ANALYSIS OF ECHO SOUNDING DATA NORTH-CENTRAL PACIFIC
(AND WEST NORTH ATLANTIC)

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Abstract

The activities during the life of this project fall into four categories. I) Initial site specific data assessment: Here we examined all available geophysical/geological data in and around the MPG-1 area ($\sim 29^{\circ}$ - 31° N; $\sim 156^{\circ}$ - 160° W). We described the topographic relief and mapped the disposition of the thin (< 100 m) sediment blanket and the acoustic character. II) Conducted a 15-day cruise in the MPG-1 area aboard the R/V VEMA and included detailed seismic measurements and heatflow/coring experiments to discern the variability of these parameters. We also developed near bottom seismic experiments to determine, with high resolution, the lateral continuity of reflectors, and a profile of V_p versus depth for sediments. III) Preliminary search for additional potential disposal sites: Recognizing the need to consider other areas beyond MPG-1 and MPG-2, we initiated a preliminary search of existing and easily accessible data. Very few areas were found that could satisfy the basic selection criteria, although many areas were rejected because of "no data." IV) Expanded comprehensive data search and disposal criteria definition: We have identified existing geophysical track lines in the North Pacific and North Atlantic Basins. We have focused on identifying areas of suitable sediment characteristics (> 50 m thick, uniform, low permeability) that fall within the general venue of MPG concepts. This portion of the task is not yet completed and is being pursued to its conclusion through a related contract with Sandia Laboratories.

Introduction

This work has progressed through several phases, some closely related, others independent. The following account of our results generally traces chronologically our research pursuits (four general task areas) through the duration of this contract.

- I. A. Nature and extent of small scale topography, sediment thickness and subbottom reflectors.

The primary area of interest, located between 29°N to 31°N and 156°W to 160°W, is north of Hawaii and east of the Musician Seamount Chain, Figure 1a. The southern section of the survey area is dominated by the troughs and escarpments of the Murray Fracture Zone. Relief there is rugged, basement outcrops are frequent, and the sediment thickness and character are variable.

The remaining two-thirds of the study area north of the Murray Fracture Zone has considerably lower relief, outcrops are infrequent, and sediment thickness and character are more uniform, Figure 1b.

The sediment is very thin throughout the area especially in view of the presumed age of the underlying oceanic basement (< 80 m.y.). Analyzing paleomagnetic data from piston cores, Opdyke and Foster (1970) have established a sedimentation rate of less than 3 mm/1000 yrs for much of the Central Pacific Basin during the past 5 m.y. At that rate, sediment accumulation for 80 m.y. would be less than 240 m. Since the thickness is actually less than 80 m in the study area, the average rate of accumulation is considerably less than 3mm/1000 yrs, perhaps as low as 0.5-1 mm/1000 yrs and suggests the strong possibility of major sedimentary hiatuses here. The occurrence of manganese stains, microneodules, or nodules in all the cores from this area supports the inference of a very slow sedimentation rate.

The sediment type in the area is predominantly yellowish-brown clay with varying amounts of manganese and pelagic components, e. g., fish teeth, palagonite, sponge spicules, quartz, etc. The coarse fraction constitutes only a small percentage of the cores with yellowish-brown clays making up the rest. The clays cored in the area probably are the major components of the upper part of the sediment column. The upper part, a transparent layer 0-40 m thick, overlies an opaque layer of at least comparable thickness. The precise boundary of the sediment/basement contact is obscured by the presence of a very strong reflector, the lower opaque layer, which may represent a zone of alternating chert and zeolite rich clay (Winterer, Ewing et al., 1973).

The combination of thin sediment cover and deep water (5500-6000 m in the northern part, 5500-6700 m in the south) means that standard sonobuoy studies do not yield detailed information about sediment thickness or velocities (as discussed later).

From examination of 3.5 kHz echograms from all the available crossings (there was no 3.5 kHz data obtained during the Taft cruise), a regional sub-bottom reflector can be traced in the area and also several degrees north. This reflector varies in depth from 0-20 m, closely parallels topography, and is shown in Figure 2, profile a. Also seen in Figure 2 is a weak second reflector and regular hyperbolae tangent to the deepest subsurface reflector.

Figure 2, profile c, shows an outcrop and the manner in which it affects the echo character in the abyssal hill region. The major internal reflector disappears or appears only irregularly; resolution on the 3.5 kHz echograms become poorer, and the reflection hyperbolae become large and irregular. The effect of the outcrop is localized, and it can be seen sediment laps up to the outcrop.

Figure 2, profile b, is taken from a transition zone travelling north from the fracture zone province into the abyssal hill region. The features described in the preceding paragraph are evident here; that is, resolution is good in the flat areas but is progressively poorer in hills of even modest size, < 160 m. Figure 2, profile d, is from the fracture zone province. The sediment here is more opaque (at 3.5 kHz), hyperbolae are more irregular than those of the abyssal hill region, and the internal reflector is absent. Seismic reflection profiler records show that sediment thickness in the fracture zone is variable and, where ponding occurs, thicknesses exceed 160 m (see Fig. 3, profiles a and b near right side).

The deepest reflector observed on the profiler records appears as a gray/black region below the transparent layer. This gray region is probably about the same thickness as the transparent layer.

I. B. A 3.5 kHz pinger probe has been designed and built by ORE (Ocean Research Equipment, Inc.).

The prototype instrument was recently tested on board R/V VEMA en route from Bermuda to New York. The value of general pinger probe studies has been summarized in a report by Ewing et al. (1973) using a 12 kHz energy source. A much greater penetration is anticipated with the low frequency (3.5 kHz) energy source. The tests were conducted in an area of abyssal depths between Bermuda and New York. Sub-bottom penetration of ~ 50 meters and several coherent sub-bottom reflectors were recorded with the bottom pinger while no coherent sub-bottom reflections could be recognized using a hull-mounted 3.5 kHz transducer. A 12 kHz bottom-pinger was also used simultaneously as part of the sediment coring operation, but no sub-bottom penetration was recorded at this frequency. Although

more tests are needed to include a wider variety of bottom and sediment characteristics, our preliminary results indicate the 3.5 kHz pinger probe will be extremely useful in mapping the detailed acoustic properties of the upper 100 m of the seafloor. Two additional instruments have also been fabricated, delivered to Lamont-Doherty and bench checked. One unit was partially defective and was returned to O.R.E. for repair.

II. R/V VEMA Cruise

The R/V VEMA cruise 32-11 departed Honolulu 1 July 1975 and ended in Honolulu on 16 July 1975. Most of the 15-day cruise was spent within an area about 200 km by 200 km, centered near 30°N; 159°W north of the Murray fracture zone (see Fig. 4). Continuous 100 Hz seismic (airgun) profiling (see Fig. 5) and 3.5 kHz echo sounding (see Fig. 6) was conducted throughout the cruise. In addition, 13 expendable sonobuoys were deployed to determine the compression wave velocities of the basement rocks. Ten of these experiments yielded useful results. Near-bottom seismic experiments using a 3.5 kHz bottom pinger and telemetered bottom hydrophone were conducted at five sites in an attempt to precisely delineate the geometry and seismic properties of the uppermost sediment blanket approximately 50 m thick (or less). Examples of these records are shown in Figure 7. This constitutes one of the first attempts to make this type of in situ velocity measurement and the preliminary analysis confirms that V_p for the uppermost sediments is equal to or slightly less than V_p for water (~ 1530 m/s).

Further analysis of these experiments is essential in order to evaluate certain in situ geotechnical properties of the sediments which relate to possible free-fall cannister emplacement techniques. The collective

family of seismic observations will allow us to define the properties of the sediment blanket, their variability and predictability.

Additionally, ten piston cores, each approximately 10 m long, four large diameter gravity cores, heat flow stations, camera/nephelometer stations and other observations are summarized in Figure 4.

Revised bathymetric and sediment isopach maps of the survey area incorporating the VEMA data are now in preparation.

A highly interesting and pertinent special heat transfer experiment was devised in conjunction with Marcus Langseth and successfully implemented at two sites within the survey area. The results of this pilot experiment are extremely important in evaluating the effectiveness of the sediment as a barrier for all potential exchange processes which have a significant temperature dependence.

Normal heat flow observations were conducted and show very consistent results with values ranging from about 1.24 HFU to 1.70 HFU, slightly higher than expected for crust of the age (~ 100 m.y. old).

Brief summary of survey results

1. Approximately 1,200 m. mi. of continuous bathymetric and seismic data were collected in the survey area, largely along E-W oriented lines. Previous data in the area was confined almost entirely to N-S lines.
2. Numerous cores were obtained for sedimentation, chemical, and geotechnical studies.
3. An average of ~ 1.50 HFU was established as the representative heat flux for the area and with little scatter among 10 observations.
4. V velocities were obtained for two main oceanic crustal layers (layer 2 $V_p \approx 5.0$ km/s; layer 3 $V_p \approx 7.0$ km/s). Uncertainties remain

regarding the thickness of high velocity cherts and/or layer 2A ($V_p \approx 4$ km/s) lying between the known low velocity, thin clay veneer and the crystalline basement layer 2. These uncertainties should be resolvable through further analysis of existing data.

5. Surface sediments within the survey area transfer heat conductively for delta temperature at least as great as 50°C .

6. There are indications from sonobuoys of a subtle N-S grain or fabric (possibly the relief of the basement layer) that is not readily apparent from the bathymetric studies even though the area has rather high density of sounding lines.

7. Near surface sediments exhibit low V_p velocities very nearly equal to that of the overlying water layer.

III. A. The continuing analysis of geophysical/geological data (especially bathymetry and 3.5 kHz echograms) for the MPG-1 area.

A final bathymetric map has been completed and is shown in Figure 8. The synthesis of all 3.5 kHz echograms has been completed in cooperation with Charles Hollister at WHOI who also presented a summary of echo/sediment types. We are continuing to analyze acoustic data collected in MPG-1, specifically sonobuoy (combined airgun-explosion sources), to determine the character, depth, and fabric of layer 2 and deeper crustal layers in the MPG-1 area. We are also analyzing data from the near-bottom 3.5 kHz pinger-hydrophone experiments. The purpose of these experiments is to provide high resolution information on the vertical and lateral coherence of reflecting horizons in the upper 100 m of the sediment column (note there is only about 40 m total sediment in the

MPG-1 area) and to determine the in situ velocity profile of these sediments for direct comparison with physical properties measurements on the giant piston cores and conventional piston cores. A schematic representation of the technique is given in Figure 9 along with the results of one experiment. A summary of the acoustic stratigraphy and the results of a second pinger hydrophone experiment are given in Figure 10.

We are continuing to develop the experimental techniques (instrumentation) to facilitate more routine implementation of these types of observations. We anticipate these experiments would be required as the first generation of detailed geophysical/geological studies following reconnaissance surveys of any potential deep-sea floor disposal site area. Very elaborate/expensive studies such as "deep-tow" should only be conducted after suitable results are obtained from experiments like the near bottom pinger-hydrophone.

III. B. Expanding search for potential disposal sites.

a) North Pacific. Recognizing the need to consider several (or all) potentially suitable sites for disposal of high level wastes, we have made a very preliminary search through available data for such sites in the North Pacific. The criteria we used are:

1. Site must be between high-productivity belts ($\sim 20^{\circ}$ to 40°N), and west of Hawaii, outside of 200 mile limit in western Pacific;
2. Minimum of 50 meters of sediment, preferably 100-150 meters;
3. Sediment should be "red clay" with minimum or no biogenic components;
4. Sediment should contain no unconformities;
5. No strong discontinuous internal reflectors;

6. Area of no tele-seismicity;
7. Area topographically subdued;
8. Area of minimal bottom currents;
9. Area of no or low economical potential (Mn nodules, etc.)
10. Area large enough (1° - 2° on a side) to be feasible for disposal.

Some of these criteria may need to be relaxed; others may need to be added.

Seismic data were the basic information used to cull out potential areas, and there are very few areas that meet the criteria as interpreted seismically. These areas are shown in Figure 11. Also shown are some sites that are acceptable in terms of the seismic section, but the sediments probably contain siliceous biogenic debris; these sites are north of about 40° N and beneath the siliceous productivity belt south of the Aleutian Arc. Selected examples of L-DGO seismic profiles records for suitable potential sites are shown in Figure 12. Locations of these and other sites are given in Table 1. Additional tracks and seismic data in these areas have been requested from Scripps Institution of Oceanography for further study.

Figure 13 shows the lithology and some physical properties for a core in one of the potential-site areas. The uniformity of the acoustic signature suggests that the entire region will be characterized by similar sediments.

b) Western North Atlantic. Using the same criteria as those outlined for the Pacific, a reconnaissance search is being made for potential disposal sites in the western North Atlantic.

A substantial part of the North American basin is automatically eliminated from consideration because of the presence of active bottom

currents (shaded on Fig. 14). Furthermore, the Mid-Atlantic ridge flank is an unacceptable area because it is mantled with calcareous sediments and further holds potential for seismic hazard.

One promising area is shown within the box in Figure 14. This crustal segment was generated at the mid-ocean ridge axis during the Late Cretaceous when the carbonate-compensation depth was very shallow; as the crust cooled and subsided with time, it also remained below the deepening CCD. Thus, the sedimentary section consists almost entirely of pelagic clays, and it averages about 100 m in thickness. Biogenic components are possible in the upper Maestrichtian section (carbonate) and are almost certain in the Eocene section (siliceous), as they are everywhere in the North American Basin.

Figure 15 shows some physical properties of a piston core not within the boxed area, but from a seismically comparable section slightly to the west. Note the very uniform physical properties; the seismic section in 3.5 records shows no subbottom reflectors.

Part of the boxed area in Figure 14 was studied for a Ph. D. Thesis (Tom Shipley; University of Texas). The southwestern part of the area contains manganese nodules, but the economic potential has not yet been evaluated.

We wish to emphasize that a much more in-depth study is required for both the North Atlantic and the Pacific areas so as to insure that all geologically/logistically feasible areas have been identified in order to guide us in determining the priorities for additional site specific research.

IV. Data search and disposal criteria definition.

A. Completed a preliminary assessment of the existing marine geological and geophysical data for the purpose of identifying additional

deep-sea areas which appear to warrant further detailed studies as candidate radioactive waste disposal sites. These studies have primarily involved the examination of bathymetric, seismic (12 kHz, 3.5 kHz and 100 Hz), and piston core data in the North Pacific and North Atlantic mid-plate/mid-gyre regions in conjunction with C. Hollister (WHOI) and others.

B. Continued to develop high resolution near-bottom acoustics experiments and data analysis techniques that can address the question of the degree of vertical and lateral coherence of acoustic horizon (generally lithologic boundaries) in the upper 100 m of the sediment column. A close communication is being maintained with WHOI regarding their corehead pinger-probe developments and recent experiments have been conducted in conjunction with the closely-related objectives (technically) of other programs (e.g., selected IPOD site surveys).

REFERENCES

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- Shipley, T. H., 1975, Echo characteristics, reflector horizons and geology of the Western Central North Atlantic; Ph. D. Thesis, Rice University, Houston, Texas.
- Winterer, E. L., Ewing, J. I., et al., 1973, Initial Reports of the Deep Sea Drilling Project, Vol. 17, Washington, D. C. (U. S. Government Printing Office).

Table 1. Sites identified in Figure 11.

Sites	L-DGO profile I.D.	Approximate Coordinates
A, B	V21 #525, #826	29.5°N, 150°E
C	C12 #2780	41.0°N, 167°E
D	C10 #840	32°N, 161.5°E
E	C10 #953	37.5°N, 172°E
F	C10 #960	41.5°N, 175°E
G (questionable)	C11 #1063	39.5°N, 169°E

Figure 1

RC 1303

20 KILOMETERS

10 NAUTICAL MILES

Figure 2

A 02-08 2130

17

04-08 0030

2800 M -

3200 M -

RC 1210

B 19-09 0930

21-09 1030

200 KILOMETERS

100 NAUTICAL MILES

Figure 3

R/V VEMA
Cruise 32-11
Honolulu to Honolulu
July 1 - July 16, 1975

Dr. Dennis E. Hayes,
Chief Scientist

Ship Station	Core	Thermograd (heat flow)	Special heat transfer	Camera	Nephelometer	Near-bottom seismics	Gravity core	Pebble dredge	
S200	CI13	TG 22	SHF	K85	N52	NBS	GC	PD	JULY 4
S201	CI14	TG23A		K86	N53				4
S202			SHF1			NBS 1			5
S203				K87A	N54	NBS 2	GC 1		6
S204				K87	N55		GC 2		7
S205							GC 3		7
S206			SH2A						7
S207	CI15	TG 23				NBS 3			8
S208	CI16	TG 24		K88	N56				8
S209	CI17	TG 25		K89	N57	NBS 4			9
S210	CI18	TG 26		K90	N58			PD1A	10
S211			SHF 2						11
S212	CI19	TG 27		K91	N59	NBS 5		PD1	11
S213	CI20	TG 28							12
S214	CI21	TG 29							12
S215	CI22	TG 30		K92	N60	NBS 6	GC 4	PD 2	13

SB 93-105

LEG TOTALS:
STEAMING TIME 240.2 hrs.
STATION TIME 113.9 hrs.
DISTANCE 2247 mi.

Figure 4

Figure 5

Figure 6

(OBH) OCEAN BOTTOM HYDROPHONE SIGNALS
 FROM: A) BOTTOM 3.5 KHZ PINGER (BP)
 B) SHIP'S 3.5 KHZ TRANSDUCER
 FOR TWO SEPERATE OBH EXPERIMENTS

Figure 7

Figure 8

Composite of several elements of the near-bottom wide-angle seismic reflection experiment using the hydrophone pinger (H-P) instrumentation. The various elements of ray path geometry used in a standard $T^2 - X^2$ analysis of velocity and thickness. The lower left shows a $T^2 - X^2$ plot for one H-P station taken in the central North Pacific. Iterative computations are performed to determine small (but significant) corrections to T (time) and X (horizontal distance).

Figure 9

Top: Line drawings of 100 kHz seismic profiler records near 31°N, 160°W in the North Pacific. Profile A-A' is along an east-west track, while profile B-B' is along a north-south track; a prominent north-south fabric is evident in the relief of layer 2 (shown black). Lower right: Detailed acoustic stratigraphy of the area as inferred from various seismic techniques. Lower left: $T^2 \times X^2$ plots from HP station 5 taken in the vicinity of profiles A-A', B-B'. The average velocity of 1532 m/s was computed for the upper 30m lying above acoustic basement for 3.5 kHz.

Figure 10

WORLD 1:40,000,000

DSDP DRILL SITES

Figure 11

V21-75

Figure 13

Figure 14

Figure 15