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OBSERVATIONS FROM DSRV ALVIN OF QUATERNARY FAULTING ON THE SOUTHERN CALIFORNIA CONTINENTAL MARGIN

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by

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ABSTRACT

Five DSRV ALVIN dives were made in the southern California continental borderland to observe and sample stratigraphic sections displaced along active faults scarps and to evaluate the use of a free deep diving vehicle in studies of offshore faulting. The faulted sequences are composed of complex series of Mesozoic plutonic and metamorphic rocks, early Tertiary (middle Eocene) and late Tertiary (Miocene and Pliocene) volcanic and sedimentary rocks, and unconsolidated Pleistocene and Holocene sediment. The faults studied are manifest both in sea-floor and subsurface displacements and are among the most significant structural elements of the rapidly evolving (late Miocene-Holocene) southern California continental margin. Focal mechanisms associated with local earthquakes indicate that the seismicity of this area is related to oblique slip that is commonly normal and right lateral in nature.

INTRODUCTION

Five deep-submersible dives were made 27-30 July 1979 aboard DSRV ALVIN from the support vessel RV LULU to investigate the character and recency of faulting of a tectonically active portion of the southern California continental margin. The dive sites were selected from detailed analyses of seismic reflection and near subsurface gravity-core data collected by the U.S. Geological Survey (Clarke and others, 1983). Dives were made on fault and/or fault-line scarps associated with the Rose Canyon-Newport-Inglewood, Coronado Bank-Palos Verdes Hills, and San Clemente fault zones (fig. 1). A representative seismic-reflection profile and track map is given for each dive to provide a reference for comparing fault location, fault geometry, bathymetry, geomorphology and stratigraphy (figs. 2-9).

A total of 36 rock outcrop and 14 sediment core samples (tables 1-4) were collected during the five dives. An effort was made to collect these samples in orderly stratigraphic succession. However, limited visibility often made it difficult to determine that slopes were being traversed normal to bedding or layering.

DSRV ALVIN is navigated by an onboard gyro, a 200° front-to-side-looking sonar, and an altimeter. Its exact course is plotted aboard RV LULU by way of slant-range-corrected echo-sound-tracking. This method of tracking allows ALVIN's position to be known within 5-10 m of LULU's position at all times. Satellite, Radar and Loran C navigation were used to calculate LULU's position with respect to each launch site.

ACKNOWLEDGMENTS

We thank K. Barrows for X-ray diffraction analysis of barite samples and E. D. Goldberg for discussions on the origin of marine barite. We also thank A. Barrows for his review and helpful suggestions, and J. Donnally, R. Hollis and G. Ellis, ALVIN pilots, for their help before and during the dive series.

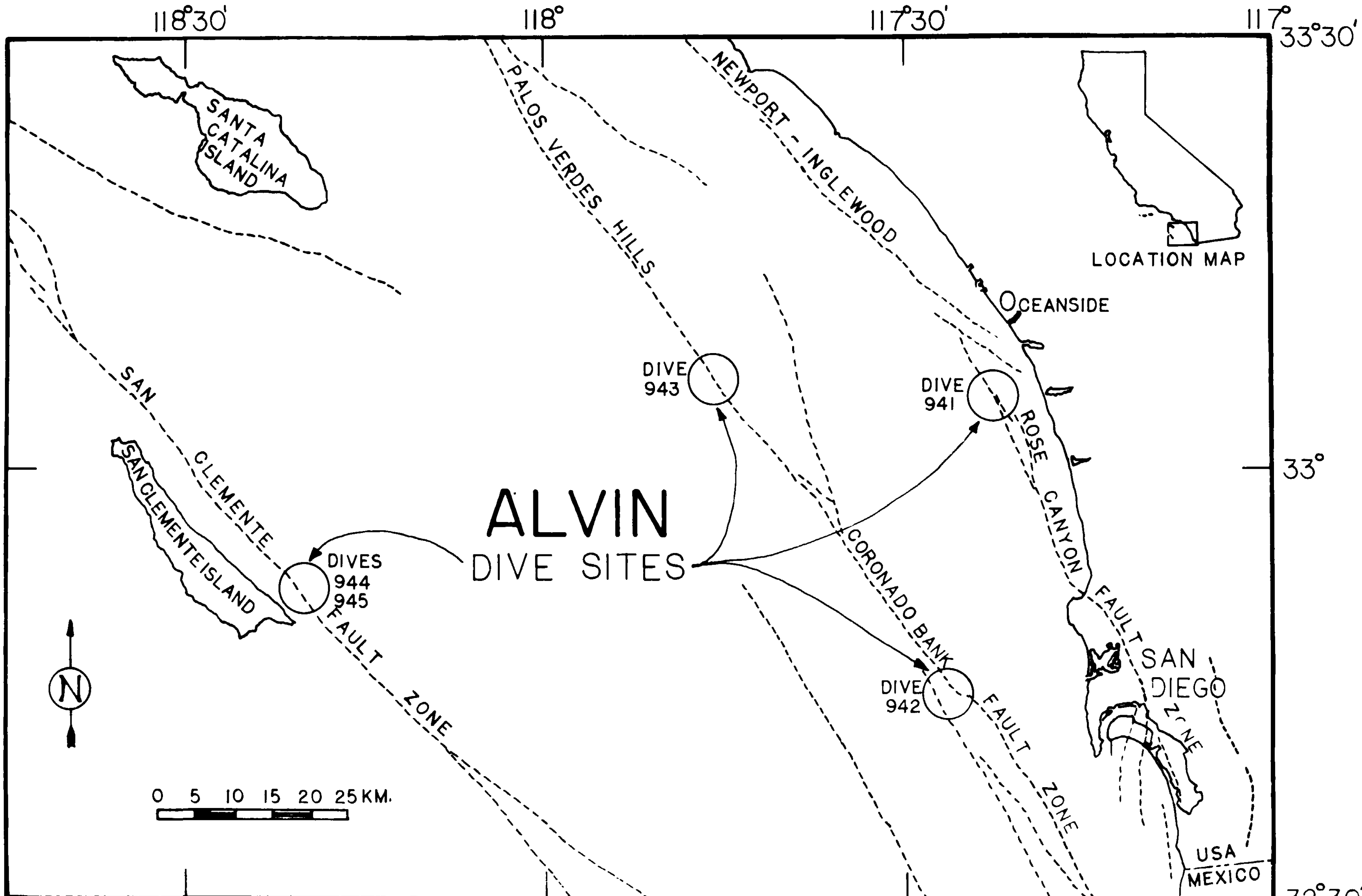

Figure 1. Index map showing the location of DSRV ALVIN dive sites 941, 942, 943, 944, and 945.

DESCRIPTION OF DIVES

ALVIN Dive 941

Dive 941 was launched in the vicinity of the Carlsbad submarine canyon near Oceanside, California (figs. 2, 3). The principal purpose of this dive was to investigate a branch of the Rose Canyon-Newport Inglewood fault zone.

Seismic reflection data suggest that this fault is geologically youthful (Green and others, 1979). These data show that a 100 ms (approximately 75 m) high scarp associated with this branch of the fault zone is well developed and well exposed.

ALVIN's transect 941-941' began in approximately 280 m of water in a small tributary of Carlsbad submarine canyon (fig. 3). This canyon formed following uplift along the western side of the most recent trace of the Rose Canyon-Newport-Inglewood fault zone (fig. 2). A westward thickening (1 to 25 ms) apron of water-saturated, acoustically transparent (Holocene?) sediment abuts against the scarp formed by this uplift (fig. 2). This apron was traversed from east to west for a distance of approximately 1 km. The surface sediment of this sequence is extensively bioturbated, unconsolidated, fine grained and olive gray in color. The material has very low cohesion and did not remain fully in the core barrel when sampled.

Thin ledges of resistant bedrock crop out beneath the soft sediment along the middle part of the apron. Here the slope approaches 15° from horizontal and the bedrock ledges strike approximately N.20°E. These ledges are composed of a sequence of shallowly (5-10°) west-dipping, strongly jointed (blocky), partly conglomeratic, calcareous sandstone and siltstone beds. The rock is extensively altered but remains resistant through induration and iron-rich, limy cementation. Two rock samples (941 R1-R2) and one unconsolidated core sample (941 C1) were collected in this part of the section (table 1). ALVIN continued westward and upslope (scarp) to a depth of 220 m, then turned southward and eastward, crossing and recrossing the crest of the ridge west of a small tributary to Carlsbad submarine canyon (fig. 3). Near the axis of this tributary valley, linear outcrops of arkosic sandstone were encountered and sampled (941 R3). These outcrops strike N.20° to 25°W. and dip nearly vertically.

Following the transects of the sediment apron, scarp and ridge, ALVIN moved southwest and then northward to a position near the foot of the prominent east-facing fault scarp (fig. 2). Here, the fault scarp is characterized by a sharp break in slope, although the bottom is, in most places, smooth and covered with a layer of unconsolidated silt. The average slope of the scarp is about 30° from horizontal. A series of seven rock samples (941 R4-R10) and four sediment core samples (941 C2-C5) were collected along the westward traverse between the base and top of the scarp. The sediment samples were taken from the lower slope immediately east and west of the mapped position of the fault trace, and from the mid slope. They are similar in lithology to that collected from the sediment apron farther east but show notable increases in both cohesion and clay content. The bedrock underlying this slope is a sedimentary sequence of fossiliferous, fine- to very fine-grained, extensively altered sandstone interbedded with carbonate-rich mudstone. The bedding strikes north to northeast and dips 30° to 40° W.

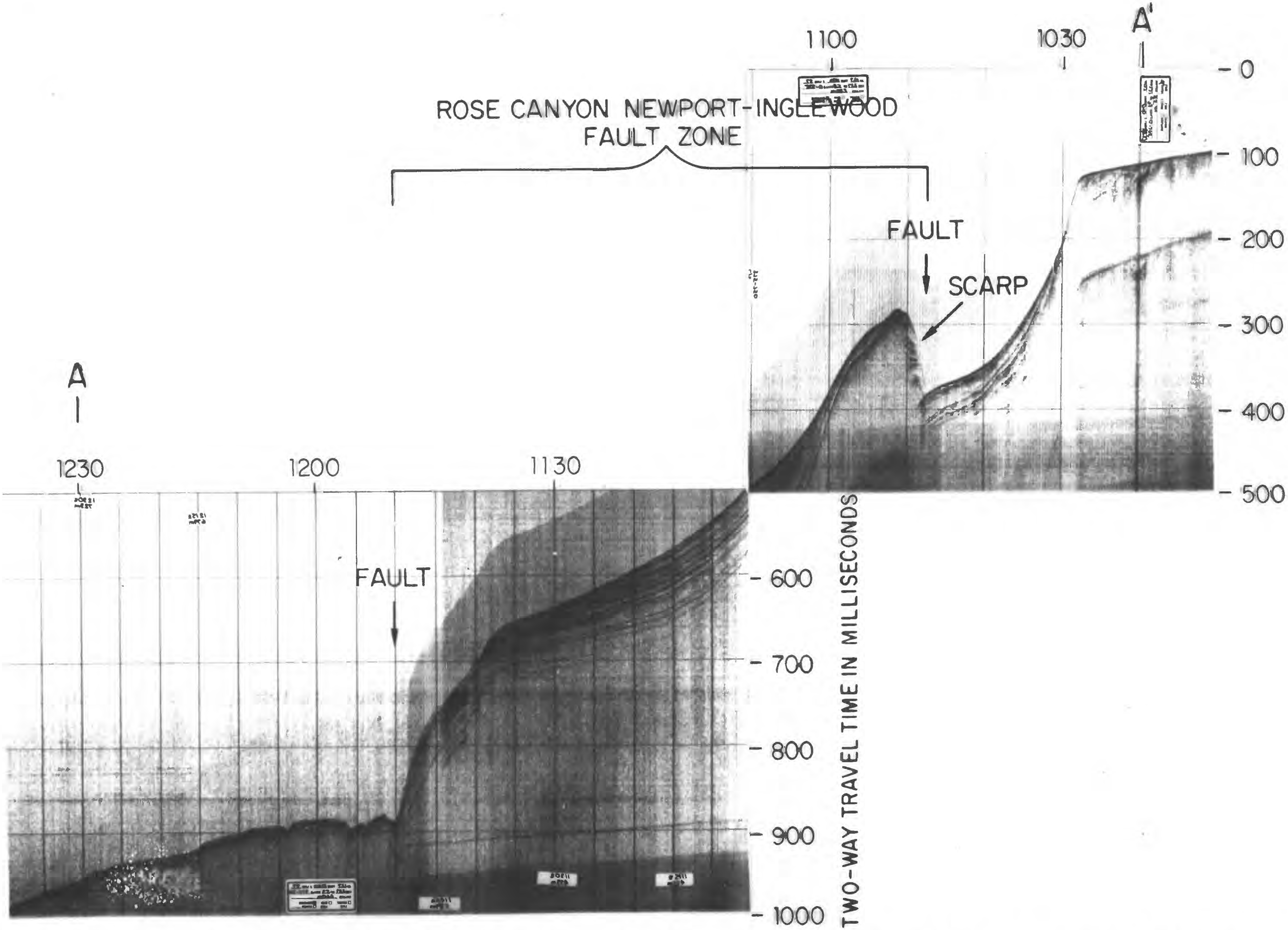

Figure 2. Subbottom reflection profile A-A' showing the Rose Canyon-Newport-Inglewood fault zone offshore from Oceanside. Note east-facing scarp and buttressed sediment to the right of the scarp (trackline location shown in fig. 3). Profile from USGS cruise S2-78-SC, line 37.

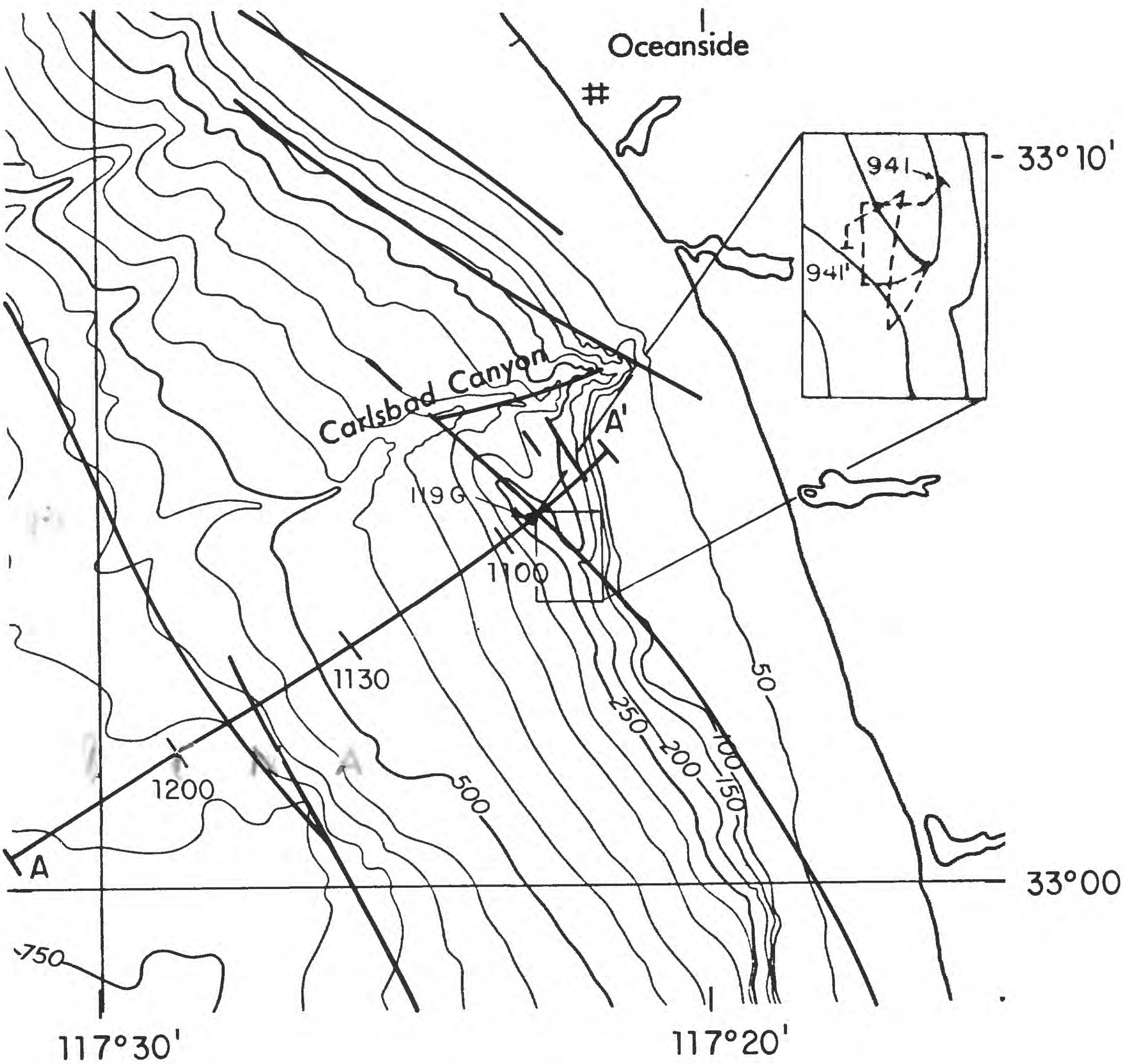

Figure 3. Bathymetric map showing the area of Alvin dive 941, location of subbottom reflection profile A-A' (shown in fig. 2), and location of ALVIN transect 941-941'. Base map modified from 1:250,000 scale NOS sheet 1206N-16. Sample location 119 from USGS cruise S2-79-SC. Faults shown by solid heavy lines after Greene and others (1979). Contour interval 50 m.

A core sample collected during a previous U.S. Geological Survey cruise from the sediment overlying these rocks contained bioturbated, foraminiferal olive-gray clay dated as late Pliocene (Venturian) age (R. E. Arnal, written commun., 1980; sample 119, fig. 3). Because no Pliocene rock of similar age crops out within onshore sections immediately adjacent to this area, we are unable to correlate the sampled rock with certainty to a known rock stratigraphic sequence. Based on both age and lithology it is possible that these rocks are correlative with the San Diego Formation to the south or the Niguel Formation to the north.

ALVIN Dive 942

This dive was made in the vicinity of Coronado Bank and Loma Canyon on the southern California borderland off San Diego, California. Its purpose was to investigate possible surface manifestations of the Coronado Bank fault zone observed on seismic reflection records (fig. 4) and to compare stratigraphic sequences across major fault segments of this zone.

The transect began in 586 m of water on the gentle (5°) slope east of Loma Canyon (fig. 5). A reconnaissance traverse was made upslope from the landing point on a course of approximately 70°, to investigate the easternmost fault of the Coronado Bank fault zone (fig. 5). No surface disruption of the sediment was noted. The surface sediment overlying the fault is unconsolidated, olive gray, water-saturated very fine sand and silt. Bioturbation is so extensive that a rather uniform hummocky topography has developed over the entire area. The amplitude of the mounds and hollows characteristic of this topography reaches 2 m. Biological activity is so intensive that surface ruptures associated with faulting in the area are likely to be obliterated in a short time. In addition, erosional features such as fault-line scarps probably could not develop in such an environment.

A traverse heading approximately 250° was made from a water depth of 500 m downslope to the axis of Loma Canyon and the foot of the Coronado Bank escarpment (fig. 4). The easternmost fault of the Coronado Bank fault zone was then crossed at a point approximately 200 to 300 m south of the initial crossing and, again, no surface expression of faulting was noted. In addition, a fault central to the fault zone (fig. 5) was crossed during this traverse and its trace was also masked by heavily bioturbated, fine-grained, unconsolidated sediment. A strong bottom current (approx. 0.5-1 km/h, J. Donnally, personal commun., 1979) that moved suspended sediment to the north-northwest and formed small northwest-oriented sand waves was noted within the central part of Loma Canyon.

At the toe of the Coronado Bank escarpment (730 m depth), a stratigraphic section was measured upward to the top of Coronado Bank (490 m depth). Soft unconsolidated sediment covers the base of the section where the slope steepens abruptly (20-25° from horizontal) at a water depth of 690 m. Between depths of 690 and 570 m a thin veneer of sediment (table 2, 942 C1) made the collection of bedrock samples impossible. Bedrock samples were collected farther up slope at nine locations from prominent, outcropping ledges through a nearly continuous, 150 m-thick section between water depths of 570 m to 490 m (942 R1-R9). This succession strikes N.20° to 30°W. (subparallel to the slope) and dips 50° to 60°W. Although the rock sampled in traverse 942-942' were barren of dateable fossils, lithologically equivalent rocks containing

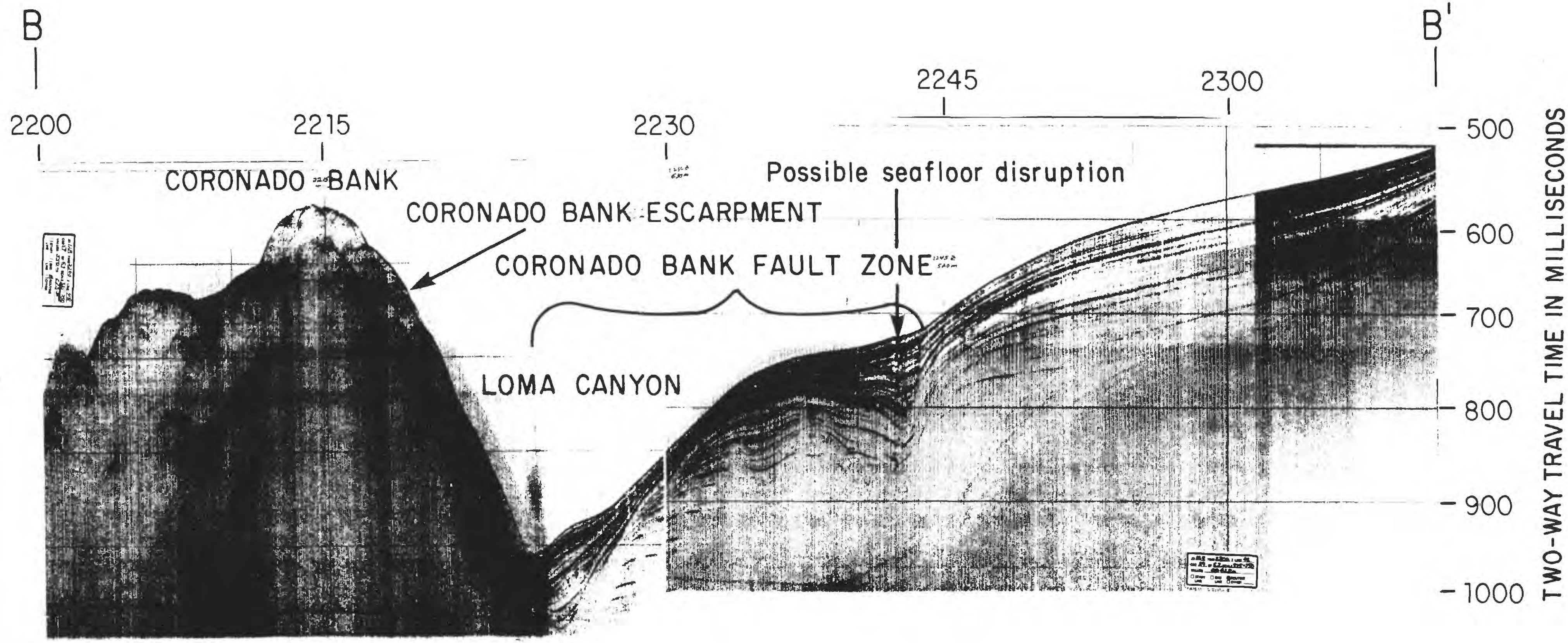

Figure 4. Subbottom reflection profile B-B' showing Loma Canyon, Coronado Bank, and Coronado Bank fault zone (location shown in fig. 5). Profile from USGS Cruise S2-78-SC, line 48.

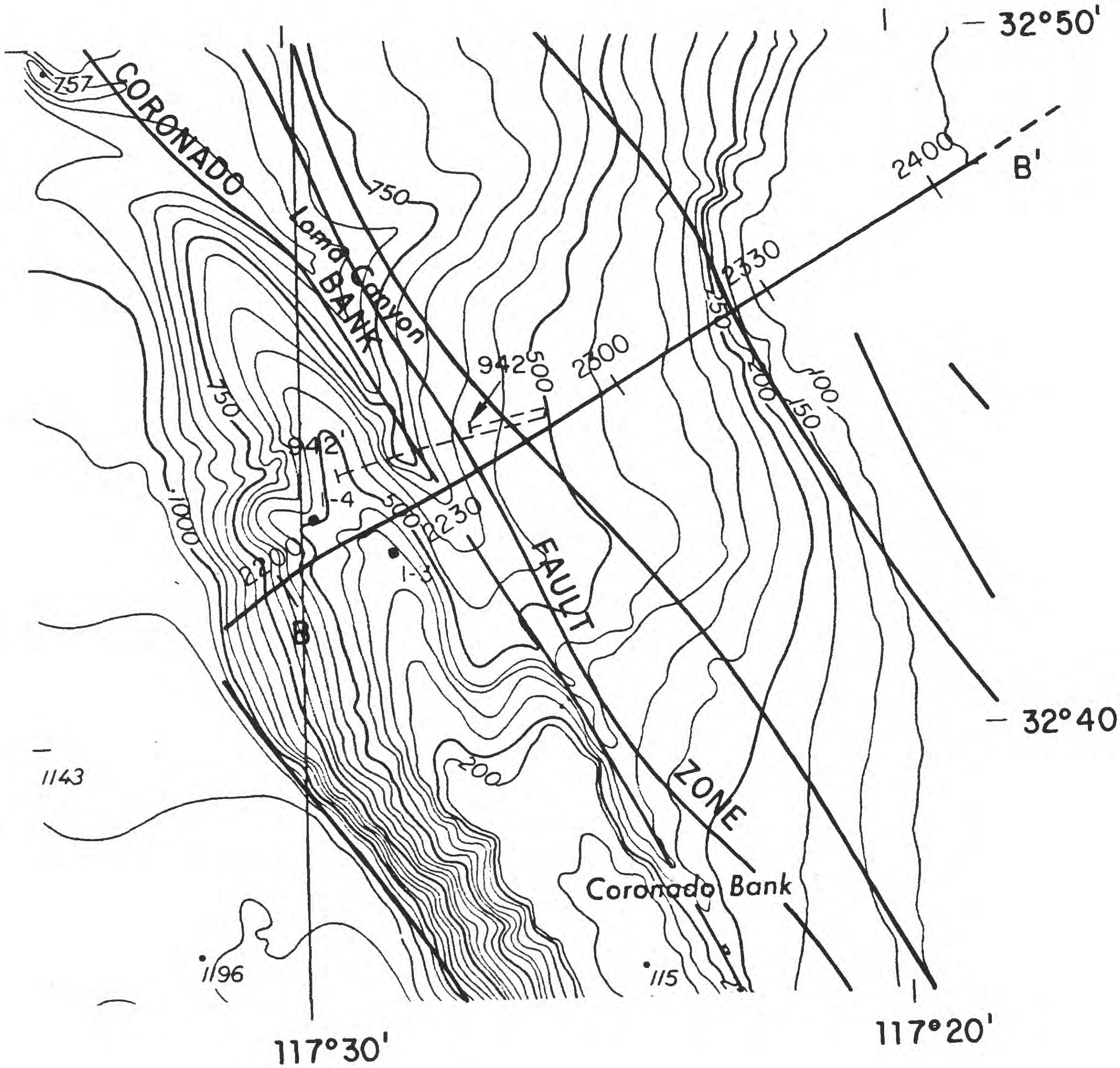

Figure 5. Bathymetric map showing the area of ALVIN dive 942, location of subbottom reflection profile B-B' (shown in fig. 4) and location of ALVIN transect 942-942'. Base map modified from 1:250,000 scale NOS sheet 1206N-16. Sample locations 1-3 and 1-4 from Vedder and others (1977). Faults shown by solid heavy lines after Greene and others (1979) and Kennedy and others (1980). Contour interval 50 m.

late Miocene coccoliths and Mohnian foraminifers crop out in nearby exposures (Vedder and others, 1977; fig. 5).

ALVIN Dive 943

Dive 943 was made along a prominent, 50 ms (approximately 38 m) high scarp (fig. 6) within the Palos Verdes Hills-Coronado Bank fault zone (fig. 7). This dive was undertaken to determine if this scarp is tectonic in origin and to obtain evidence of the character and recency of fault movement. High-resolution seismic-reflection profiles of the area indicate that the scarp is developed adjacent to a major and geological youthful strand of this fault zone (Greene and others, 1979). Samples (82, 83, 84, fig. 7) were obtained during a previous U.S. Geological Survey cruise from the west flank and crest of the bathymetrically positive feature traversed during this dive. These samples are laminated to homogenous (bioturbated) olive-gray mud containing foraminifers dated as uppermost Miocene (Delmontian) or early Pliocene (Repettian) in age (R. E. Arnal, written commun., 1980). Additional surface sediment samples (79, 80 and 81, fig. 7) collected during this cruise from near the base of the slope and from the adjacent basin are predominantly homogenous (bioturbated), medium-gray mud containing a late Pliocene to Holocene microfaunal assemblage (R. E. Arnal, written commun., 1980).

ALVIN's transect began in 828 m of water on a relatively flat bottom that lies at the foot of a prominent west-sloping scarp (figs. 6, 7). The initial legs of this transect explored the toe and lower slope, and then ascended the relatively gentle northwest flank of the 100-m high knoll presumed to have been formed at least partly by fault movement. The surface sediment underlying the toe and lower slope of the scarp was cored in three locations (table 3, 943 C1-C3). The sediment is fine-grained, olive-gray, unconsolidated, water-saturated sand and silt that contains abundant Holocene shell debris. A lithologically similar core (943 C4) was obtained from the crest of the hill at a water depth of 720 m. The lower part of the slope is steep, estimated to be 20° to 30° from horizontal, whereas the upper slope is closer to 5° to 10°. The slopes are sediment covered and everywhere are extensively bioturbated. Large closed depressions, up to 3 m across and 1 m deep, presumably formed by gas escape or by the enfauna, were encountered along the upslope portion of this traverse. These depressions are especially common in the vicinity of the mapped trace of the fault (fig. 7).

The final leg of the traverse was an ascent on an eastward course up the steeper part of the scarp face. Outcropping rock was first encountered at a depth of 831 m (943 R1). The rocks are conglomeratic, containing fragments of sandstone, siltstone and volcanic rock, and are exposed in resistant ledges that strike about N.20°W. They are overlain by soft, unconsolidated surficial sediment, considered by way of lithology and continuity to be genetically equivalent to that at the toe of the slope. Additional rock samples were taken at successively higher stratigraphic intervals at depths of 820 m, 800 m and 789 m (943 R2-R4). Two cores (943 C5-C6) taken of the surficial sediment on opposite sides of the fault are identical in lithology.

ALVIN Dives 944 and 945

These dives were made on the steep eastern submarine face (San Clemente Escarpment) of the San Clemente Island platform (figs. 8, 9). Dive 945 was a

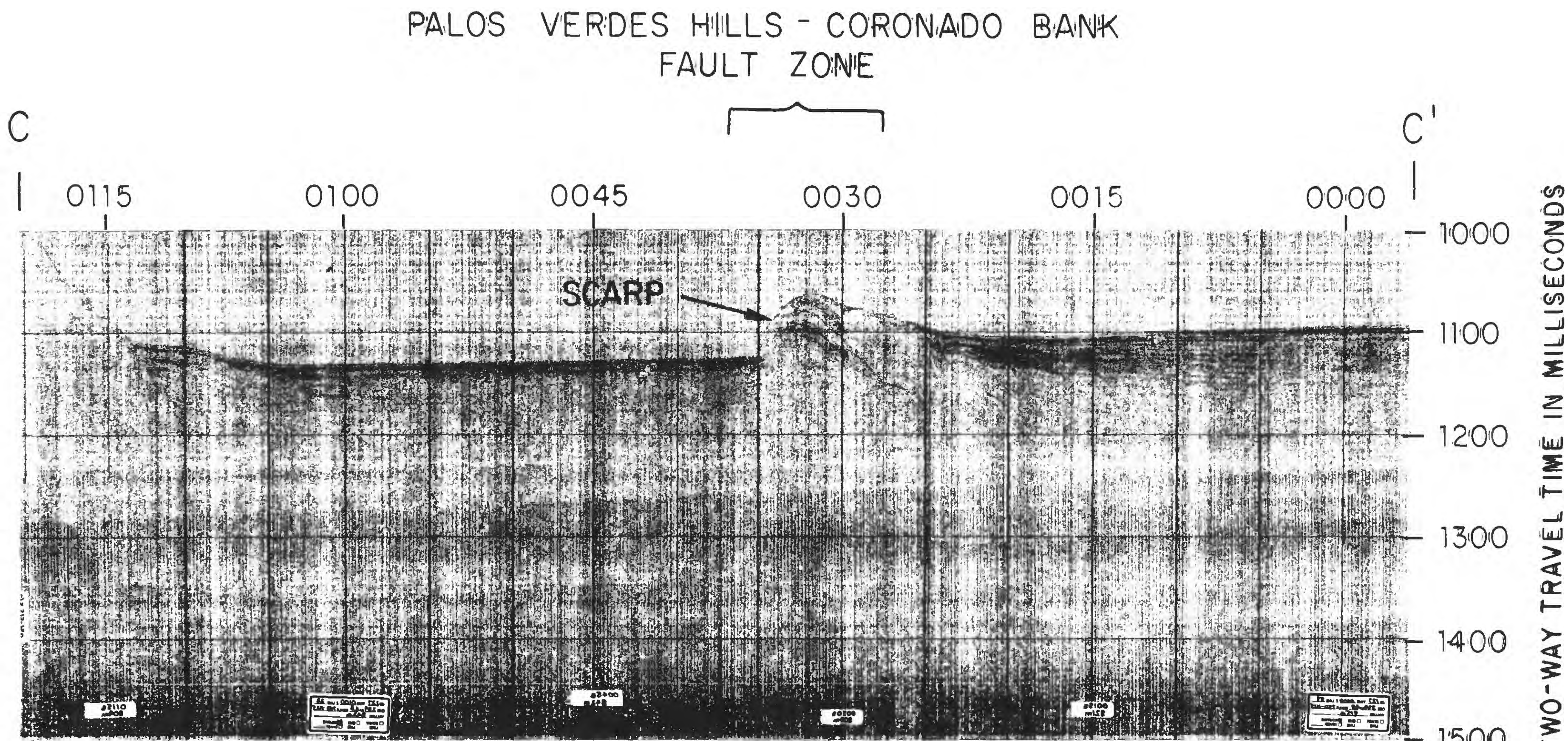

Figure 6. Subbottom reflection profile C–C' showing the Palos Verdes Hills-Coronado Bank fault zone and associated scarp (location shown in fig. 7). Profile from USGS cruise S2-78-SC, line 33.

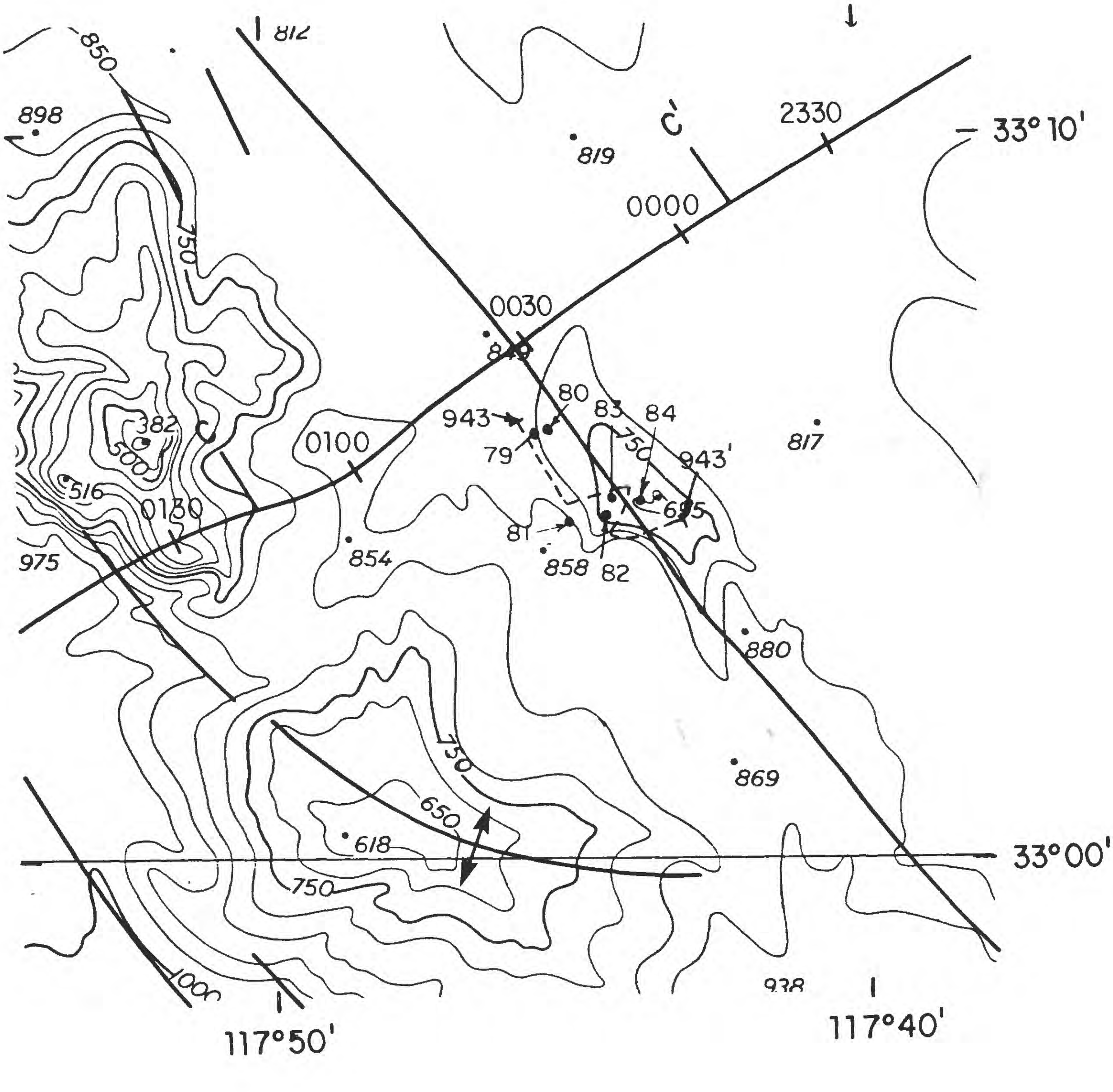

Figure 7. Bathymetric map showing the area of ALVIN dive 943, location of subbottom reflection profile C-C' (shown in fig. 6), and location of ALVIN transect 943-943'. Base map modified from 1:250,000 scale NOS sheet 1206N-16. Sample locations 79-84 from USGS cruise S2-79-SC. Faults and fold shown by solid heavy lines after Greene and others (1979). Contour interval 50 m.

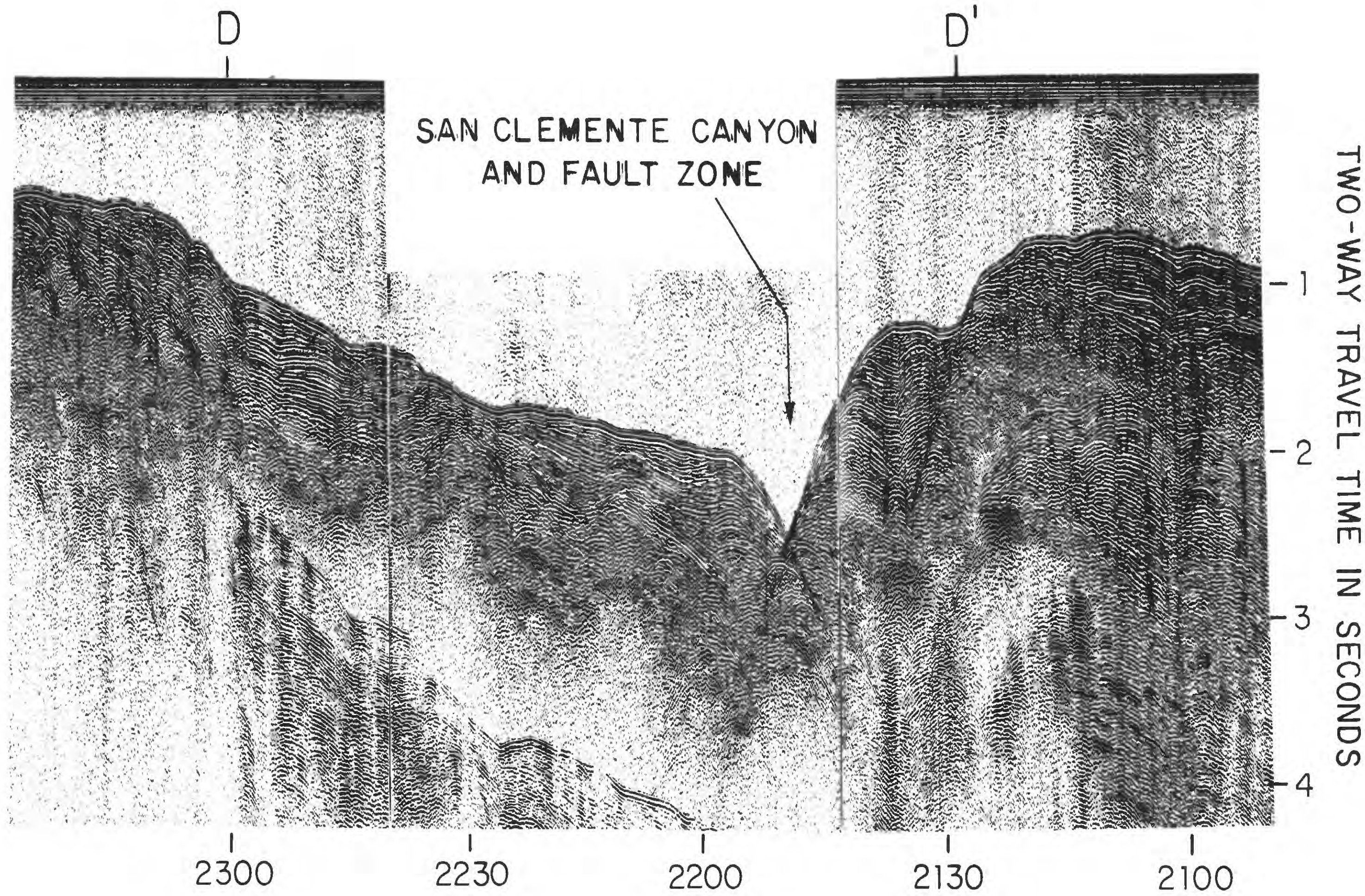

Figure 8. Subbottom reflection profile D-D' showing San Clemente Canyon and fault zone (location shown in fig. 9). Profile from Nov. 1973 USGS R/V KELEZ cruise, line 975.

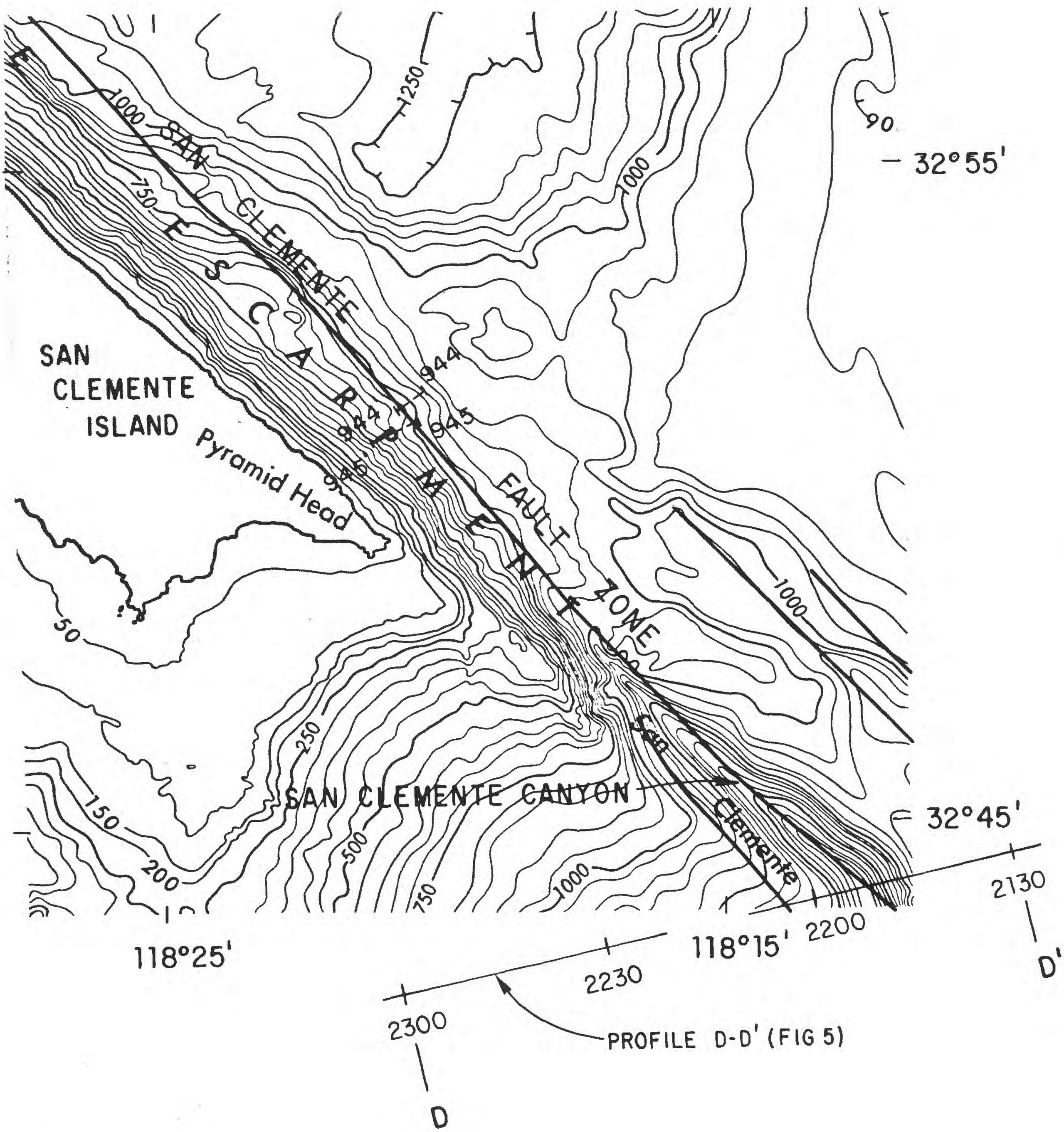

Figure 9. Bathymetric map showing the area of ALVIN dives 944 and 945, location of subbottom reflection profile D-D' (shown in fig. 8) and location of ALVIN transects 944-944' and 945-945'. Base map modified from 1:250,000 scale NOS sheet 1206N-15. Faults shown by solid heavy lines after Vedder and others (1974). Contour interval 50 m.

continuation of dive 944, which was aborted as a result of an accidental ballast drop. The dives were made to study the character and recency of movement of a faulted stratigraphic succession associated with offset on the seismically active San Clemente fault zone.

ALVIN's transect 944-944' ascended the San Clemente Escarpment from a water depth of 871 m to a depth of 714 m; transect 945-945' ascended this escarpment from 738 m to 397 m (fig. 9). Rock samples were collected from 13 locations (table 4). These samples were taken at intervals of 10 to 150 m at successively decreasing water depths of 871 to 480 m. The sample interval was predicated upon the quality of exposure and presence, in an otherwise uniformly massive and resistant section, of broken or loose rock that could be sampled by ALVIN's mechanical arm.

Bedrock samples from the lower part of the section, collected at water depths from 871 m to 779 m, are poorly sorted granule to cobble conglomerate composed of a fine-grained Quaternary sandstone matrix and dark gray Miocene(?) basalt clasts. Samples from higher in the section, between water depths of 769 m and 480 m, are Miocene(?) basaltic rocks similar to those reported by Vedder and others (1974) from stratigraphically higher in the section and underlying San Clemente Island. Thin patches of fine-grained, olive-gray, unconsolidated sediment that locally mantle the face of the slope were cored at two locations (944 C1-C2).

The Quaternary part of the measured section owes its position either to landsliding or faulting, but the nature of its contact with the adjacent volcanic rock was not observed.

The strike of the observed bedding subparallels the regional trend of the escarpment, and beds dip steeply to the west. This attitude might be indicative of a rotational slump origin for this part of the section.

DISCUSSION

Location of the fault zones studied and their associated seismicity are shown in Figure 10. The dive sites were selected where strands of these faults extend upward to the sea floor within acoustically transparent (water saturated) and poorly consolidated Quaternary sediment, and have prominent bathymetric expression. Although in some cases erosional development or modification of these scarps is a possibility, this sea-floor expression of faulting is considered to be principally tectonic in origin.

We were able to confirm by onsite study the presence of a linear scarp-like ridge of significant dimension at each dive locality. However, the identification of other manifestations of recent fault movement was generally not possible because of the combined effects of recent sedimentation, bioturbation of surface and near-surface sediment and the smoothing effects of current action, which tend to quickly obliterate the surface expression of faulting. The direct observation of sea-floor features is further hampered by limited visibility (generally not exceeding 4-6 m) caused by darkness and by backscattering of light from the submersible's high intensity lamps. To retain a sense of perspective about geologic features much larger than the observer's field of view, under these circumstances, very close attention must be paid to the relationship between the submarine's position, heading and

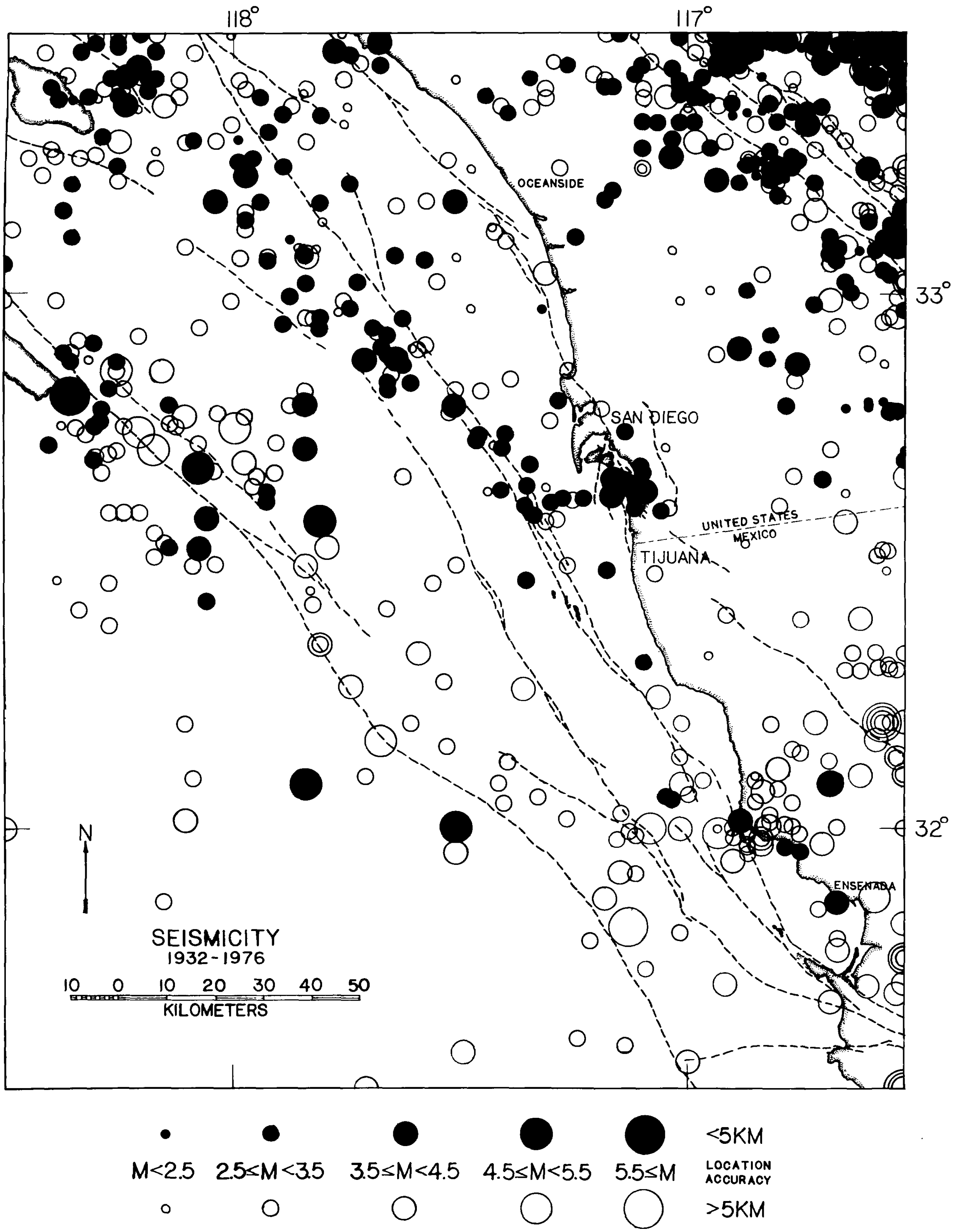

Figure 10. Map showing major fault zones of the inner-southern California continental margin and their associated seismicity (after Legg, 1980).

distances traveled between location fixes and their relationship to the sea-floor features being studied. In spite of these limitations, the manned submersible proved most useful in that it permitted the direct observation, description, measurement and areal mapping of sea-floor exposures. Perhaps most importantly, exposures can be sampled with the observer's knowledge of their geologic context and position within a stratigraphic succession, and with the absolute certainty that the samples obtained are in place; this is virtually the only way, short of drilling, that such samples can be obtained in the marine environment.

The Quaternary sediment deposits were of particular interest because they comprise the principal units underlying the modern sea floor off southern California (Vedder and others, 1974). These deposits have widely varying lithologies because of the broad range of rocks types from which they are derived (Kennedy, 1975). The Quaternary age for these sediments has been previously presumed, based on their poorly consolidated nature, extremely low compressional wave velocities (1.4-1.7 km/sec) and water saturated state (Kennedy and others, 1980). During the course of this investigation, Quaternary Coccoliths including *Reticulo fenestra sp.* were obtained from these sediments (David Bukry, written commun., 1980). The fossiliferous section was sampled at two locations adjacent to the San Clemente escarpment (fig. 9); samples 944 R1 and 944 R6, table 4). The rock is composed of distinctive fine-grained, poorly sorted, yellowish-brown and olive-gray, carbonate-cemented sandstone and siltstone.

Barite deposits (sample 944 R4, table 4) were encountered on the San Clemente Escarpment at a depth of 797 m, stratigraphically adjacent to the Quaternary fossil Coccolith assemblage noted above. The barite occurs as fine-grained fresh crystals interspersed with more weathered grains of quartz, plagioclase and K-feldspar. Barite was also collected from late Miocene or early Pliocene rocks (samples 943 R2, 3, and 4, table 4) exposed of the face of a dramatic scarp of the Palos Verdes Hills-Coronado Bank fault zone. Geochemical data suggest that barite dredged from southern California was not formed in a normal marine environment (Goldberg and others, 1969). Analyses of barite collected from offshore southern California and from sea cliff exposures at Palos Verdes, near a more northerly part of the Palos Verdes fault zone, are considered by Goldberg and others (1969) to be either hydrothermal in origin or to have been formed in a restricted lagoonal environment. We initially expected that a distinctive occurrence of barite of lagoonal origin would be associated with the Quaternary rock. The barite mineralization of all four samples collected is similar in physical nature in both thin section and X-ray pattern. A hydrothermal origin for these barite deposits seems more tenable to us, in that the mineralized rocks are of differing ages and the fault zones themselves could have provided a natural conduit through which passed warm or hot aqueous solutions. A restricted lagoonal origin is perhaps also tenable for the San Clemente deposits, which probably owe their present deep water location to landsliding or faulting in an environment that is otherwise undergoing tectonic uplift.

We feel that onsite studies of sea-floor exposures by way of manned submersible observations and sampling is very useful in better understanding the details of geological and geophysical data previously collected by remote sensing techniques. The ability to obtain three dimensional compass data applicable to structural analysis for engineering geological applications, combined with sediment core samples from each site, also suggests that submersible observations and sampling could provide a valuable means of data acquisition for geotechnical investigations of continental margins.

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Table 1. General description of samples from dive 941

SAMPLE #	WATER DEPTH	BRIEF DESCRIPTION	COMMENT
941 R1	250 m	Medium-light-gray carbonate-cemented siltstone (90% subround quartz grains; minor plagioclase, K-feldspar, biotite).	Rock ledge overlain by soft unconsolidated sediment. Strike N20°E.
941 C1	250 m	Olive-gray, unconsolidated, clay and silt with Holocene shell fragments.	
941 R2	220 m	Light olive-gray and medium-light-gray pebble conglomerate in calcareous siltstone matrix (70% matrix; 25% fossil shell fragments; minor quartz and feldspar).	
941 R3	250 m	Moderate yellowish-brown sandstone in calcareous matrix (40% quartz; 10% K-feldspar and plagioclase). Matrix contains fine grains of fossil shell material.	Base of west-facing linear slope. Heading northeast. Strike N20°-25°W. Dip near vertical.
941 C2	280 m	Olive-gray, unconsolidated, cohesive clay and silt with Holocene shell debris.	Samples C2 and C3 from immediately east and west of mapped fault trace.
941 C3	280 m	Olive-gray, unconsolidated, cohesive clay and silt with Holocene shell debris.	
941 R4	270 m	Olive-gray, poorly sorted sandstone in carbonate matrix.	Upslope traverse heading west. Samples R4,R5,R6,R7,C4,C5 taken on upslope traverse of linear, east-facing slope.
941 R5	245 m	Dark-yellowish-brown fine-grained sandstone with carbonate matrix. Contains fossil debris.	
941 C4	228 m	Olive-gray, unconsolidated, cohesive clay and silt. Contains Holocene shell debris.	
941 R6	220 m	Grayish-black, fine-grained, well-sorted quartz sandstone. Quartz grains are subround. Contains thin veins of $CaCO_3$ cement.	

Table 1. General description of samples from dive 941 (continued)

SAMPLE #	WATER DEPTH	BRIEF DESCRIPTION	COMMENT
941 C5	220 m	Olive-gray, water-saturated, unconsolidated clay and silt. Contains Holocene shell debris.	
941 R7	210 m	Dark-yellowish-brown fine-grained sandstone and carbonate-rich mudstone. Contains fossil debris.	
941 R8	205 m	Dark-gray, very fine-grained sandstone and carbonate-rich mudstone. Grains are composed primarily of fossil shell debris, with lesser quartz, feldspar, and mica grains.	Samples R8, R9,R10 taken from crest of ridge
941 R9	205 m	Dark-gray, very fine-grained sandstone and carbonate-rich mudstone. Grains are composed primarily of fossil shell debris, with lesser quartz, feldspar, and mica grains.	
941 R10	205 m	Dark-gray, very fine-grained sandstone and carbonate-rich mudstone. Grains are composed primarily of fossil shell debris, with lesser quartz, feldspar, and mica grains.	

Table 2. General description of samples from dive 942

SAMPLE #	WATER DEPTH	BRIEF DESCRIPTION	COMMENT
* 942 R1	570 m	Light-gray siltstone.	Begin traverse (heading 270°) upslope from flank of Loma Sea Valley to Coronado Bank. Section strikes approximately N. 20°-30°W. and dips 50°-60° W.
942 C1	570 m	Olive-gray, unconsolidated, water-saturated silt and sand.	
* 942 R2	555 m	Light-gray siltstone clast with phosphate coating. Limey matrix.	
942 R3	530 m	Pebble and granule conglomerate in brownish-black, fine-grained sandstone and limey mudstone matrix. Sandstone is 80% quartz with minor plagioclase, K-feldspar, mica grains, and rock fragments.	
942 R4	520 m	Granule conglomerate in pale yellowish-brown, very fine-grained carbonate-rich claystone matrix.	
942 R5	495 m	Pebble and granule conglomerate in limey, fine-grained, olive-black sandstone.	R5 from top of Coronado Bank
942 R6	495 m	Medium-light-gray and pinkish-gray very fine-grained quartzite.	Rounded clast.
942 R7	494 m	Pale-purple, porphyritic, weathered metavolcanic.	Rounded clast.
942 R8	490 m	Olive-gray, limey claystone. Contains fossil shell debris.	Section strikes approximately N. 30°W. and dips 50°W.
* 942 R9	510 m	Olive-gray, limey claystone. Contains fossil shell debris, Foraminifera, and minor quartz grains.	

* Sample correlative to upper Miocene rocks collected in close proximity to 942-942' (Vedder and others, 1977).

Table 3. General description of samples from dive 943

SAMPLE #	WATER DEPTH	BRIEF DESCRIPTION	COMMENT
943 C1	828 m	Olive-gray, water-saturated, fine-grained sandstone and siltstone containing Holocene shell debris.	Sediment cored at base of escarpment.
943 C2	840 m	Same as 943 C1.	
943 C3	780 m	Same as 943 C1.	
943 C4	720 m	Same as 943 C1.	
943 R1	831 m	Olive-gray, limey, fossiliferous claystone.	Outcrop on face of scarp.
943 R2	820 m	Dark-yellowish-brown, poorly-sorted sandstone/conglomerate composed of fresh barite crystals and weathered rock fragments. Rock fragments are fine-grained sandstone, siltstone, claystone and volcanic rock.	
943 R3	800 m	Dark-yellowish-brown, poorly sorted sandstone/conglomerate composed of fresh barite crystals and weathered rock fragments. Rock fragments are fine-grained sandstone, siltstone, claystone and volcanic rock.	
943 C5	776 m	Olive-gray, poorly consolidated, fine-grained sand and silt.	Ponded sediment.
943 R4	789 m	Dark-yellowish-brown, poorly sorted sandstone/conglomerate composed of fresh barite crystals and weathered rock fragments. Rock fragments are fine-grained sandstone, siltstone, claystone and volcanic rock.	Outcrop on scarp.
943 C6	720 m	Olive-gray, poorly consolidated, fine-grained sand and silt.	Ponded sediment.

Table 4. General description of samples from dives 944 and 945

SAMPLE #	WATER DEPTH	BRIEF DESCRIPTION	COMMENT
944 C1	871 m	Olive-gray, poorly-consolidated silt.	Base of slope sediment apron.
944 R1	871 m	Dusky-yellowish-brown, fine-grained, carbonate-rich fossiliferous sandstone and siltstone.	Began upslope traverse on course of 230°. Contains early Quarternary Coccolith assemblages.
944 R2	871 m	Dark-gray basalt.	Well-rounded clast.
944 R3	853 m	Medium-dark-gray basalt.	Rounded clast.
944 R4	797 m	Dusky-brown, weathered, micro-fossiliferous, sandstone with fresh barite crystals. Contains unaltered grains of plagioclase and K-feldspar.	Outcrop on ledge of escarpment.
944 R5	797 m	Medium-dark-gray basalt.	Rounded clast.
944 R6	796 m	Dark-yellowish-brown, microfossiliferous sandstone in carbonate matrix.	Contains early Quarternary Coccolith assemblage.
944 R7	796 m	Medium-dark-gray basalt.	Subrounded clast.
944 R8	779 m	Yellowish-brown, microfossiliferous, sandstone in carbonate matrix.	Mid-slope outcrop.
944 R9	769 m	Medium-light-gray basalt.	Clast?
944 C2	769 m	Olive-gray, soft, unconsolidated silt or clay.	Slope veneer.
945 R1	738 m	Light-gray basalt.	Began upslope traverse. Course approximately 225°.
945 R2	706 m	Light-gray basalt.	
945 R3	557 m	Light-gray basalt.	
945 R4	480 m	Light-gray basalt.	