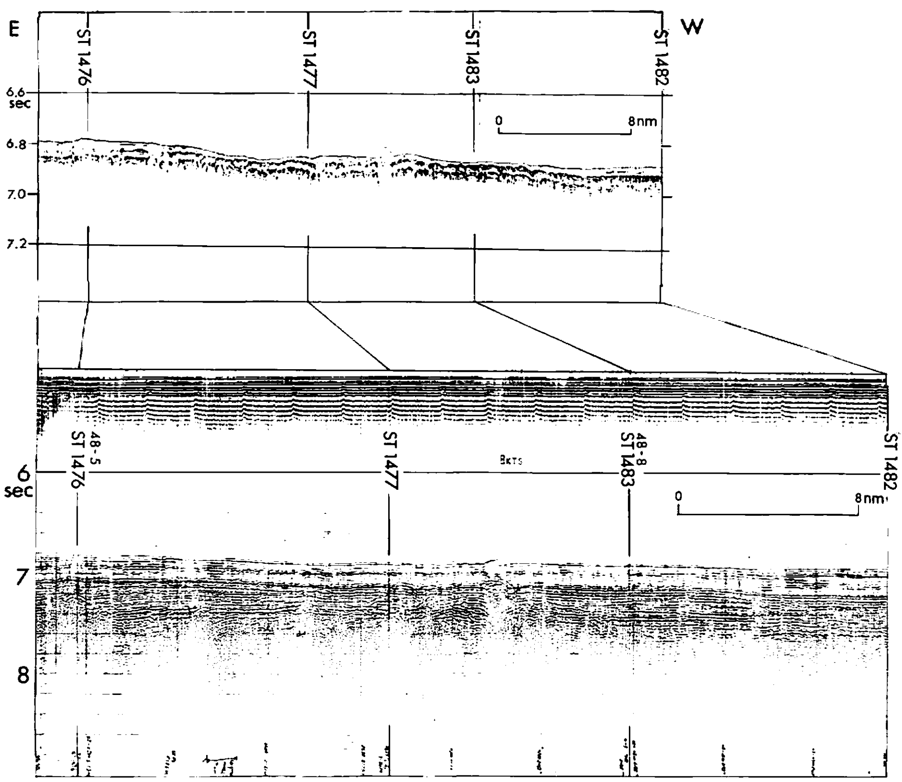


Fig. VII-7 3.5 kHz record with seismic profiler record in the detailed survey area. The upper shows 3.5 kHz record.

in the detailed survey area may be resulted from erosion and deposition by turbidity activity. The turbidites in Unit I of the detailed survey area are estimated to have been derived from the Cross Trend seamount chain north of the detailed survey area, because Unit I tends to become thicker to the north. Unit I is generally thicker in the detailed survey area than in the main survey area due to the deposition of the turbidites. The reverberant horizon at the bottom of Unit I in the detailed survey area may be correlated to the bed of chert fragments above the massive chert beds. The fragments of chert may make hyperbolas because of their horizontally discontinuous appearance, while the main chert beds beneath the chert fragments make strong reflector of reflector A′. Reflector A′ is confirmedly correlated to the top of the middle Eocene chert bed. The reflective parts of upper Unit IIA may be correlated to chert, marl, and limestone. Semi-opaque pattern of Unit IIA may be correlated to sandstone, limestone, and volcanic turbidites. Transparent to semi-transparent pattern of Unit IIA may correspond to ooze, claystone, and chalk. The age of Unit IIA is estimated to be from the late Cretaceous to middle Eocene. We estimate that reflector B′ is correlated to basalt flows above basement basalt. The results at DSDP Site 165 suggest that Unit IIB is composed of the complex of basalt flows and volcanogenic turbidites. These basalt flows and volcanogenic turbidites appear to have deposited in the basement depressions. The age of basement is

Table VII-3 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
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 IIA	M. Eocene to Late Cret. chert and limestone. Volcanogenic turbidites. (thickness: 190 m)	M. Eocene to E. Cret. chert rad. ooze. Volcanogenic 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)
	Unit IIB	Volcanogenic turbidites with basalt flows. (thickness: 50 m)	(lack of Unit IIB)	Basalt (not penetrated, 4 m in thickness).
	Acoustic basement	Massive basalt	Basalt	

the early Cretaceous, which is deduced from the identification of magnetic anomaly lineations (Tamaki *et al.*, this cruise report).

Many bottom samples by a grab sampler and a piston corer during the present cruise are mostly correlated to Unit I except for P140 (St. 1487). The lowermost part of Core P140 is hard mudstone which is possibly correlated to Unit IIA. Such mudstone was observed below chert bed at DSDP Site 170. Lower part of Core P138 in the detailed survey area is interbedded with turbidites of nanno ooze which is correlated to the weak reflectors commonly observed in Unit I in the detailed survey area. Such ooze turbidites were observed at DSDP Site 167. Other samples except from P138 and P140 are clay or ooze which is correlated to Unit I.

Unit I in the detailed survey area was previously attributed to Type B by Tamaki (1977). The constituents of the reflective horizons of Type B–Unit I have been unknown. The presented results show that the reflective horizon intercalated in Type B–Unit I is ooze turbidites in this case. Type B–Unit I may intercalate turbidites in the same manner as Type C–Unit I, although the turbidites of Type B–Unit I are not so abundant or coarse as those of Type C–Unit I.

Structure

Many seamounts occur in the main survey area while a few seamounts are observed in the southern area (GH74–5, 76–1, and 77–1 survey areas). The abundant occurrence of seamounts is related to the proximity of the Mid-Pacific Mountains. The seamounts make exposures of acoustic basement with no or little deposition of overlying sediments. Unit I and Unit IIA, and Unit IIB abut to the acoustic basement of seamounts. It is suggested that the seamounts were formed before the deposition of Unit II, that is, almost simultaneously with the initiation of acoustic basement-oceanic crust.

Sea bottom, reflector A′, and reflector B′ are not parallel to each other in general. This unparallelness suggests irregular depositional environment in the inter-seamount basins.

Two rise-like features occur in the western part of the main survey area. The rises are composed of basement overlain by Unit II of normal thickness and by thin Unit I, without showing thick sedimentary cover as commonly observed on the other major rises in the Pacific such as the Shatsky Rise, the Magellan Rise, and the Manihiki Plateau. Unit II outcrops at many places on the two rises. The other rises in the Pacific have thick sediments because its high relief of the basement caused a large amount of deposition above CCD (Carbonate Compensation Depth), whereas the two low rises in the present survey area are estimated to have been below CCD and they have thin sediments.

Some large displacements of sea floor occur. The maximum displacement observed attains to 1000 m (Fig. VII-8-v, around 25d 5:00). The trends of these displacements are not confirmedly traced from profile to profile. The feature of these displacement is alike to that of the fracture zone. These displacements are estimated to be caused by complex development of the northern Central Pacific Basin which is suggested by the magnetic anomaly lineations (TAMAKI *et al.*, this cruise report).

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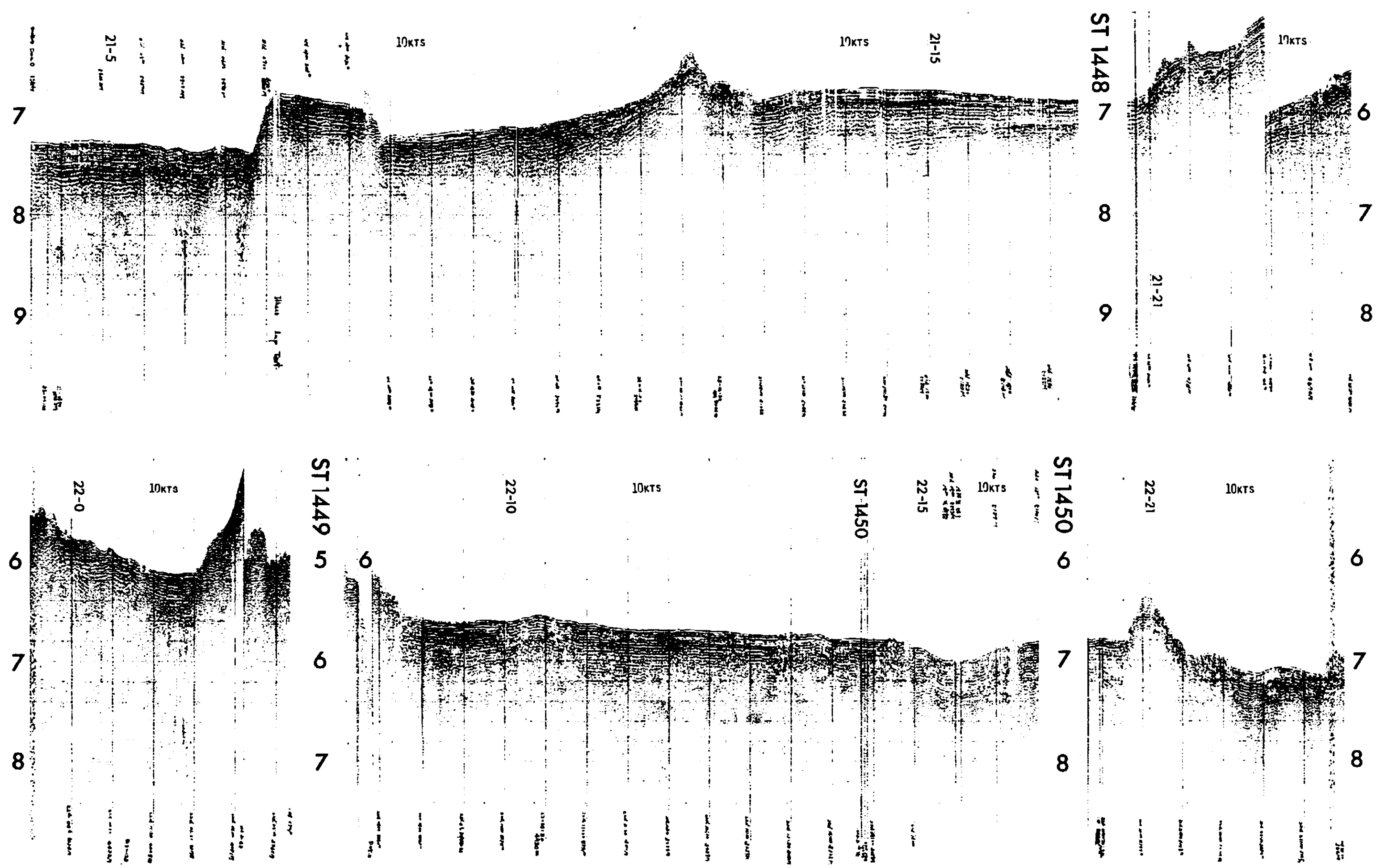
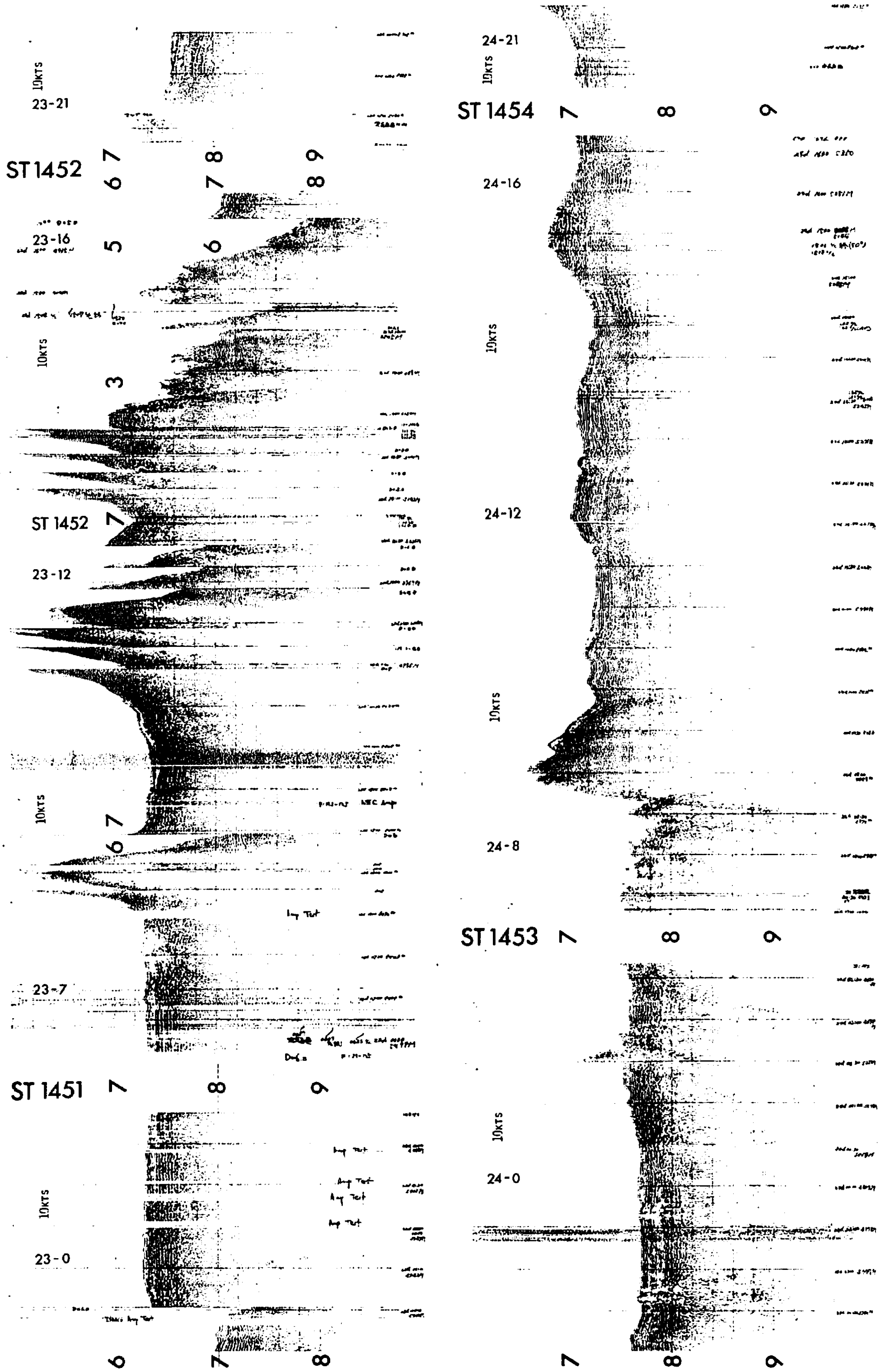


(i)

Fig. VII-8 All the seismic profiler records obtained during the survey, with the identification of the reflectors and units, the GMT days and hours, two-way acoustic travel time in seconds, ship's speed, sampling station, and vertical exaggeration.



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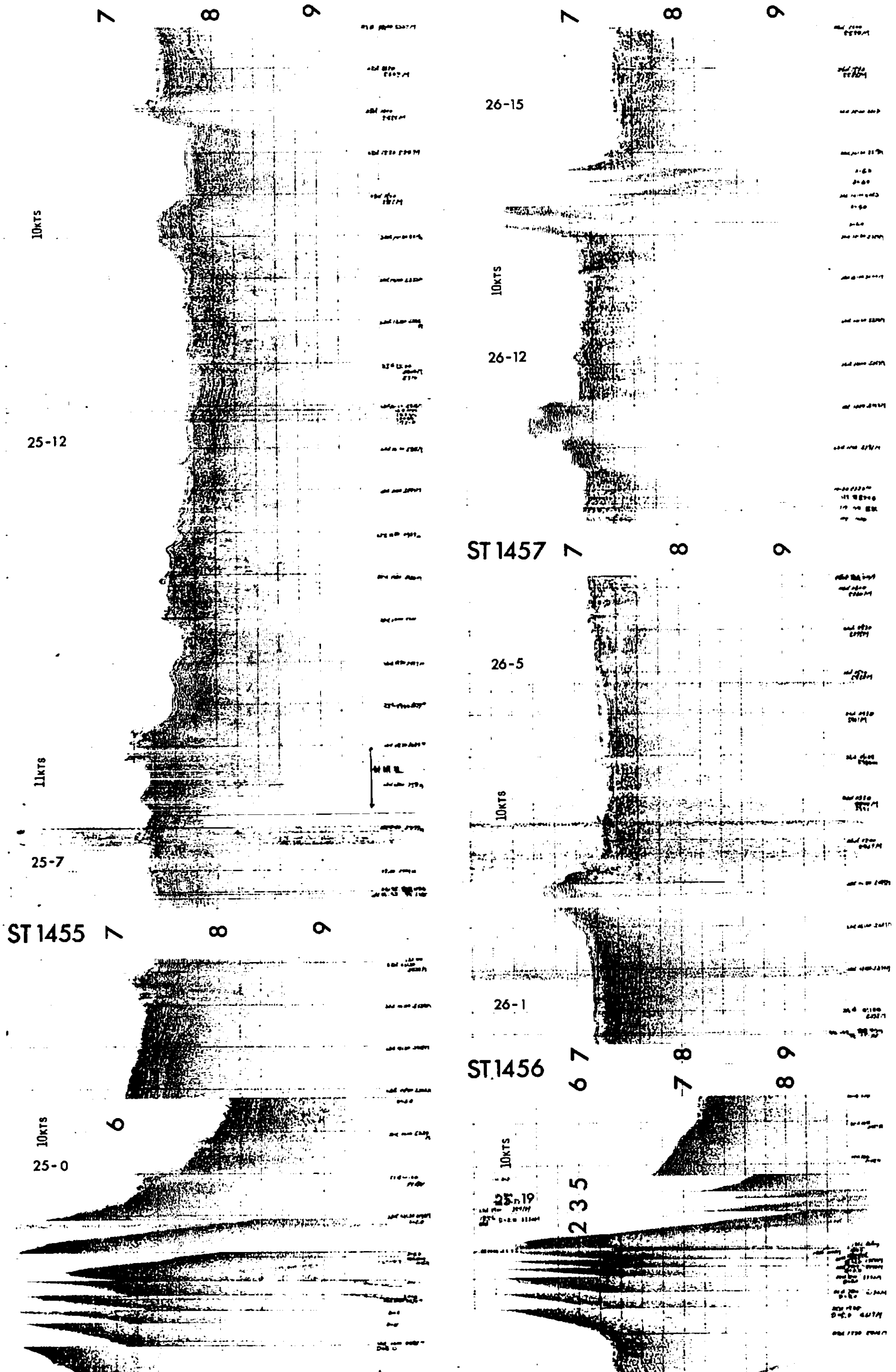
23-12
23-7
ST 1451
23-0
ST 1454
24-21
24-16
24-12
24-8
ST 1453
24-0
10KTS

(ii)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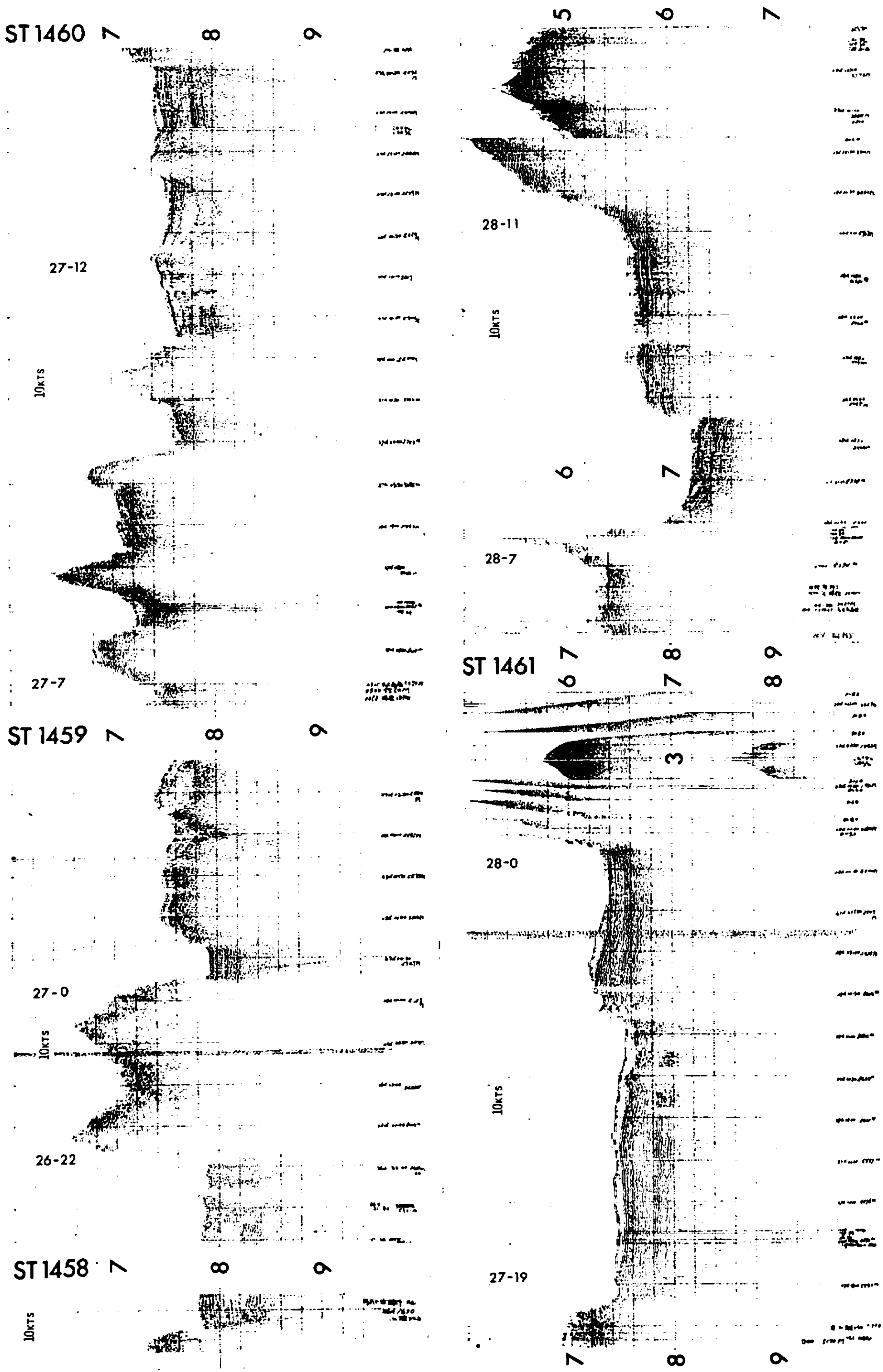
25-12
25-7
25-0
ST 1457
26-15
26-12
26-5
26-1
ST 1456
10KTS
11KTS

(iii)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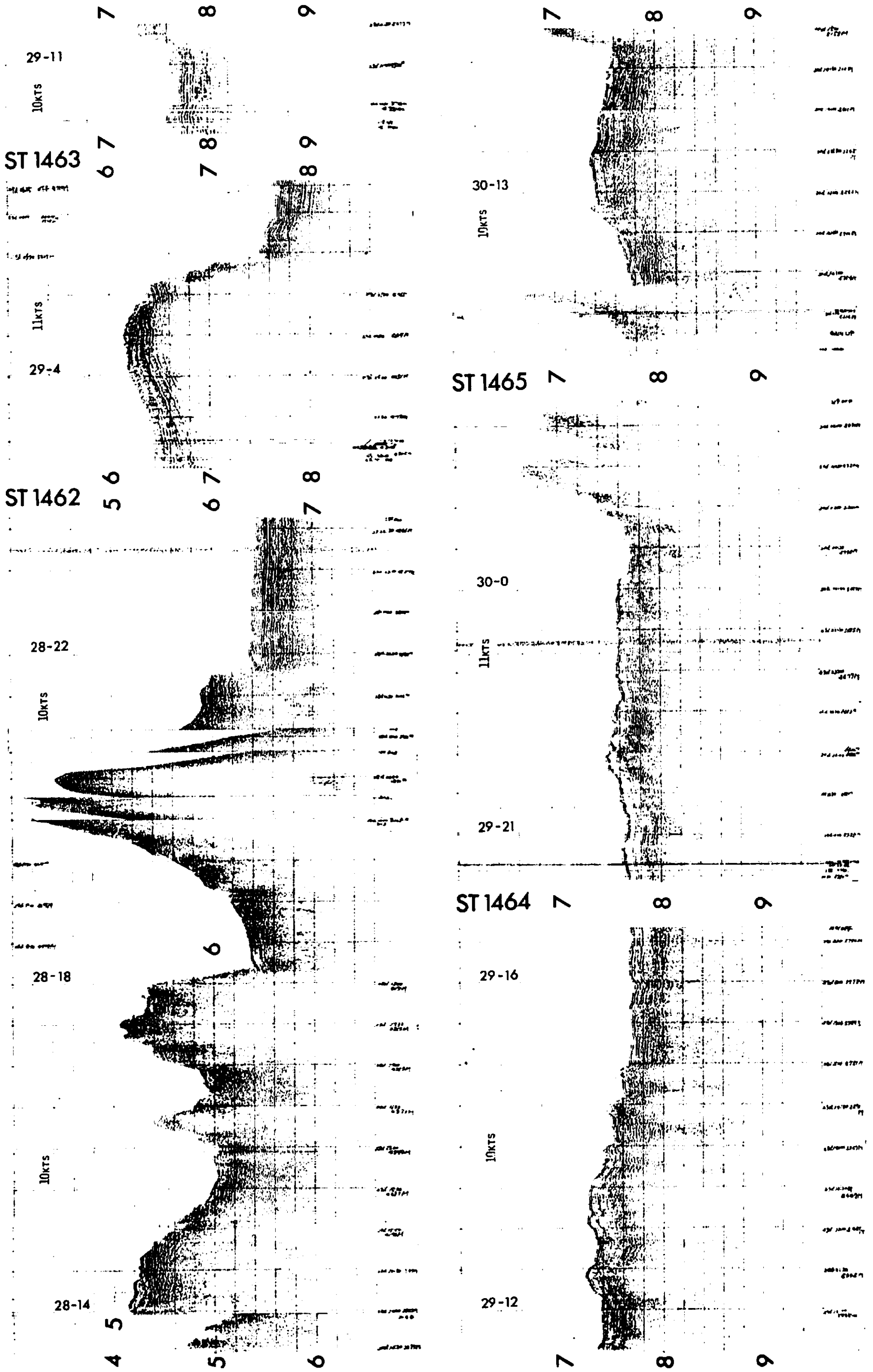
ST 1461
28-0
10KTS
27-19

(iv)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30-0
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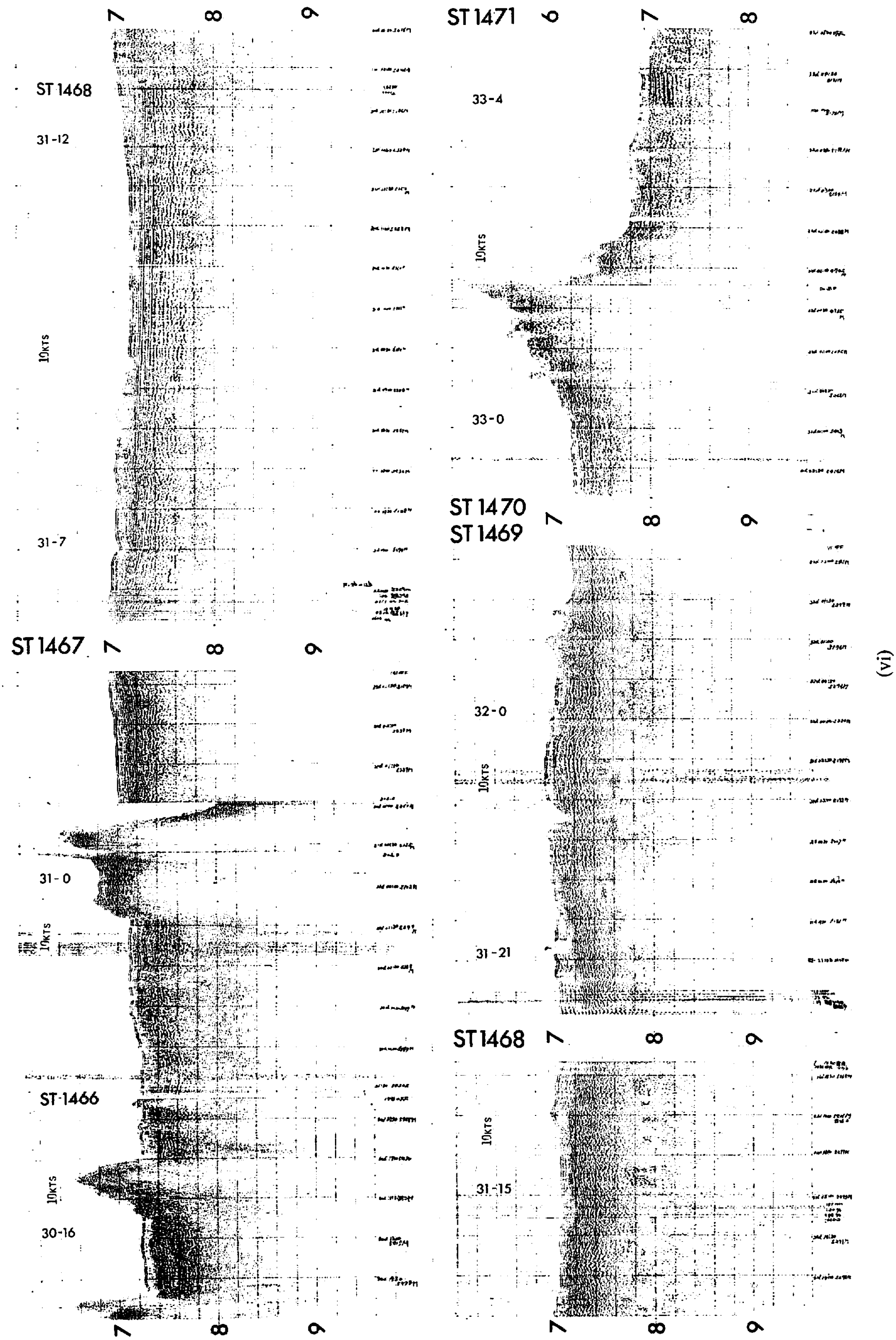
29-21
ST 1464
29-16
10KTS
29-12

(v)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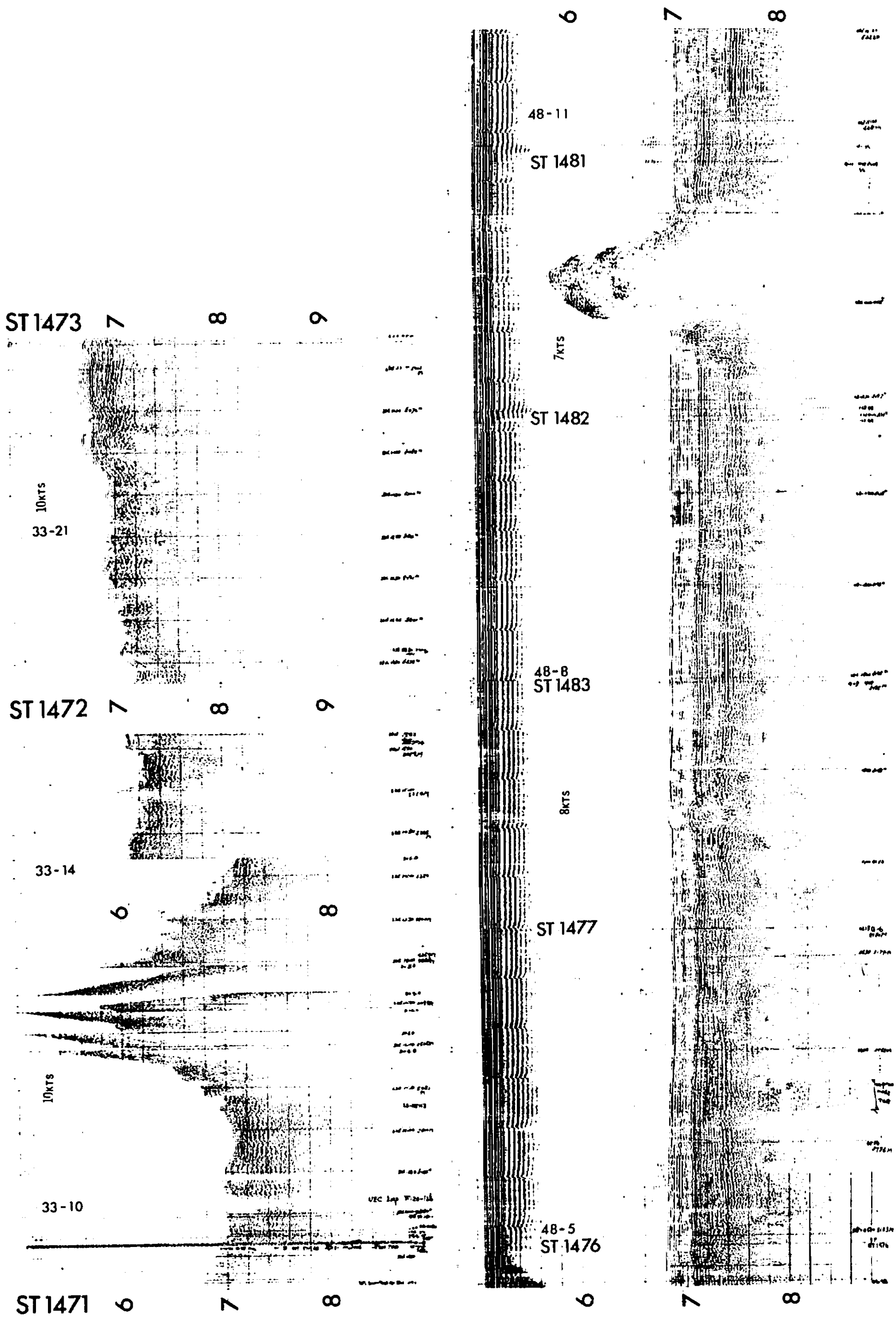
31-15
(vi)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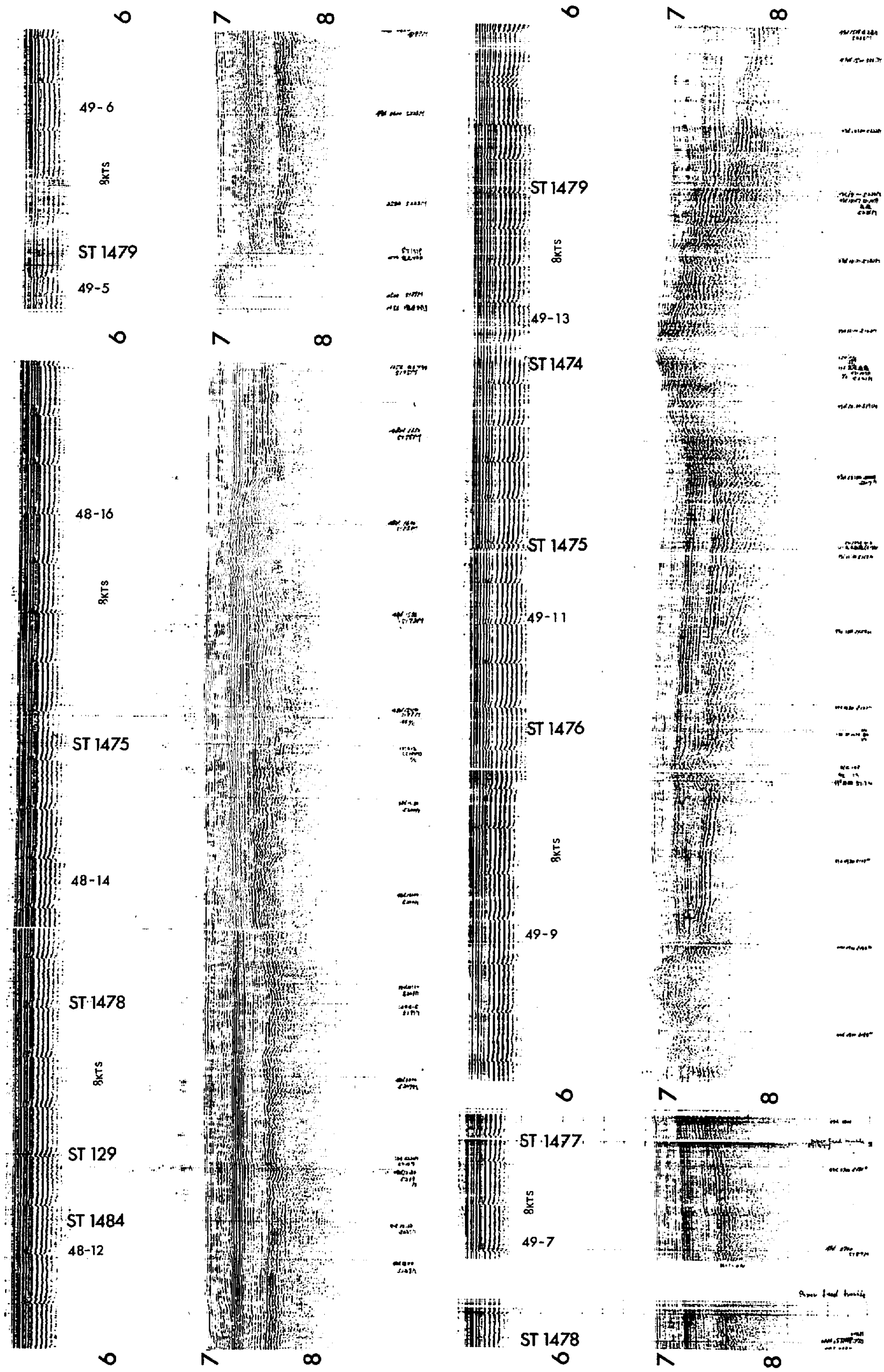
ST 1477
48-5
ST 1476

(vii)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ST 1479
8KTS
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8KTS
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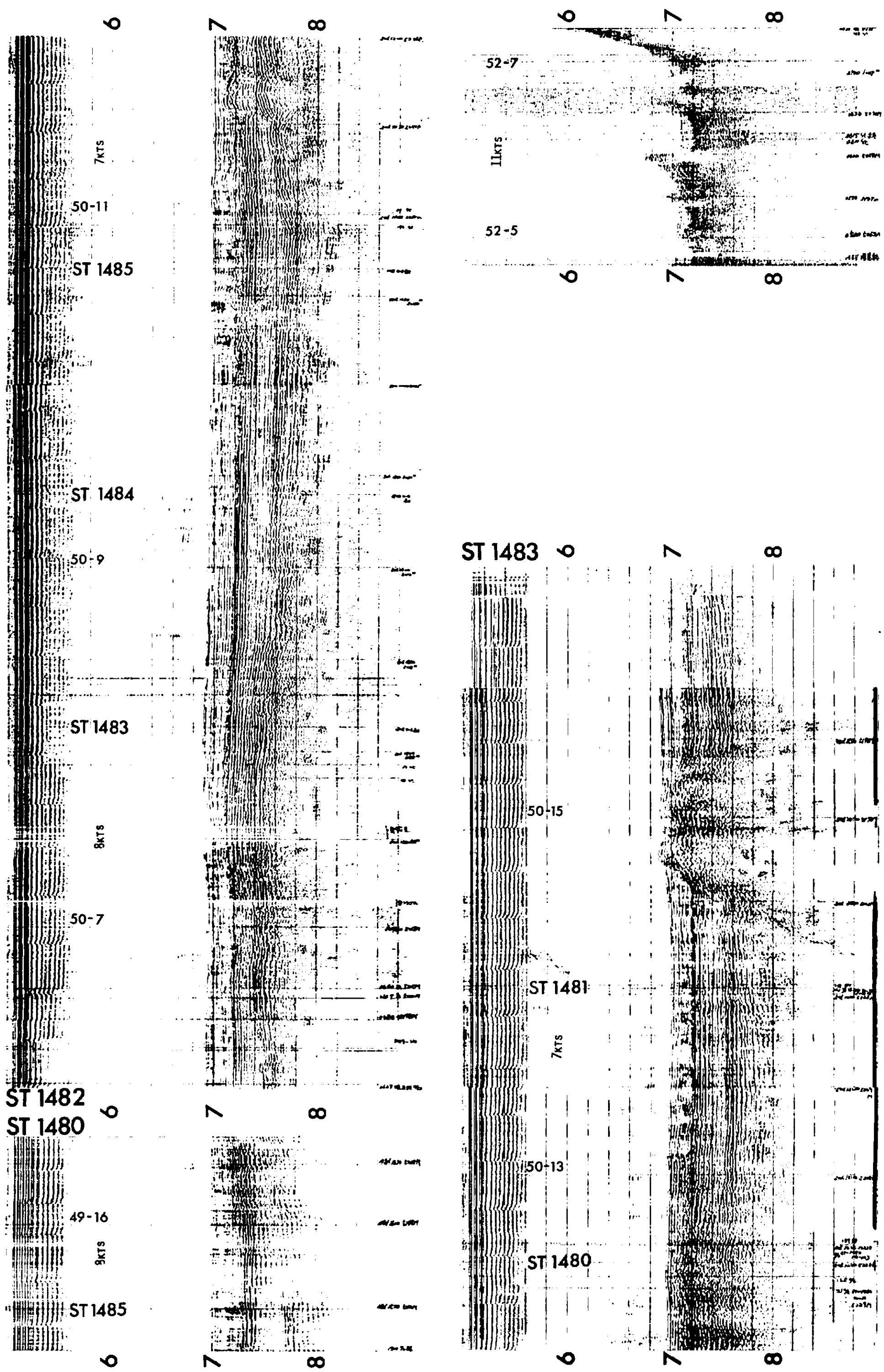
ST 1477
8KTS
49-7
ST 1478

(viii)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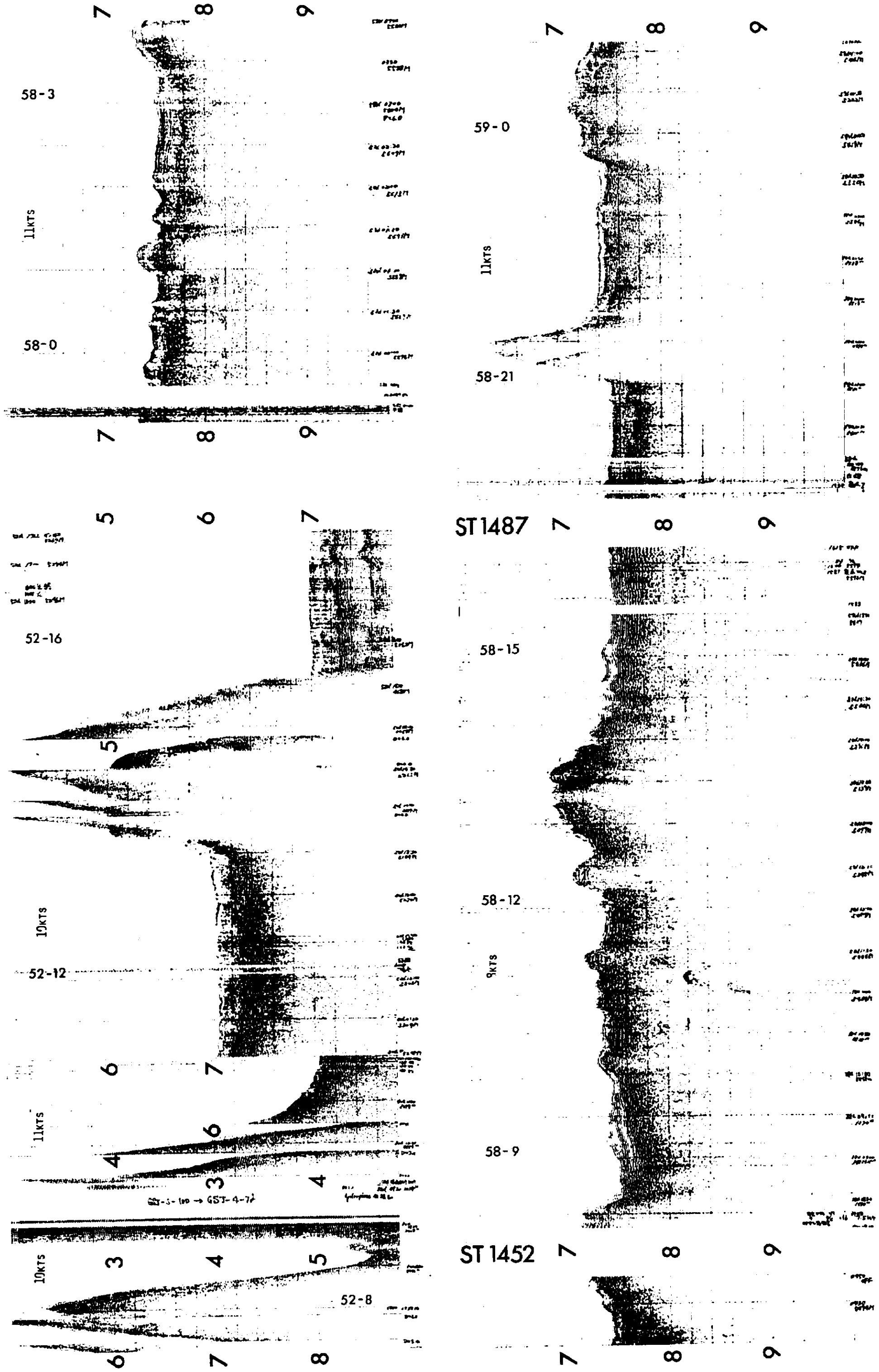
(ix)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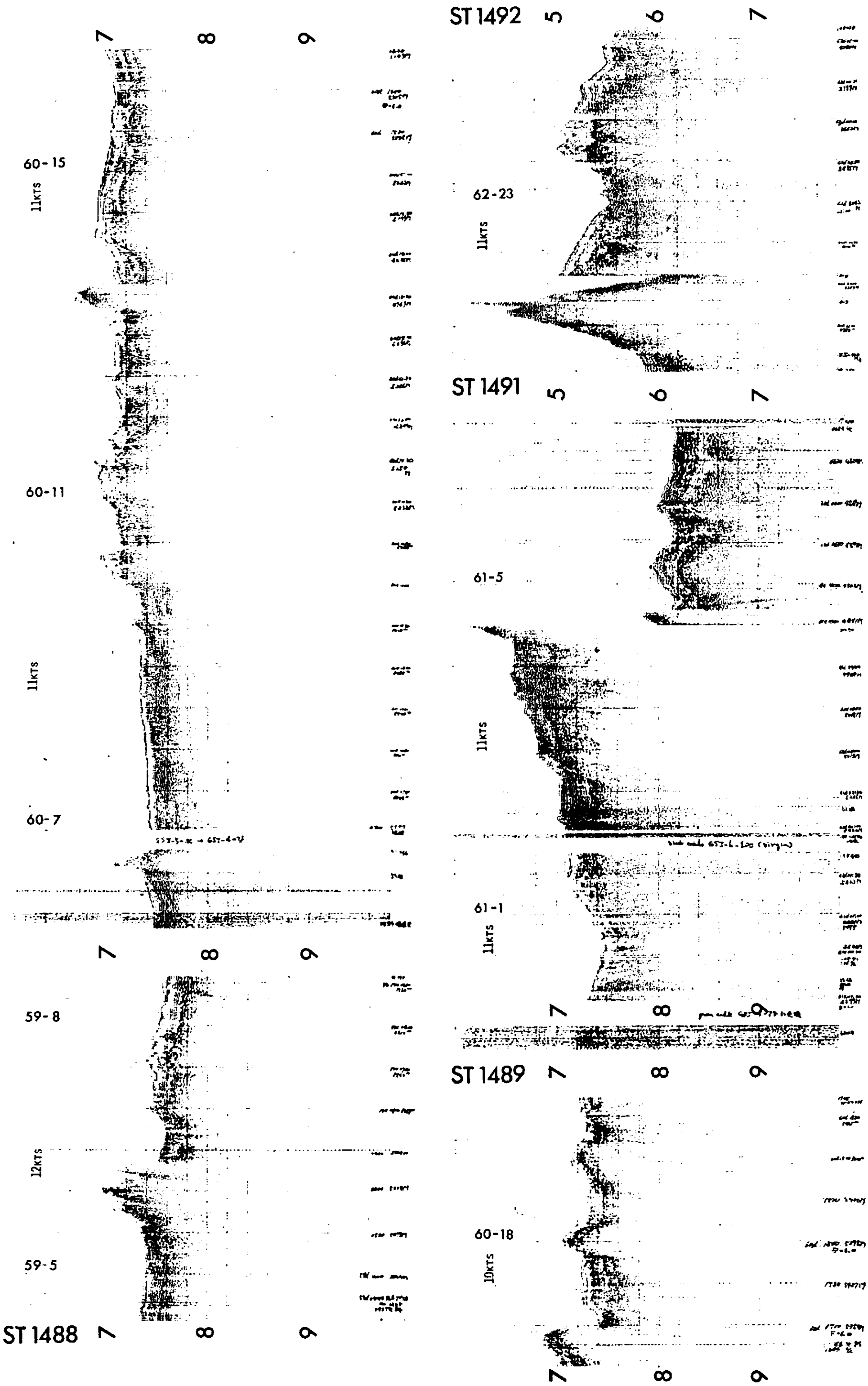
10KTS

(x)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60-11
11KTS
60-7
59-8
12KTS
59-5
ST 1488

(xi)