SEABED DISPOSAL PROGRAM: GEOCHEMICAL AND SEDIMENTOLOGICAL
STUDIES OF NORTH PACIFIC SEDIMENTS

Progress Report

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Abstract

Continued work on field data and cores from study area MPG-2 (33°20'N, 151°00'W) has shown that sediments are being laid down over the entire region, but that the rate of deposition in depressions is up to 70 percent greater than the rate on ridge tops. The relative fractionation has generally been constant for more than 30 million years, leading to a high degree of confidence in the predictability of the geologic future of the region, and implying that singular events and climatic changes have little effect on patterns of deposition. Continued monitoring of manganese nodule compositions has failed to identify any deposits that can be considered potentially mineable either now or in the future. Bulk samples of the major types of deep-sea clays recovered by 10-12 meter sediment cores have been prepared for experiments on sorption properties of heavy metals and transuranic elements.

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General bathymetry of the North Pacific study area MPG-2. Numbered stars show the locations of the long cores used to establish uniformity of sedimentation in the area. Blue areas are deeper than 2960fm (5570m); yellow areas are shallower than 2900fm (5480m). Dotted rectangles are detailed survey areas described in report C00-2689-1.

Introduction

As part of a multidisciplinary, multi-institutional study to evaluate the bed of the deep sea as a repository for the permanent disposal of high-level radioactive waste, we are determining the barrier properties of the sediments and the long-term physical stability of two areas in the central North Pacific. Factors guiding the selection of test areas and the overall plan of attack for the Seabed Disposal Program are outlined in reports by Bishop and Hollister (1974) and Anderson et al. (1975).

To allow work done under this contract to be viewed in the perspective of the overall program, the Progress Report is broken down to the following sections: Manganese nodule analyses; Field data from MPG-2 area; Nature of sediment cores from MPG-2 area; Chemistry of sediments from core Y74-3-58P; Patterns of sedimentation in MPG-2 area; and Sorption studies of North Pacific sediments.

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1. Manganese nodule analyses. One of the few potential conflicts between the Seabed Disposal Program and other users of the sea floor is in the mining of manganese nodules. We have analyzed representative nodules from both the MPG-1 and MPG-2 areas (Figure 1) and find $(\text{Ni} + \text{Co} + \frac{1}{2}\text{Cu})$ values of 1.0 to 1.5 (analyses are listed in report C00-2689-2), far below the values of about 2.4 found in areas around 10°N 150°W now being considered by mining consortia. In view of the reported patchiness of nodule compositions, we will continue to analyze nodules as they are recovered. Results to date, however, suggest that the MPG areas will never be economically attractive as mining sites.

Figure 1: Location of MPG-2 area relative to Hawaiian Islands and regional bathymetry. Stars in MPG-1 and MPG-2 are near-bottom current-meter locations. Contour interval 200 fm.

2. Field data from MPG-2 area. The bathymetric and station data collected during cruise YALOC-74 (R/V Yaquina, Nov-Dec. 1974) have been summarized in technical report C00-2689-1. The profiler data show several tens of meters of pelagic clay overlying a strong acoustic reflector assumed to be chert. An unknown, but probably thin sediment layer separates the chert from basalt basement.

Detailed isopaching of the 3.5 kHz data has been deferred until additional personnel are available, but preliminary results suggest that the sediment blanket is continuous enough to justify assessment of its barrier properties with respect to long-lived nuclides.

3. Nature of sediment cores from MPG-2 area. Nineteen sites were cored in the MPG-2 area. In four cases, 10-13m piston cores were recovered. These cores have been opened, described and sampled for paleomagnetic, chemical, water content and mineralogic analyses. The upper 8 to 185 cm of the cores is a buff, illite- and quartz-rich clay. This grades to 2 - 4m of dark brown clay with increasing smectite and decreasing illite and quartz. The next 2 - 3m contains up to 9 beds of highly altered basaltic ash, intercalated with smectite-phillipsite clay. This ash zone corresponds to a strong acoustic reflector in the 12kHz and 3.5kHz records.

The remaining 4 - 6m of the cores is a very dark brown clay rich in smectite with variable phillipsite.

The water-content analyses have been made by C. Nickerson at Worcester Polytechnic Institute, and will be reported elsewhere.

The paleomagnetic analyses show that the buff surface sediment has a stable remanence that preserves the magnetic stratigraphy from the Brunhes to the middle Gilbert epoch (3.5-4 million years ago). The older dark-brown sediments are magnet-

Table 1. Bulk chemical analyses of sediment from MPG-2 area.

LAB ID	CORE #	DEPTH cm	Si %	Al %	Mg %	Fe %	Mn %	Cu ppm	Ni ppm	Zn ppm	QUARTZ %
NO 10315	Y74-3-58MG4	7-12	33.26	9.17	2.09	5.22	0.25	178	88	131	10.48
10316		47-25	34.02	9.02	2.06	5.14	0.30	206	114	132	9.18
10304	Y74-3-58P	18-23	25.35	8.82	1.75	5.56	0.86	303	277	155	6.35
10305		118-123	24.18	8.68	2.06	6.12	1.26	370	313	146	4.33
10306		218-223	22.88	7.99	1.97	6.01	1.91	562	906	162	3.15
10307		328-333	22.26	8.20	1.95	6.06	1.95	453	501	167	4.20
10308		428-433	21.06	7.81	1.70	6.46	2.76	362	408	159	1.83
10309		518-523	21.14	8.02	1.52	6.37	2.33	347	358	144	1.00
10310		618-623	24.81	8.04	1.50	6.51	2.54	293	364	157	0.94
10311		718-723	25.43	7.62	1.90	8.54	2.30	411	403	183	1.70
10312		818-823	23.04	6.62	1.90	12.88	2.94	612	436	251	0.73
10313		918-923	21.12	5.90	1.83	13.97	3.11	752	593	301	0.93
10314		1018-1023	20.61	5.35	1.86	13.57	3.22	890	580	344	1.12

Table 2. Percentage of each element removed by buffered oxalic acid solution.

CORE #	DEPTH	Si	Al	Mg	Fe	Mn	Cu	Ni	Zn
Y74-3-58MG4	7-12	0.3	1.9	16.1	5.8	87.0	35.0	65.9	12.2
	47-52	0.1	1.3	12.2	3.7	88.3	30.3	67.7	6.4
Y74-3-58P	18-23	0.3	1.3	17.1	7.7	99.5	47.3	89.9	30.5
	118-123	0.4	2.3	17.9	9.4	95.1	39.5	94.1	26.3
	218-223	1.0	2.6	22.4	13.9	97.4	47.9	51.5	33.0
	328-333	0.5	2.4	23.4	14.9	99.8	53.7	92.2	29.0
	428-433	1.0	7.4	28.5	31.1	98.4	59.3	90.7	36.7
	518-523	1.1	15.0	31.5	30.1	100	48.3	94.0	36.0
	618-623	0.9	12.3	33.6	28.7	100	52.6	95.1	38.2
	718-723	0.6	4.2	27.4	16.6	99.1	34.5	94.8	27.6
	818-823	0.9	4.7	31.2	17.4	96.3	26.2	96.2	34.8
	918-923	0.9	3.8	32.4	14.2	96.9	27.8	95.2	35.7
	1018-1023	1.1	4.4	35.2	18.0	98.7	31.3	99.9	40.7

Figure 2: Profiles of selected elemental abundances down core Y74-3-58P (see Table 1 for data). Si, Al, Fe and Mn in weight percent, Cu, Ni and Zn in ppm.

ically unstable and have a component of chemical remanent magnetization that masks any original stratigraphy. Even in the dark-brown sediments, however, the intensity of the natural remanent magnetization shows consistent vertical variations throughout the area, allowing detailed correlations of the cores (see section 5, following).

4. Chemistry of sediments from core Y74-3-58P. A knowledge of the chemical composition of the sampled sediments is a first indication of the uniformity of sorption properties that can be expected for the clay layer, and provides evidence of the nature and rapidity of changes in depositional conditions in the area. The chemical data, in conjunction with mineralogic analyses, form the basis for selecting samples for sorption studies.

Thirteen sediment samples from core Y74-3-58P (location on p.2) were subjected to bulk chemical analysis and analysis after leaching with pH3 ammonium-oxalate/oxalic acid solution. The results are summarized in Tables 1 and 2. The oxalate leach removes only poorly crystallized ferromanganese hydroxides and associated phases. Thus, Table 2 is a measure of the lability or reactivity of each of the elements as a function of depth in the core.

Profiles of selected elements are shown in Figure 2. Si and Al both increase from older to younger sediments, reflecting an increase in wind-blown continental material as the global climate deteriorated towards its present intermittent ice-age condition. The peak in leachable Al in the zone of ash beds reflects the diagenetic breakdown of the originally basaltic debris.

Mn and Fe again reflect the transition from a depositional regime dominated by authigenic precipitation and influx of oceanic volcanic material (including metalliferous sediment from the East Pacific Rise some 2000km to the west) to a

regime dominated by continental input. Again, the reactivity of the ash beds is reflected in the leachable Fe curve.

Of the trace metals, Zn closely resembles Fe, Ni resembles Mn, and Cu is intermediate in behaviour. The anomaly in Cu and Ni at 200cm results from a higher concentration of manganese micronodules at that level.

4. Patterns of sedimentation in MPG-2 area. One of the problems facing any scheme for the permanent or quasi-permanent disposal of high-level waste in a geologic formation is predicting the stability of the formation for 10^6 - 10^7 years. The sedimentary record in the MPG-2 area, by establishing stability for the past 10^7 years, provides at least some assurance of future stability.

The coherent paleomagnetic data indicate a fairly uniform deposition rate of about 1 meter per 10^6 years for core Y74-3-71K (p.2) for the past 4 million years. For older deposits, no absolute deposition rates can be measured directly, but core-core correlations allow an assessment of relative deposition rates between cores. The correlative horizons used in the following discussion are summarized in Table 3. The color change has already been discussed. The ash beds are distinctive; when the cores are laid out side by side, the correlations are obvious. The correlations of natural remanent magnetization (NRM) maxima are more subject to errors than the ashes or color change. Inasmuch as C. Visser's independent magnetic correlations are completely consistent with the author's ash and color correlations, however, the likelihood of serious errors in Table 3 is small.

In Figure 3, the data from Table 3 for core 58P, 65P and 73P are plotted against the correlative data from core 62. These plots lead to several important conclusions:

Table 3. Correlative horizons in Yaloc-74 Leg 3 piston cores collected in MPG-2 area. NRM = natural remanent magnetization.

	58P	62P	65P	73P
Color change	8	167	180	147
NRM Max I	240	290	400	340
Ash 7	413	410	531	513
Ash 5	470	441	563	573
NRM Max II	550	480	610	600
Ash 3	596	516	657	696
NRM Max III	650	545	680	750
Ash 1	676	563	705	765
NRM Max IV	710	585	740	800
NRM Max V	840	640	840	900
NRM Max VI	940	690	945	1020
NRM Max VII	1030	765	1015	1120

Figure 3: Relative accumulation rates in piston cores from MPG-2 area, based on correlation of lithologic and magnetic properties (NRM = natural remanent magnetization). See page 2 for topographic locations.

a) There is no evidence of interruptions in the sedimentary record at any of the sites. This implies depositional stability for more than 10^7 years (see subsequent discussion).

b) There is marked fractionation of sediment between sites. The slopes of the lines in Figure 3 indicate, for example, that sediment has accumulated about 70 percent faster in core 58P than in 62P.

c) The fractionation between cores is remarkably uniform over the time interval sampled. Only core 73P shows a change in rate about 10 million years ago. This uniformity implies that the mechanism fractionating the sediment has not responded to the dramatic climatic changes of the last few million years. The actual fractionation mechanism, which seems to favor deposition in depressions relative to ridge tops (p.2), is not known. The consistency over such a long interval, however, points to features of the tidal or inertial bottom circulation, rather than to advective features, inasmuch as the intensity of advection has probably changed markedly in the past ten million years (Johnson, 1972).

Although we cannot presently date the sediments below the color change at 3.5-4 million years, a crude estimate of the interval represented in the cores can be made from the chemical data of Table 1. Mn is an authigenic component of North Pacific sediments. If the rate of precipitation has remained constant throughout core 58P, the concentration data can be converted to a time scale. For the surface sediments, the deposition rate is about 1mm/1000yr and the Mn concentration ranges from 0.25% near the sea floor to 0.86% just about the color change. Use of the latter value leads to a conservative estimate of 32 million years for the base of core 58P. This is compatible with accumulation rates of less than 1mm/1000 yr that have been measured in comparable smectite-phillipsite sediments now accumulating

in the South Pacific.

On the basis of the chemical and stratigraphic data, we can conclude that the MPG-2 area has received a continuous rain of sediments for at least the past 30 million years. The composition and rate of influx of the sediments have changed gradually through time, but the pattern of deposition over the area, as revealed by core-core correlations, has persisted essentially unchanged.

These data cannot rule out singular events, such as large earthquakes. However, such singular events, if they occurred, did not interrupt or modify the pattern of sediment accumulation in the MPG-2 area.

5. Sorption studies of North Pacific sediments. On the basis of the lithologic, mineralogic and chemical data of the preceding sections, three bulk sediment samples have been selected for studies of sorption properties relative to heavy metals and ultimately actinides. These studies are designed to assess the chemical barriers separating a buried cannister of high-level waste from the sea floor.

The sediment samples are a quartz-illite clay from just below the sea floor (Q-1), a quartz-illite-smectite clay from just below the color change (T-1), and a very dark brown smectite-phillipsite clay from below the ash zone (T-2). These samples have been homogenized and quantitatively split into 1gm working fractions.

Sets of splits forwarded to V. Bowen are being used for experiments with low concentrations of transuranic elements. In our laboratory, higher concentration U and Th solutions are being used to assess the effects of temperature and concentration on solid-solution partition coefficients and on the reversibility of sorption reactions. These experiments have just begun. Initial results will be presented in a subsequent report.

References

- Anderson, D.R., et al., 1975, Release pathways for deep seabed disposal of radioactive wastes. Sandia Laboratories, Rept. SAND74-5854, 25p.
- Bishop, W.P., and C.D. Hollister, 1974, Seabed disposal - where to look. Nuclear Technol., v. 24, p. 425-443.
- Johnson, D.A., 1972, Ocean-floor erosion in the equatorial Pacific. Geol. Soc. America Bull., v. 83, p. 3121-3144.

Other Project Activities of the P.I.

- January 6-7, 1975, WHOI, Mini-workshop on in situ seabed experiments.
- February 26, 1975, URI, Presentation on Seabed Disposal program at marine geology seminar.
- March 20-22, 1975, Lake Wilderness, Wash., Review and planning workshop.
- April, 1975, Narragansett, R.I., Briefed E. Schneider, Director, EPA National Marine Water Quality Laboratory on Seabed Disposal Program.
- June 2-3, 1975, Alexandria, Virginia, Briefed ONR Code 480 personnel on Seabed Disposal Program and on survey work in MPG-2 area.
- July 22, 1975, Rockville, Md, Participant in briefing for A.E. Daking, ERDA consultant.
- August 3-6, 1975, Corvallis, Or., Described and sampled MPG-2 cores for magnetic and geochemical studies.
- September 30, 1975, URI, Discussions on chemical barrier properties of sediments with V.T. Bowen, WHOI.
- October 7-8, 1975, Albuquerque, N.M., Discussions of waste form-sediment interactions.

October 31-November 1, 1975, WHOI, Mini-workshop on marine geochemistry-geophysics future program.

November 18, 1975, URI, Discussions on in situ instrument requirements with F. Yost, Sandia.

November 21, 1975, URI, Discussion of characteristics of MPG area on east Bermuda Rise with E.P. Laine, WHOI.

December 2-5, 1975, Albuquerque, N.M., Workshop and DBER review.

December 12, 1975, URI, Discussions of program with C. Hollister (WHOI) and A. Silva (WPI).

Papers and Technical Reports

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- Heath, G.R., 1975, Results of R/V Yaquina Cruise YALOC-74, Leg 3: Seabed Disposal Program, North Pacific Study Area MPG-2, 33°20'N, 151°00'W, Nov. 30-Dec. 21, 1974. Univ. Rhode Island Tech. Rept. Ref. 75-4, ERDA Ref. C00-2689-1.
- Heath, G.R., 1975, Seabed Disposal Program: Geochemical and sedimentological studies of North Pacific sediments, ERDA Ref. C00-2689-2.