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SEACLIFF DIVING AND SEDIMENT STUDIES ON THE GORDA RIDGE

by

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Final Report for Contract No. 63-630-8806

Submitted to:

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and the

Gorda Ridge Technical Task Force

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NOTICE

This report is based on results of a research program directed by the joint federal-state Gorda Ridge Technical Task Force, managed by the Oregon Department of Geology and Mineral Industries, and funded by the Minerals Management Service, U.S. Department of the Interior, through Cooperative Agreement. Opinions expressed are those of the author and do not constitute endorsement by the sponsoring agencies or the Task Force.

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SUMMARY

Diving operations were conducted with the Navy submersible *SeaCliff* to examine the nature and extent of sediment hosted massive sulfide deposits in the NESCA area of the Escanaba Trough. The contracted work was to participate in the dive program to better define the areal distribution of hydrothermal deposits and evaluate the use of the sediments as recorders of volcanism and hydrothermal activity. Because of severe weather, only four of fourteen scheduled dives were completed. During my dive, a moderate-sized inactive hydrothermal deposit was observed and a large chimney sample was retrieved. Subsequent to the cruise, descriptions and magnetic susceptibility measurements were made on a number of cores from the 1986 *Lee* expedition to the same area. The detailed magnetic susceptibility profiles revealed several proximal volcanic turbidites that could be traced to local mass slumping on one of the sediment covered domes in the NESCA area. One core shows extensive chlorization and sulfide mineralization that appears to be of Holocene age. Sedimentation rates and ages of the specific events in the cores were tentatively assigned by relating the lithoiogy and magnetic stratigraphy of these cores to C-14 dated cores from the1985 R/V *Lee* cruise.

INTRODUCTION

The Gorda Ridge is a slow spreading center located within the U.S. Exclusive Economic Zone off the coasts of northern California and Oregon. The ridge is unusual in the world's rifting system, because the southern portion, called the Escanaba Trough, is covered by a thick sequence of sediment derived from glacial weathering of the American continent during the Pleistocene. These sediments form a semipermeable, wet thermal blanket that traps heat associated with the creation of new oceanic crust along the rift zone. The hydrothermal activity associated with the ridge crest volcanism leads to the formation of large sediment hosted sulfide deposits. An understanding of the relations between sedimentation, volcanism, neotectonic, and hydrothermal activity in this environment would provide valuable insights that could be applied to ancient massive ore deposits that were formed in a similar setting, but presently occur on land.

For the last few years, the USGS, MMS, and various academic institutions have conducted a joint research program to evaluate the resource potential of the Gorda Ridge. As part of this effort, the Navy research vessel *SeaCliff* conducted a diving program in the NESCA area of the Escanaba Trough in 1988. The NESCA area is one of a series of uplifted and sediment capped volcanic domes that intrude through the sediment cover along the rise axis. Hydrothermal deposits had been located in the area previously through dredges, camera tows, and earlier diving The main goals of the 1988 dive program were to determine the size and distribution of the hydrothermal deposits and to establish their relations to tectonic fissuring and extrusive volcanism. This research contract undertaken was to participate in the diving program and to continue ongoing sediment studies in the area. With regard to the diving program, the goals of the contracted research were to evaluate the association of the sediments with sulfide deposits. Specifically, we wanted to determine whether hydrothermal activity and sulfide deposition was localized by faulting or fissuring or if more widespread heating and hydrothermal activity caused baking and metamorphism of the sediments in the vicinity of the volcanic domes. Our objectives with respect to the sediment cores were to use the sedimentary recorder to obtain a history of volcanism, tectonism, and hydrothermal activity for the last ten thousand years.

RESULTS OF THE DIVING PROGRAM

The *SeaCliff* support ship R/V *Laney Chouest* left San Diego on September 6, 1988. During the three day transit to the study area, the scientific personnel were trained as submersible co-pilots and were required to pass a qualifying exam for familiarity with diving operations and emergency procedures. On reaching the study site, a transponder network was emplaced and a navigational survey was conducted to fix the net in a geographic coordinate system. Unfortunately severe weather limited diving operations for several days. Of the scheduled fourteen dives, only four were completed. We planned to participate in three to four dives; yet only one dive was possible because of the high seas. The ship was forced to return to port early due to damage to the hydraulics on the submersible launching frame.

A transcription log of Dive 766 in which the PI participated is included in Appendix A. The dive was conducted on the eastern flanks of the southernmost of the three sediment covered hills at NESCA. The dive team consisted of the pilot (Cdr. Reid Popovich, USN), co-pilot (Dr. Robert Karlin, UW) and port observer (Dr. Robert Zierenberg, USGS). During the dive, we observed a very large sulfide deposit soon after reaching the bottom. On attempting to manuver to a location for sampling, we lost bottom contact and spent several minutes in manuvering in the water column. On regaining the bottom, we lost sight of the sulfide field and considerable time was spent in attempting to relocate the deposit in very hummocky and hilly terrain. It was our impression that the irregular topography may represent erosional mass wasting channels that intersect a linear graben feature.

Eventually, we sighted another moderate-sized sulfide field composed of ledges, mounds and small chimneys less than 1 m in height. The deposit was surrounded by an active vent fauna consisting mainly of clams, Galatheid crabs, and orange shrimp. A large chimney sample and a small sediment core were recovered from the site and brought to the surface. The dive was prematurely terminated due to worsening surface sea conditions. The dive ascent and submersible recovery were uneventful. The sulfide and barite chimney sample was placed in the USGS collection under the curatorial direction of Dr. Randy Koski. No further work was done on the sediment core, which resides at UNR.

RESULTS OF SEDIMENT STUDIES

The second phase of this project involved examination and measurements on existing sediment cores taken in the SECCA and NESCA area during cruises L1-86-NC and L2-86-NC aboard the R/V *Lee* in 1986 and one unopened 4.5" PVC core from the 1988 *AII* expedition. Core location maps are given in Figures 1-3 and a graphical description of the cores is shown in Figure 4. This work was done in collaboration with Dr. Robert Zierenberg of the USGS in Menlo Park.

Whole core magnetic susceptibility (X) profiles were made on each of the split core sections using a Bartington MS-2 susceptibility meter equipped with a 125 mm ring sensor. Susceptibility measurements are an extremely useful method of remotely logging downhole lithologic variations. Magnetic susceptibility values are controlled mainly by the concentration of magnetic minerals and to a lesser extent, by changes in magnetic grain size. The abundances of magnetic minerals are in turn influenced by changes in terrigenous, hydrothermal or volcanic sources, dilution by biogenic components, and post-depositional authigenic and diagenetic processes involved in the early diagenesis of organic matter.

In an earlier MMS-sponsored study of Escanaba Trough sediments, Karlin and Lyle (1986) found that a regionwide lithologic change occurred at approximately 11 ka associated with a transition from glacial to interglacial conditions. This lithologic change is recognizable as a subtle color transition from olive grey to grey and a fining of the sediments from a mottled silty clay to a slightly calcareous homogeneous stiff clay. The change in lithology is easily recognizable in whole core susceptibility profiles as a doubling in X values toward the base of the gravity core sections.

The profiles of the whole core susceptibility determinations are shown in Figures 5-9 for the *Lee* and *AII* cores examined in this study. Measurements were done at 1 cm intervals and were depths were determined relative to the top of the sediment rather than from the edge of the core liner. Susceptibility units are 10^{-5} cgs (emu/Oe) and the stability of the instrument was about $\pm$ 1 unit. Because of the sensor geometry, each value represents a center weighted average over a width of ~5 cm.

Several noteworthy features oı the susceptibility profiles are described in the following paragraphs. Cores designated L1 and L2 refer to cruises L1-86-NC and L2-86-NC, respectively.

1. As found in the1985 study (Karlin and Lyle, 1986), the X profiles along with the color and lithologic change record the Holocene/Pleistocene boundary at 11 ka. X values for the Holocene sediments are ~10 and the finer grained Pleistocene sediments have values of 20-30. This boundary is observed in L1 cores 1,19,25, and 26, and L2-28, 7?, and AII-7.

2. In SESCA, the upper portion of the Holocene sediments contain a series of four well- defined turbidite events that can be correlated among the valley cores, especially L1 cores 8, 25, 26, 1, AII-7 and maybe L2-28. Only one valley core (L1-7) does not record these events, but this core may contain only Pleistocene material, suggesting non-deposition or erosion (The core may have been recovered from one of the many erosional channels observed from the submersible). The turbidites appear to be proximal and from the nearby central SESCA hill, since the highest values are from cores 25 and 26 from the side of the hill and the lowest values are from core 1 in the basin to the east. Core 19 from the western flank of the hill does not show these events, thus mass wasting must have occurred only on the eastern side. These episodes are also not seen in core L2-7 from the south of SESCA, thus the turbidites could not have come from the south.

3. It is interesting that the turbidites found here appear to be similar in timing and gross structure to those found at NESCA in our 1985 study. Further work is necessary to determine whether these similarities are a coincidence or or due to coseismic disturbances associated with simultaneous uplift and/or volcanism at both sites. One important difference between the NESCA and SESCA events is that the NESCA cores contain a significant amount of volcanic glass and sulfides. Initial petrographic scans of the silt layers in the SESCA cores suggest erosion and reworking of relict terrigenous material, such as might occur as a result of slumping and mass wasting of the uplifted sediment capped hills. Unlike NESCA, fresh volcanic glass and sulfides such as pyrrhotite were not observed in the turbidite intervals of the SESCA cores.

4. Cores L2-2 and L2-4 from the tops of two hills in SESCA appear to be relict Pleistocene, based on their high susceptibility values. These features are consistent with submersible observations by Rob Zierenberg, who found the tops of the hills to be barren and eroded in appearance.

5. Core L1-27 is highly altered and contains massive sulfide veins, particularly pyrrhotite. The mineralization appears to have occurred near a turbidite band that may have acted as a conduit for the hot sulfide rich water. The X profile shows a near-surface high associated with metaliferrous red clays and a high in the turbidite/sulfide zone. Given the extensive mineralization and pyrrhotite formation, the X peak is not as strong as might be expected. Given the short length of this core, it is not possible to estimate its age.

6. Core L2-9 from a basin in the western part of SESCA is highly altered and extensively chloritized. The susceptibility is relatively low in the chlorite zone; however, more work needs to be done on this core to see if we can put bounds on the ages.

7. The NESCA core L1-33 is highly indurated. However, the color of the sediments and the X profile suggests that it is Holocene, although it could be an older interglacial interval. Given the similarities in lithology to other Holocene-age sediments, the reasons for the induration are unclear.

CONCLUSIONS

As seems to be the case in many of the research efforts on Gorda Ridge, Mother Nature guards its secrets jealously, and man's best intentions are subject to the vagaries of the winds and seas. The results of the 1988 diving program were disappointing to all involved; yet there was little that could be done given the circumstances. The scientific personnel and, in particular, the Navy diving team performed enthusiastically and selflessly in contributing their best efforts to the success of the cruise. The available diving results suggest that hydrothermal deposition at NESCA may be confined to narrow bands along the perimeter of the sediment-capped hills. However, a core (L2-9) from a basin to the east of the volcanic/sedimentary edifice shows considerable alteration and remineralization. Another isolated core from a relatively unstudied area between NESCA and SESCA also contains extensive sulfides and low temperature metasomatism of the sediments. Thus, we still have much to learn of the local and regional distribution of the hydrothermal deposits and the possible relations between hydrothermal activity and metamorphism of the hosting sediments.

The results of the sediment studies on the existing core collection, although preliminary, show considerable promise in being able to establish a history of hydrothermal activity, volcanism, and tectonism in the areas where massive sulfides deposits have been found. There is a strong need for additional coring to better define the regional extent of the sulfide occurances. Piston cores are also needed to establish a longer term historical record.

REFERENCES

Karlin, R. and M. Lyle, Sediment Studies on the Gorda Ridge, Open file report O-86-19, Oregon Department of geology and Mineral Industries, 76 pp., 1986.

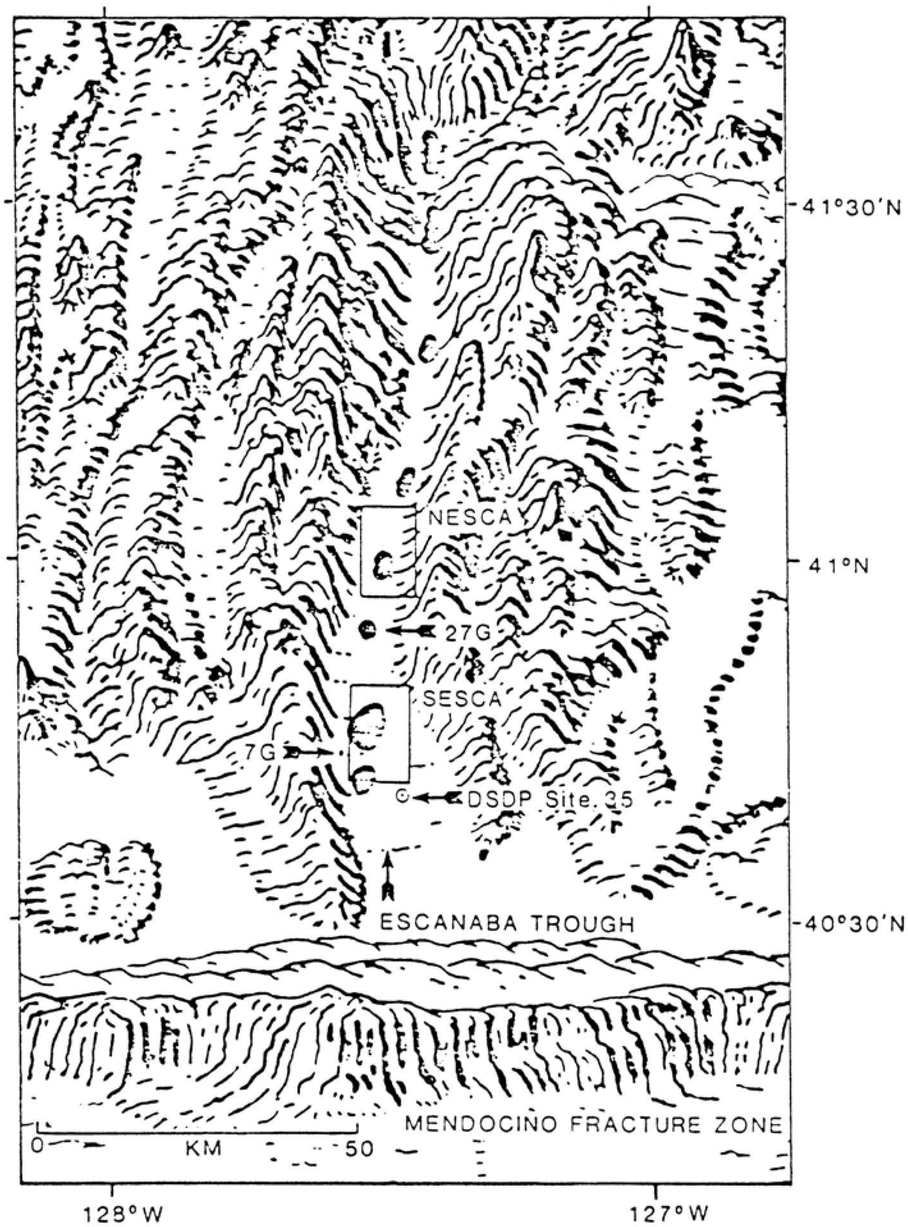

41°30'N
NESCA
41°N
27G
SESCA
7G
DSDP Site 35
ESCANABA TROUGH
40°30'N
MENDOCINO FRACTURE ZONE
0
KM
50
128°W
127°W

FIGURE 1

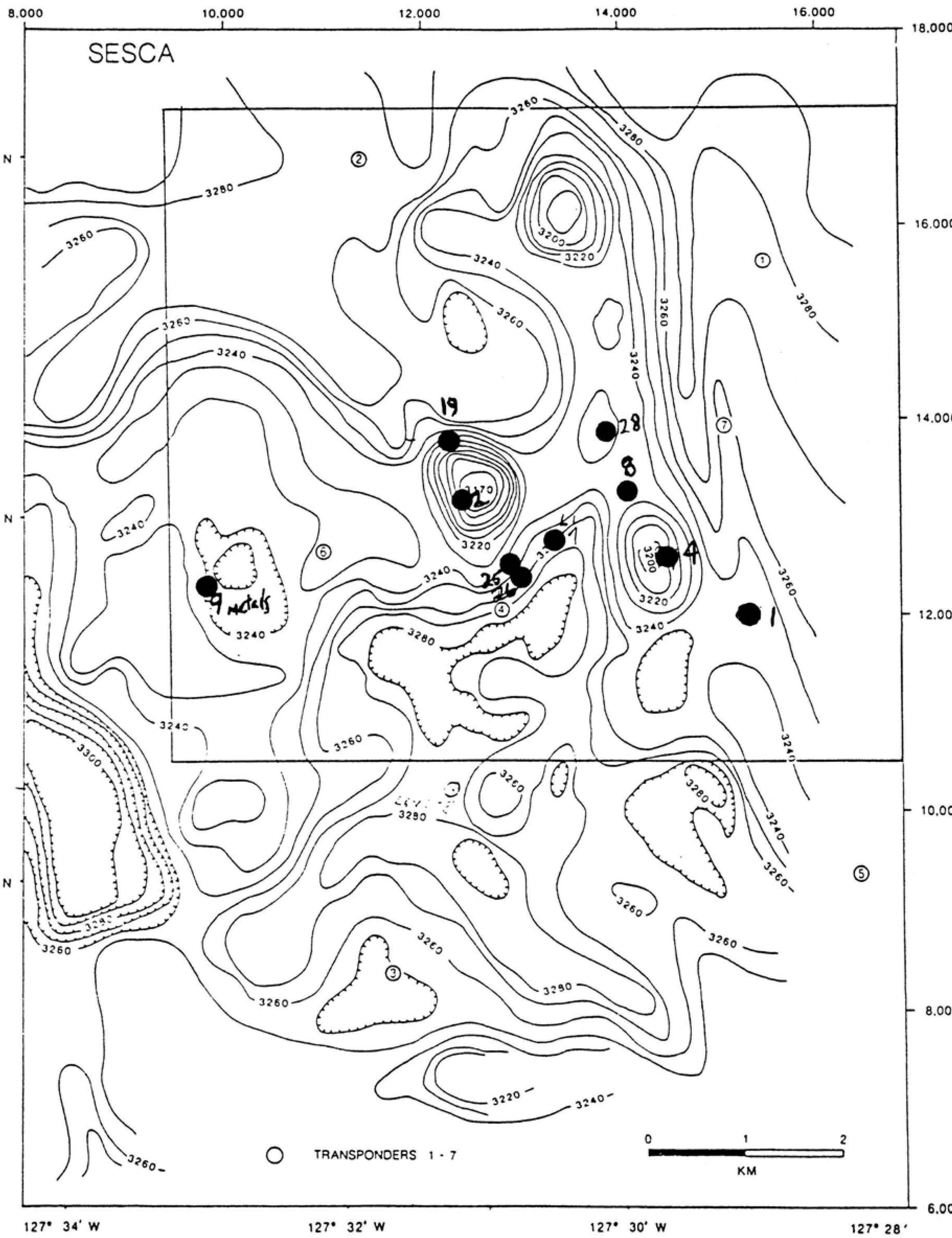

SESCA
8,000
10,000
12,000
14,000
16,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
40° 48' N
40° 46' N
40° 44' N
127° 34' W
127° 32' W
127° 30' W
127° 28'
TRANSPONDERS 1 - 7
KM
19
28
8
4
1
25
26
9 metals

FIGURE 2

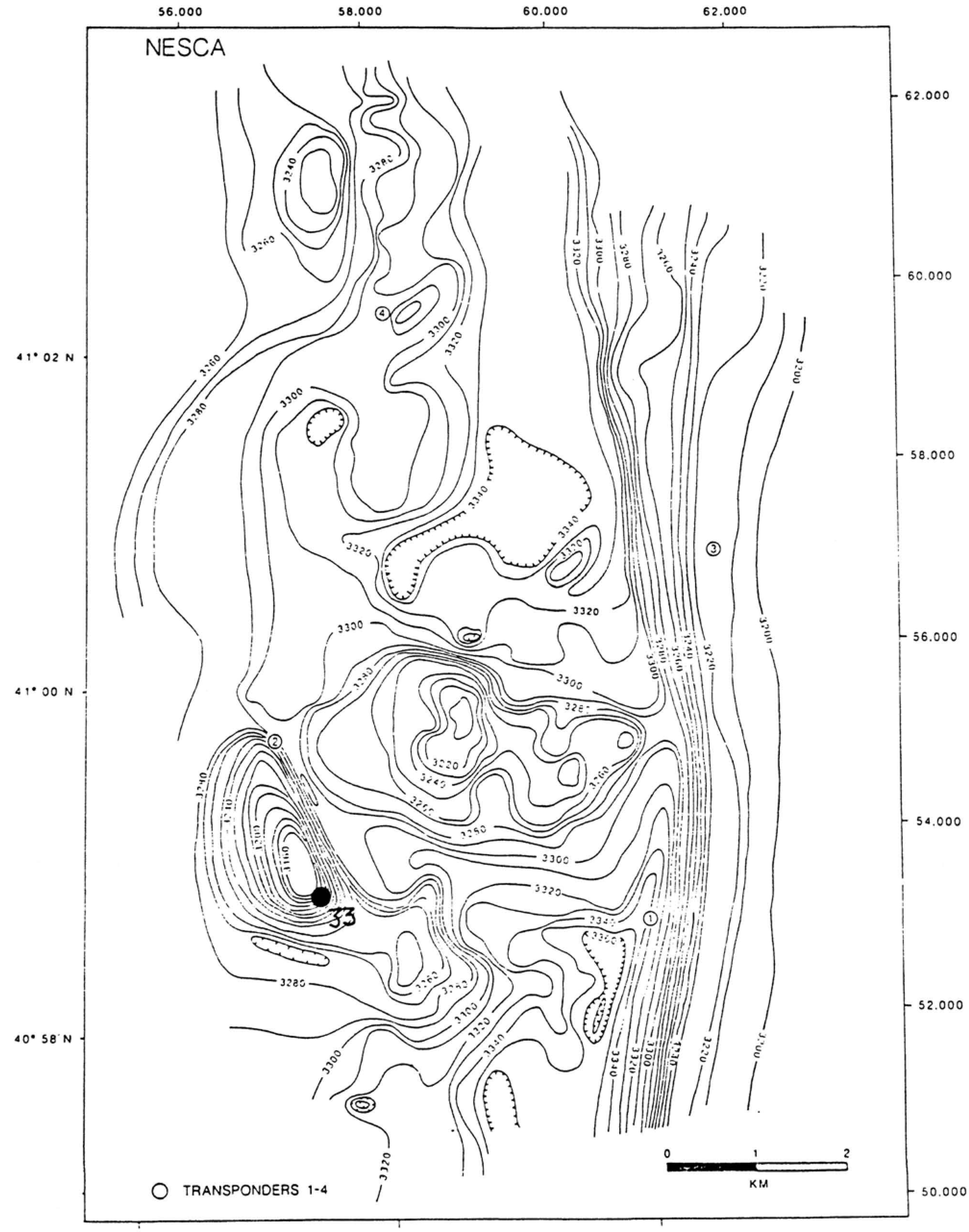
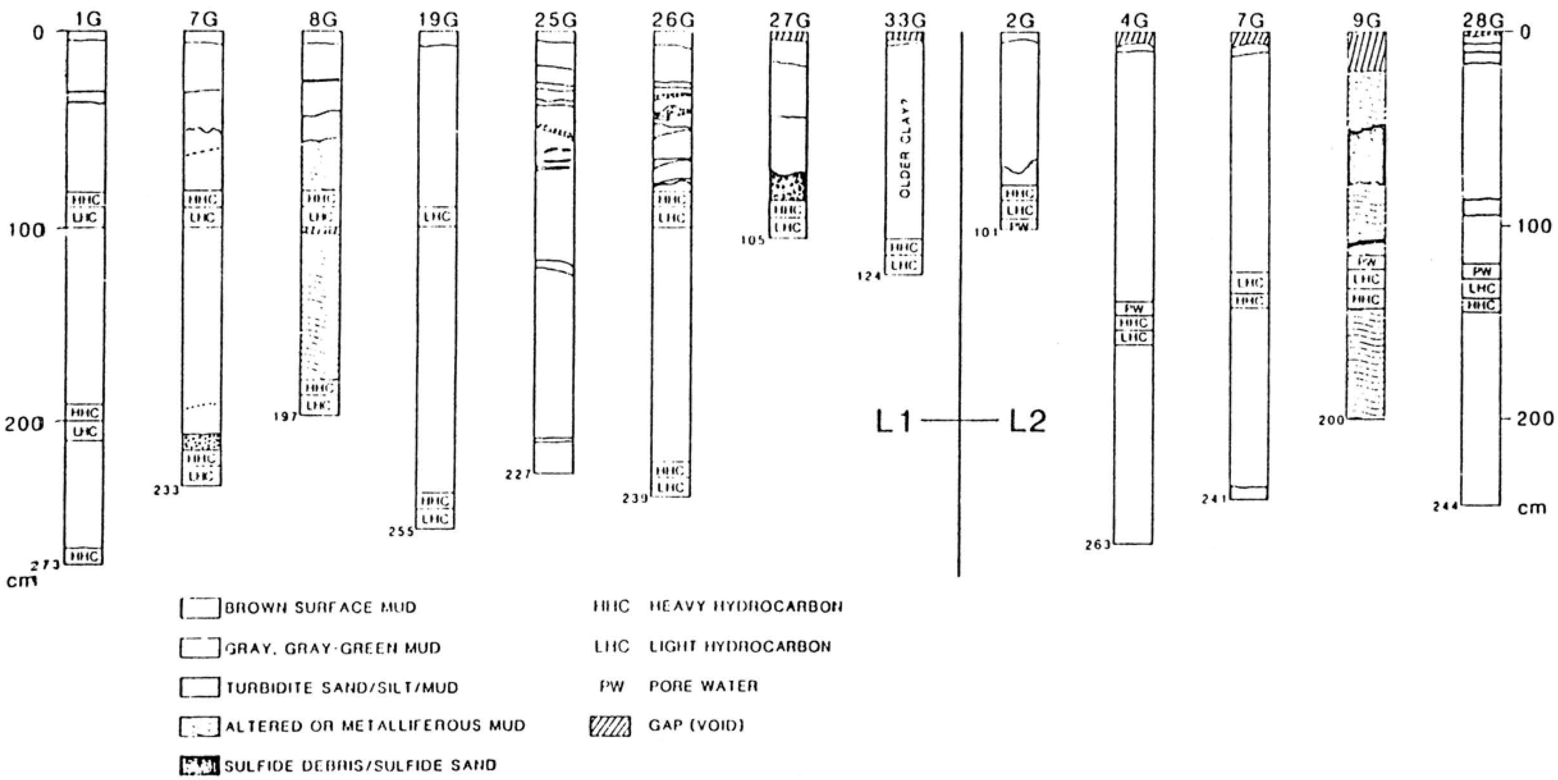

NESCA
56.000
58.000
60.000
62.000
62.000
60.000
58.000
56.000
54.000
52.000
50.000
41° 02 N
41° 00 N
40° 58 N
127° 28 W
TRANSPONDERS 1-4
KM
0
1
2

FIGURE 3



L1-86-NC AND L2-86-NC GRAVITY CORES

FIGURE 4

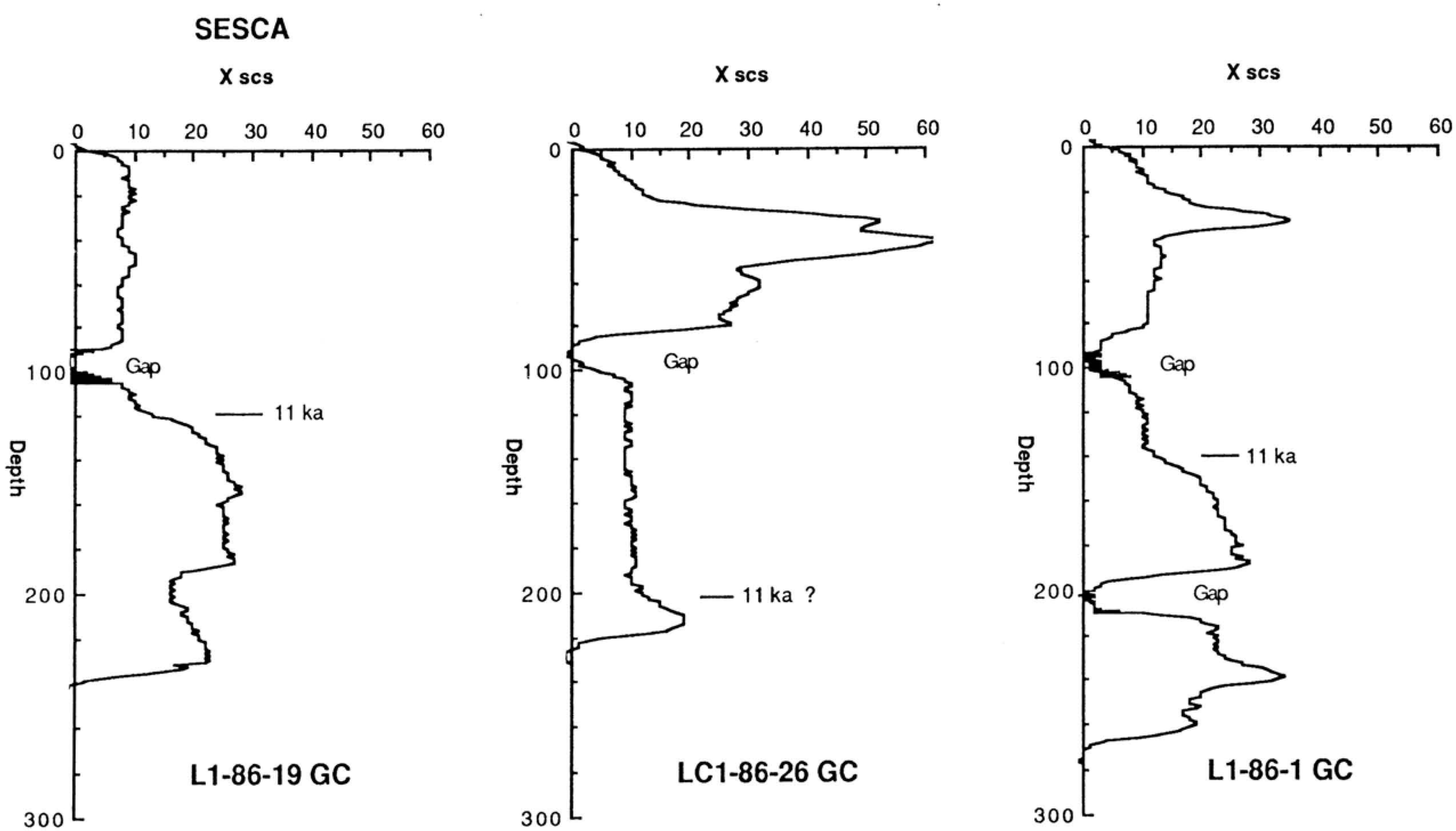

SESCA
X scs
0 10 20 30 40 50 60
Depth
0
100
200
300
Gap
11 ka
L1-86-19 GC
X scs
0 10 20 30 40 50 60
Depth
0
100
200
300
Gap
11 ka ?
LC1-86-26 GC
X scs
0 10 20 30 40 50 60
Depth
0
100
200
300
Gap
11 ka
Gap
L1-86-1 GC

Figure 5

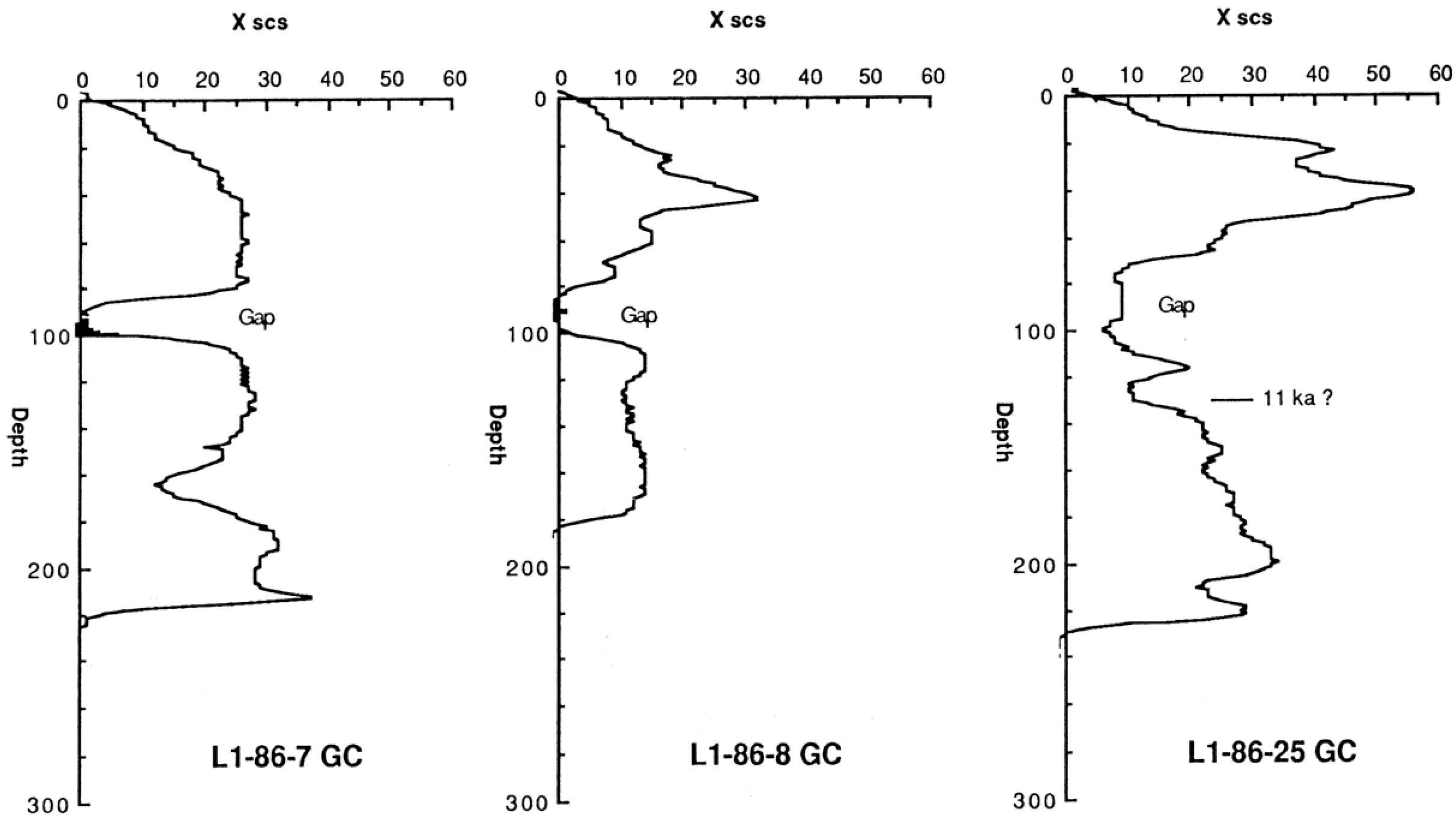

X scs
0 10 20 30 40 50 60
0
100
200
300
Depth
Gap
L1-86-7 GC
X scs
0 10 20 30 40 50 60
0
100
200
300
Depth
Gap
L1-86-8 GC
X scs
0 10 20 30 40 50 60
0
100
200
300
Depth
Gap
11 ka ?
L1-86-25 GC

Figure 6

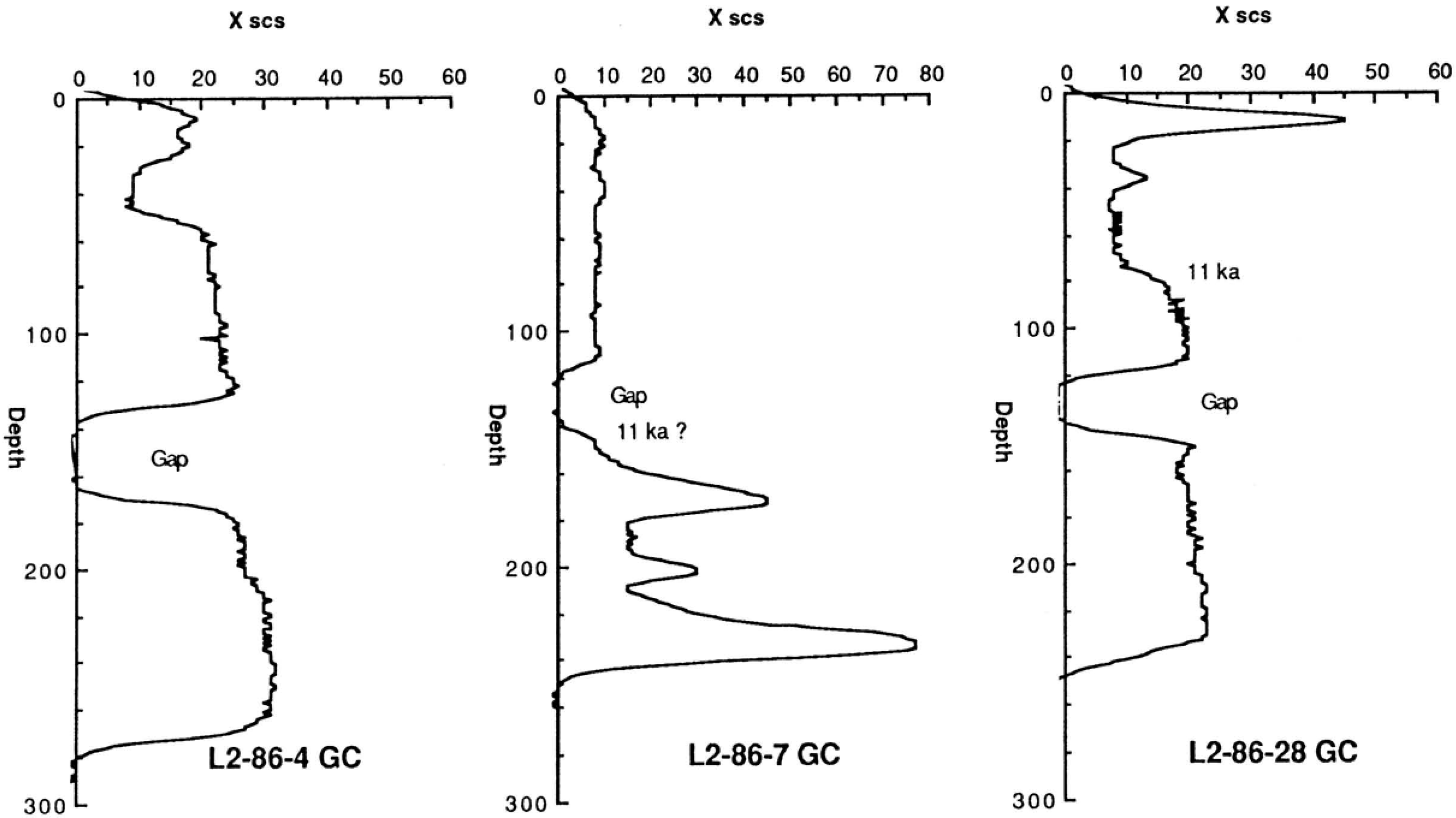

X sccs
0 10 20 30 40 50 60
0
100
200
300
Depth
Gap
L2-86-4 GC
X scs
0 10 20 30 40 50 60 70 80
0
100
200
300
Depth
Gap
11 ka ?
L2-86-7 GC
X scs
0 10 20 30 40 50 60
0
100
200
300
Depth
11 ka
Gap
L2-86-28 GC

Figure 7

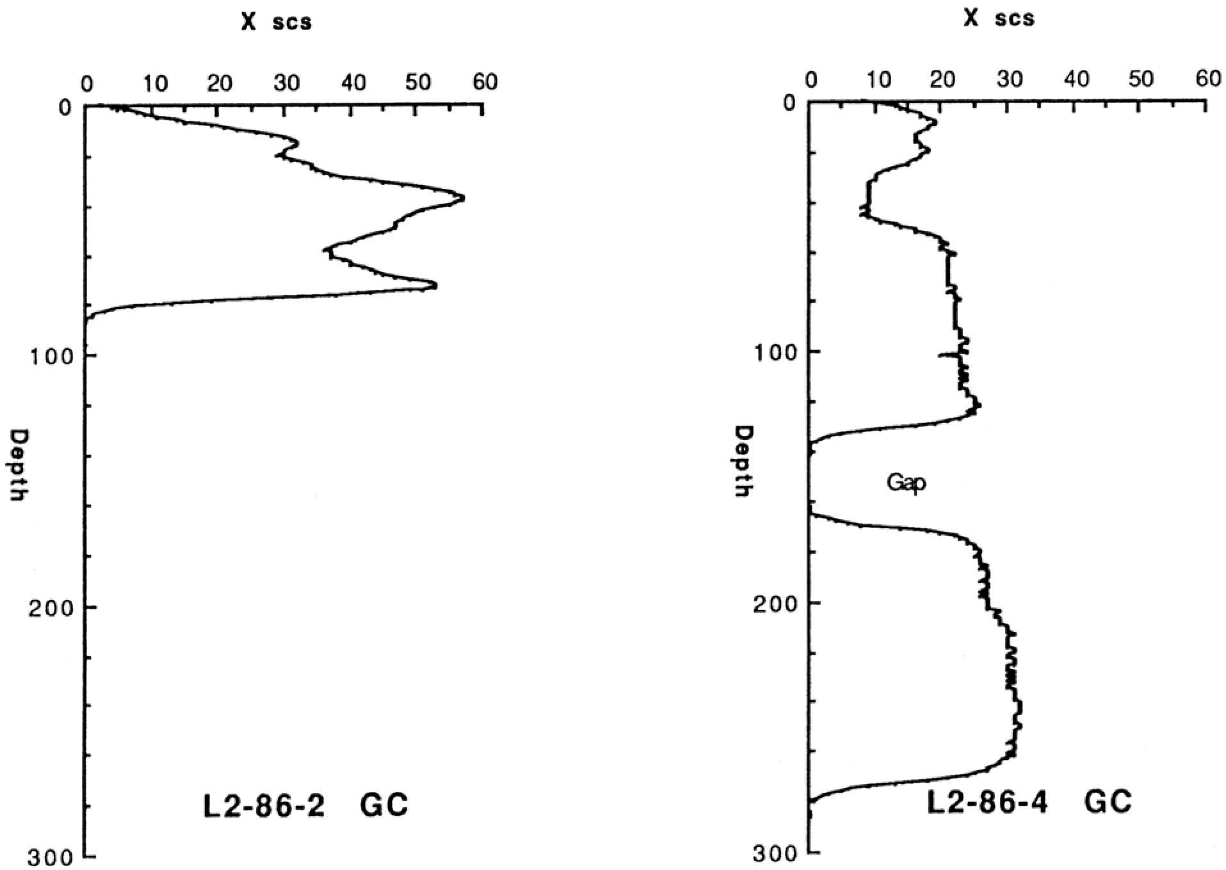

X scs
0 10 20 30 40 50 60
0
100
200
300
Depth
L2-86-2 GC
X scs
0 10 20 30 40 50 60
0
100
200
300
Depth
Gap
L2-86-4 GC

Figure 8

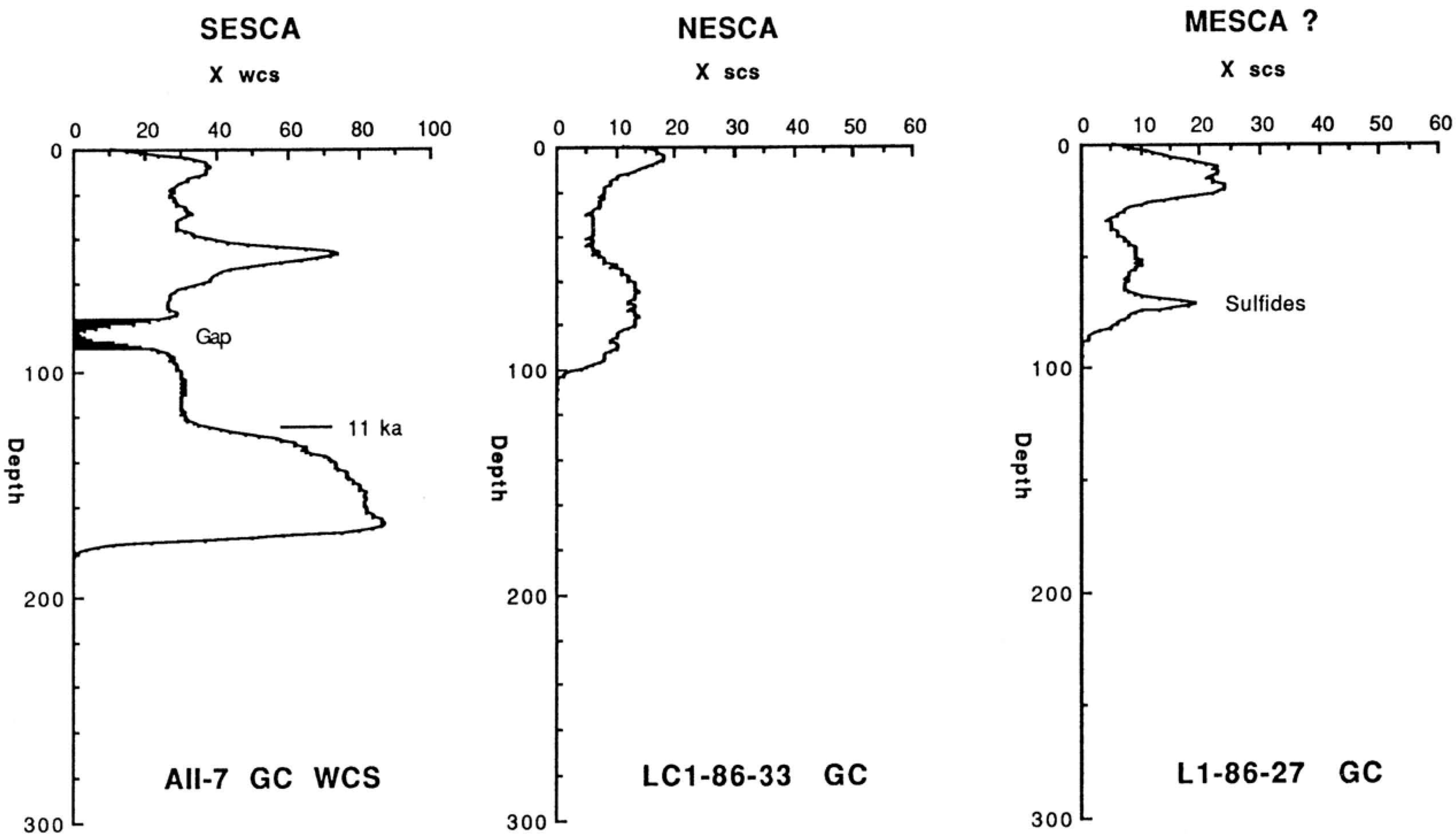

SESCA
X wcs
0 20 40 60 80 100
0
100
200
300
Depth
Gap
11 ka
AII-7 GC WCS
NESCA
X scs
0 10 20 30 40 50 60
0
100
200
300
Depth
LC1-86-33 GC
MESCA ?
X scs
0 10 20 30 40 50 60
0
100
200
300
Depth
Sulfides
L1-86-27 GC

Figure 9

SEA CLIFF TRANSCRIPTION LOG
ROBERT KARLIN

DIVE: 766
GORDA RIDGE LOCATION: NESCA
PORT OBSERVER: R. ZIERENBERG
STBD OBSERVER: R. KARLIN

PAGE: 1 of
JULIAN DAY: 250
DATE: 6 SEPTEMBER 1988
PILOT: R. POPOVICH

Time (GMT)	Depth (m)	Hdg	Photo	Obs	Comments
2033	3251	–		S	Bottom in view; landing on crest of sediment hill
2036	3247	200		S	Underway to launch point LIMA using side pods to allow surface tracking; range 400 m; bearing 200...
2037	3251	200		S	Lost bottom while transiting to LIMA
2038		200		S	Commence using stern shrouds
2040		200		S	Sighted bottom
2041		200		S	Lost bottom; fathometer shows that we are suddenly~10 m over the deck (possibly a graben?)
2045		200		S	Mudstone talus covered by a thin veneer of loose tan sediment; steep slope on stbd side sloping stbd to port.
2046	3257	189		S	Clam shell on port side; bottom is hummocky - relief 3-5 m
2047				S	Turned on Benthos camera with 16 sec sweep
2048	3249			S	On crest of hill; mudstone dusted with sediment; numerous mounds ~10-20 cm high by 20-40 cm diameter; little obvious colonization on rocks; numerous holothurians, crinoids, and brittle stars.
2050	3246	200		S	Hilly bottom - wavelength ~20-30 m, height 5-10 m
2055	3245	200		S	Steep slope; lost bottom, seems to be strong current; sub pushed off course to 255...; pilot turned back to 200...
2058	3239	200		S	Regained bottom; hummocky topography; hills 3-5 m high; relatively little biota; clam shell seen on port side; Galatheids & orange shrimp also noted.
2101	3239	200		S	Rattail swimming over bivalve shell; bottom is hilly and sediment covered
2102	3241	200		S	Several clam shells & crabs
2104	3233	200		S	Large sulfide deposit observed; composed of ledges, chimneys, and mounds; no active venting seen; Outer rim of mounds appears to be barite; shingled sulfides at base of chimneys; possible bacterial mats; clam shells common;

2106			S	VCR tape #1 done; replaced with tape 2
2107	3239		S	Drifted off mound and temporarily lost bottom; sub backed off site by a few meters and descended to sediment covered bottom. For next 5 minutes, we took ground/leak checks.
2115	3239		S	Lifted off bottom & started search for sulfide deposit
2117			S	Dusted bottom; from 2117 to 2121, pumped into SWVB and waited for dust to settle
2121			S	Sub has been turned by currents (Heading 111...).Sub returning to course 200... CCW.
2122			S	Bottom dusted; still returning to course
2125			S	Off bottom, still turning; top of dust cloud visible
2130			S	Lost at sea; manuvering in water column; CTFM put in operational mode
2132	3225		S	On course 210...; about 13 m off bottom.; still trying to find the sulfide deposit
2134	3225	210	S	About 10 m off bottom driving forward - rattail visible
2138	3233		S	On sediment covered bottom; Galatheids; holothurians; dead clams seen
2140			S	On relatively flat bottom with small mounds- video put sideways for special effects
2141	3234		S	End of Tape #2; Tape #3 starts at 2150
2150			S	On top of sediment hill - dusted out; examining sonar for wall; sonar not operating well
2155			S	Sonar target noted to stbd; ship turning right
2158	3235	290	S	We may be in a graben (?) Bottom sighted - flat sediments with small mounds; Biology includes brasingids, holothurians, and crabs
2159	3233		S	Changing course to 010...
2200		010	S	From the sonar, we still appear to be in a graben trending 040-050... True. Changing course 30... to stbd to manuver to graben wall.
2203	3327		S	Problem with CO2; checked sensor (reads ...); Shifted to Batt B - still not working right
2204	3231	265	S	CTFM shows wall to stbd side; bottom in sight- sediment covered
2206	3235	261	S	On bottom, checking CO2 sensor
2210			S	Manuvering, nothing visible
2214	3231		S	Bottom sighted- flat sediment covered with small mounds
2218		025	S	Still manuvering - using CTFM to locate wall
2220			S	Drove off scarp & lost bottom
2222		080	S	Manuvering - pilot getting very aggravated
2223			S	Control gave bearing (056...), range (335 m) to point LIMA

2224			S	End of Tape #3; Replaced with Tape #4
2225			S	Took Drager CO2 sample which showed 1.2% CO2
2231	3228	025	S	Change course to 025... traveling along sedimented bottom to point LIMA
2232	2332		S	Control recommended limiting bottom time to 2 hr; sediment covered bottom with rolling hills
2234	3230	020	S	Control says to terminate by 0030; not much life on bottom except brittle stars and holothurians
2236		060	S	Changed course
2239	3256		S	Lost bottom
2240	3246	050	S	Recovered bottom - on steep slope that dips to stbd
2244	3238		S	Irregular terrain - we keep losing and regaining bottom
2247		079	S	Bottom sloping stbd to port
2248		090	S	Control gives point LIMA at 70 m range, 160... bearing true.
2249			S	CO2 meter bad - all have headaches; swapping LiOH cannisters
2257			S	Decided special effects on stbd camera no longer needed - placed in upright position
2300			S	Finished cannister change
2303	3242	165	S	Leaving bottom to drive to LIMA
2304			S	End of Tape #4. Replaced with Tape #5 starting at 2310
2312			S	Landed near edge of small su lfide field composed of mounds and small chimneys < 1m high. Started sampling
2314	3242		S	Taking core sample using middle push core from port side basket. (Corer has rubber core catcher) Group of dead clams and live galatheiids to port; Control gives bearing/range to LIMA as 010..., 70 m. Depth gauge acting funky with manipulators on.
2322			S	Core shaken up when put into basket. Commenced trying to get a sample of one of the sulfide chimneys. Control wants us to finish up ASAP as weather is worsening topside.
2330			S	Heroic efforts by pilot result in obtaining whole sulfide chimney
2340			S	Immediately after securing samples with manipulator, dropped ascent weights and terminated dive.
2341			S	End of video tape #5