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AVAILABILITY OF COPPER, NICKEL, COBALT AND MANGANESE FROM OCEAN FERROMANGANESE NODULES (III)

SIO REFERENCE SERIES

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

by

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Availability of Copper, Nickel, Cobalt and Manganese
in Ocean Ferromanganese Nodules

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16. Abstract Manganese nodule elemental chemical data added to the SIO Sediment Data Bank during the grant year are listed. The data include compositions of 388 samples analyzed at SIO and 845 analyses extracted from the literature. Information on analytical methods utilized for all nodule analyses stored in the Sediment Data Bank and their estimated precision and accuracy is presented. Data summaries for potential resource areas in the northeastern equatorial Pacific are updated to include information obtained in the past two years. Data summaries and maps of nodule distribution are presented for resource evaluation of additional areas in the Pacific and Atlantic Oceans.			
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FOREWORD

This report was prepared by J. Z. Frazer and M. B. Fisk, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, California 92093, under USBM grant number GO264024. The grant was initiated under the Minerals Availability System Program. It was administered under the technical direction of the Western Field Operation Center with C. T. Hillman acting as Technical Project Officer. David J. Askin was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this grant during the period September 1, 1979 to August 31, 1980. This report was submitted by the authors on August 31, 1980.

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TABLE OF CONTENTS

I.	INTRODUCTION	7
II.	EVALUATION OF ANALYTICAL METHODS	11
III.	RESOURCE AREA UPDATES.....	55
	Area 1	56
	Area 2	58
	Area 3	59
	Area 4A	63
	Area 5	65
	Area 7A	69
IV.	AREA DATA SUMMARIES FOR RESOURCE EVALUATIONS.....	71
	Area 14: Cape Basin.....	71
	Area 15: Central Pacific Basin.....	74
	Area 16	76
	Area 17	79
	APPENDIX A. Station Locations and Chemical Composition of Samples Analyzed at Scripps Institution of Oceanography, 1979-80.....	81
	APPENDIX B. Station Locations and Chemical Composition Compiled from the Literature, 1979-80	95

LIST OF FIGURES

Fig. 1a.	Pacific Ocean locations of mangane nodule assays added to the Sediment Data Bank, 1979-80.....	8
Fig. 1b.	Indian Ocean locations of manganese nodule assays added to the Sediment Data Bank, 1979-80.....	9
Fig. 2.	Locations of resource areas in the northeastern equatorial Pacific.....	55
Fig. 3.	Distribution of Ni + Cu in nodules from Area 1B	56
Fig. 4.	Frequency distributions of element concentrations for nodules in Area 1	57
Fig. 5.	Frequency distributions of element concentrations for nodules in Area 2	59
Fig. 6.	Distribution of nodule grade in Area 3.....	60
Fig. 7.	Nodule distribution in Area 3A	61
Fig. 8.	Frequency distributions of element concentrations for nodules in Area 3	62
Fig. 9.	Grade distribution of nodules in Are 4A.....	63
Fig. 10.	Frequency distributions of element concentrations for nodules in Area 4A	65
Fig. 11.	Nodule distribution in Area 5	66
Fig. 12.	Distribution of nodule grade in Area 5.....	67
Fig. 13.	Frequency distributions of element concentrations for nodules in Area 5	67
Fig. 14.	Frequency distributions of element concentrations for nodules in Area 7A	69
Fig. 15.	Nodule distribution in Area 14	72
Fig. 16.	Nickel-equivalent grade for nodules in Cape Basin.....	73
Fig. 17.	Nodule distribution in Area 15	74

Fig. 18.	Ni + Cu grade of nodules in Area 15	75
Fig. 19.	Frequency distributions of element concentrations for nodules in Area 15	76
Fig. 20.	Grade distribution for nodules in Area 16.....	77
Fig. 21.	Nickel-equivalent grade for nodules in Area 17	78
Fig. 22.	Frequency distribution of element concentrations for nodules in Area 17	80

LIST OF TABLES

Table 1.	Average nodule composition in Area 1	57
Table 2.	Average nodule composition in Area 2.....	58
Table 3.	Average nodule composition in Area 3.....	62
Table 4.	Average nodule composition in Area 4A.....	64
Table 5.	Average nodule composition in Area 5.....	68
Table 6.	Average nodule composition in Area 7A.....	69
Table 7.	Average nodule composition in Area 14.....	73
Table 8.	Average nodule composition in Area 16.....	77
Table 9.	Average nodule composition in Area 17.....	79

I. INTRODUCTION

Projections of the availability of metal contained in seafloor manganese nodules depend on the amount, accuracy, and distribution of basic data: the measurements of the physical and chemical characteristics of the nodules and their environment. When the manganese nodule chemical file of the Sediment Data Bank was established in 1972, there were about 500 analyses existent in the literature. As interest in the resource potential of the deep ocean has increased, so has the amount of data. We now store almost 6500 chemical analyses of nodules and crusts in a computer system which is flexible, fast and accessible to the public.

The data bank staff collects and codes into its computer files all publicly available data on manganese nodule grade, occurrence and abundance. The data is entered into the files without editing except in extreme cases. Our purpose is to gather together and make accessible *all* currently available data. Although one of our specific aims has been to accumulate a public data base adequate for assessment of manganese nodule resource estimates, the data have been and are being used for many other related investigations into the nature, origin and genesis of the nodules themselves.

In addition to collecting data from the literature and other sources we have for the past four years carried on an analytical program, routinely performing chemical analyses of manganese nodules. From September 1979 through July 1980 we added 1225 new assays for manganese nodules and crusts from 480 different locations. These include 329 locations from which nodules had not previously been analyzed. Fig. 1 shows the geographical distribution of stations where data on nodule composition were added in the past year. As in previous years, most of the analyses were for locations between the Clarion and Clipperton Fracture Zones.

Of the data added this year, 388 samples from 197 locations were assayed in our laboratory for

Ca, Mn, Fe, Co, Ni, Cu, Zn and Pb by x-ray energy spectrometry. The analytical method has been described in a previous report¹. These assays are presented in Appendix A along with the sample locations, all in the eastern and central North Pacific and central South Pacific Oceans. Most of the samples analyzed this year were included in three major groups: (1) samples obtained from searching the SIO core archives, (2) nodules from the 1972 *Seascope* expedition, and (3) nodules collected by MANOP Cruises 7503 and 7905 from an area centered about 11°N, 140°W (see updated study of Area 3 in Section III below).

The remainder of the analytical data added this year came from published papers and unpublished reports. We coded 845 analyses of samples from 302 locations in the Pacific and Indian Oceans, including 220 locations from which no nodules had been analyzed previously. These data are presented in Appendix B.

During the past year we have studied the analytical data stored in the Sediment Data Bank and the sources from which they were obtained. Information about analytical methods, sample preparation, and estimated accuracy and precision were extracted from the literature and are presented in Section II of this report. Using this information, as well as comparisons of analytical results reported by different investigators for either the same samples or samples from the same locations, we have where possible commented on the reliability of the analyses stored in the data bank. We have also indicated analyses from a number of sources which, while they may accurately represent the composition of the particular material analyzed, are not representative of dry bulk nodules. The data user can adjust

¹J. Z. Frazer, M. B. Fisk, J. Elliott, M. White, L. Wilson, Availability of copper, nickel, cobalt and manganese from ocean ferromanganese nodules (Scripps Institution of Oceanography Reference 78-25, unpublished, 1978).

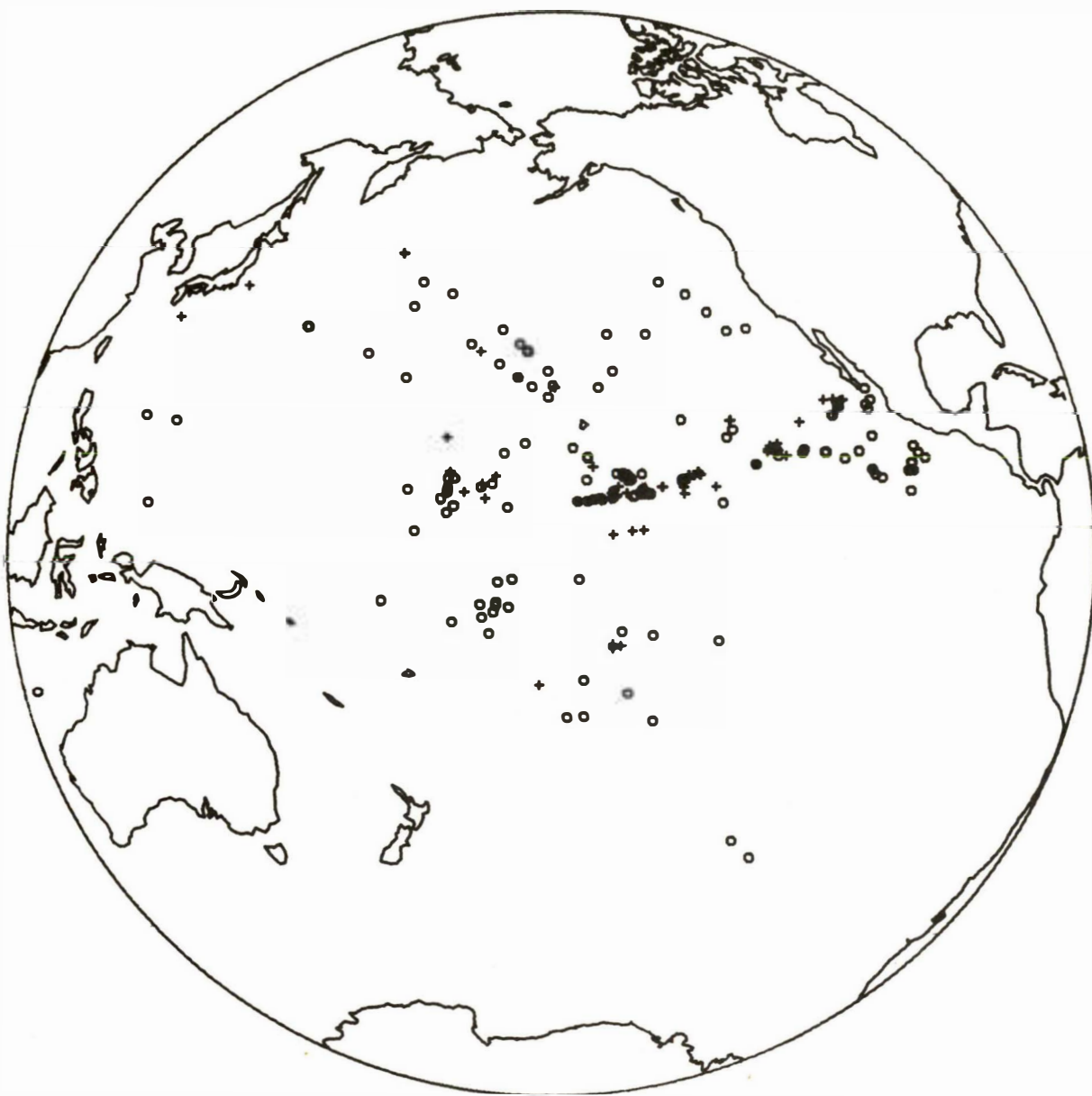


Fig. 1a. Pacific Ocean locations of manganese nodule assays added to the Sediment Data Bank, 1979-1980.

o = samples analyzed at Scripps Institution of Oceanography
+ = data from the published literature and unpublished reports.



Fig. 1b. Indian Ocean locations of manganese nodule assays added to the Sediment Data Bank, 1979-80. All are from the published literature or unpublished reports.

these values upward or downward depending on the cause of the discrepancies (upward to remove effects of included surface moisture or downward to compensate for effects of removing bound water, for example) to obtain at least semi-quantitative analyses that represent bulk dry nodules.

New information on nodule composition and distribution has been used to prepare updated data summaries for resource evaluation in six areas studied previously within the economically promising Clarion-Clipperton Zone. These comprise Section III of this report. Data summaries for several additional areas in the Pacific and one in the South Atlantic are presented in Section IV.

II. EVALUATION OF ANALYTICAL METHODS

The ideal data base for estimating the grade of manganese nodule deposits would be a set of accurate and precise analyses performed in a consistent manner on representative bulk nodule samples. Unfortunately, such a data base does not exist. Many of the mining companies have consistently performed large numbers of nodule analyses, but their samples have generally been obtained from limited regions of exploration. Almost all of these analyses are proprietary and not in the public domain. Many academic scientists have assayed manganese nodules as part of their investigations in marine geochemistry; however, because these analyses were usually not aimed at resource evaluation, the results do not always represent bulk nodule compositions.

Although data collected from many different sources is not consistent, consistency is not the only virtue. The accurate analysis of manganese nodules is a non-trivial problem, and not everyone solves it successfully. When several investigators analyze nodules from the same area, each serves as a check on the accuracy of the others.

The round robin exercise conducted by Werner Raab gives us valuable information about the general level of accuracy of manganese nodule analyses. Splits of a well homogenized nodule powder (GRLD 126) were sent to a number of investigators, mostly at universities, who analyzed them by a variety of methods: atomic absorption, x-ray fluorescence, x-ray energy spectrometry, neutron activation and emission spectrography. Raab² reported results from nine investigators, and we have since obtained results from ten others.

Three of the 19 investigators reported results for one or two elements that differed from the other analyses by 50% or more of the amounts present. This points up the usefulness of having analyses from a variety of sources. When one

set of assays for a particular geographical area differs widely from others for the same area, it is probably wrong and should be disregarded. (An occasional single anomalous assay is more likely to represent a typographical error but should also be disregarded.)

Eight of the round robin investigators reported results for the total sample after drying at 105-110°C. After omission of the anomalous values, standard deviations on Mn, Fe, Co, Ni and Cu are within 4% of the amounts present. This level of accuracy is more than adequate for resource estimates. Of course, it should be kept in mind that the investigators participating in the round robin had considerable previous experience analyzing manganese nodules.

The *precision* of an analysis is a measure of its reproducibility. Imprecision, which is due to such factors as counting statistics or the imprecise weighing or measuring of substances, is random and will have a normal distribution about a mean value. An analyst can produce results with an arbitrary precision by repeating the experiment a number of times. Many investigators perform replicate analyses to estimate the precision of their results.

The *accuracy* of an analysis indicates how close the result is to the "true" concentration of the element in the sample. Inaccuracy is frequently called "systematic error," because such errors are not random for a given analyst using a particular method.

Inaccuracy arises from several causes. It must be kept in mind that many of the instrumental techniques such as x-ray fluorescence or atomic absorption do not measure absolute quantities. The unknown sample is compared to one or a series of calibration standards, and the amount of an element in the sample is determined relative to the amount in the standard. Accurate analyses thus depend upon an accurate knowledge of the composition of the standards.

²Werner Raab, personal communication, April 16, 1974.

We conducted inter-laboratory comparisons to check one of our primary natural nodule standards. It had been supplied by an ocean mining company, who established its composition by means of analyses at six different laboratories. We submitted this standard to three other mining companies and two academic investigators. Standard deviations on these analyses were within 2% of the amount present for Ni and Cu, 4% for Mn and Fe, and 6% for Co, Pb and Zn. This level of accuracy seems adequate for assays used for resource estimates. To resolve the discrepancies, standards with the general acceptability of International Rock Standards W1 and G1 are required.

An important characteristic of many instrumental techniques is that the apparent amount of an element being measured is greatly affected by the amount and nature of the other elements in the sample (so-called "matrix effect"). For example, in one experiment we split a homogeneous nodule powder into two parts and mixed one with CaCO_3 in the ratio 4:1. The high-Ca sample thus contained 20% less of the other elements. However, raw data from x-ray fluorescence analysis showed Mn reduced by 29% and Cu reduced by only 14%.

Either the samples must be very close in composition to the standards, or they must be diluted to minimize matrix effects, or corrections must be applied to compensate for the effects. While corrections are usually based on physical theories, they are in practice quite empirical. The development of reliable empirical correction procedures usually requires considerable experimentation with a variety of samples covering the concentration ranges expected in the unknowns. Thus investigators who have made nodule analysis a major effort are likely to produce more accurate results than those who analyze a few incidental nodules.

Nodules fresh from the ocean contain a large amount of water, and some of the water evaporates gradually as the nodules are exposed to air. To give a standard basis for comparison of nodule compositions, analytical results are usually reported for samples oven-dried at 100-110°C until no further water evaporates. This removes water amounting to about 33% of the

original sample weight³. Since nodules easily reabsorb 10-15% of their weight of water from the atmosphere, especially after being powdered, samples dried before grinding must be redried and stored in a desiccator until analysis. If nodules are analyzed without drying, the element concentrations reported may be low as compared to nodules treated by the standard procedure. If they are dried at higher temperatures (800-1000°C), the bound water and other volatiles will be removed; this produces results that are high by about 10-20%. Nonstandard drying procedures lead to inconsistencies in the data base, but they are not inaccuracies per se.

When water content or loss on ignition is reported, one can often convert analyses to an air-dried basis; however, care must be used. In a method such as x-ray fluorescence, if both samples and standards are treated in the same manner, either igniting or lack of drying will have very little effect on the results. In such a case adding or subtracting the amount of water reported will induce large errors. Six of the round robin participants analyzed the total sample as received without drying. Standard deviations within this set of analyses were about the same as in the set discussed previously. Although the sample contained about 10% moisture, the average Mn, Ni and Cu values reported for this set of analyses were only 2-3% lower than those for the samples dried at 105-110°C, and differences among the different analytical techniques were minor.

For some techniques, such as atomic absorption and emission spectrography, samples are dissolved or digested. Sometimes they are treated with chemicals which dissolve the entire sample, but in other treatments (such as leaching with HCl only) only the ferromanganese oxide portions of the sample are dissolved. In the latter case some investigators calculate their results on a total-weight basis, whereas others report the composition of the ferromanganese oxides. This again is not an error, for the analyst may be interested only in the composition of these phases. However, it is difficult to compare ana-

³J. Greenslate, Manganese concretion wet density: A marine geochemistry constant. *Marine Mining* 1: 125-148.

lyses of acid-soluble nodule phases with those of bulk nodules. We note that one investigator who has analyzed acid-soluble fractions of a great many samples by emission spectrography has reported results that are generally about 20% higher for all elements than those for bulk nodules from the same or nearby locations. On the other hand, the six investigators in the round robin who analyzed the acid-soluble fraction of GRLD 126 reported results for Mn, Fe and Ni that on the average were 2-6% lower than the amounts reported for the total sample as received.

Assays in the Sediment Data Bank have been compiled from 131 different published and unpublished sources. The analytical methods used by each of these is briefly summarized and discussed below.

REFERENCE NO: N344

Source: Kalinenko, V. O., O. B. Belokorytova and G. G. Nikolayeva. 1962. The bacteriogenic formation of ferromanganese concretions in the Indian Ocean [in Russian]. *Okeanologiya* 11: 1050-59.

Number of analyses stored: 6

Sample selection: Concretions and micro-concretions

Sample preparation: Not reported

Elements analyzed and analytical method: Be, Pb, Ga, Mo, Cu, Ni, Co, Zr, V, Mn, Fe, Al, Zn, Ti, Sr, Ba, Ca, Mg, Na, Ti, Bi, Cr, Nb, Sn and Th by "spectral analysis".

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: N626

Source: Niino, H. 1965. On a manganese nodule and petrochus dredged from the banks

near the Izu Islands, Japan. *Records of Oceanographic Works in Japan* 2: 120-126.

Number of analyses stored: One

Analyst: Mr. Tatsumoto

Sample selection: Nodule

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Si and Ca; method not specified.

Accuracy and precision: Not reported

REFERENCE NO: A012

Source: Murray, John and A. F. Renard. 1891. Report on deep-sea deposits based on the specimens collected in the years 1872 to 1876. In *Report on the Scientific Results of the Voyage of HMS Challenger during the Years 1873-1876*. London: Longmans & Co.

Number of analyses stored: 43

Sample selection: Nodules

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Al, Si, Mg and Ca by wet chemistry. Ni and Cu reported as "abundant trace," "good trace," "trace," or "small trace." From comparison with known assays, Menard (Reference No. 261) suggests these terms imply 1.0-1.8%, 0.6-1.0%, 0.3-0.6%, and 0.1-0.3%, respectively; Ni and Cu values were not stored in the data bank, however.

Accuracy and precision: Not reported

Comments: Results reported on total-weight basis. Water loss on heating to 110°C for one hour was usually 10-20%. Analyses should be recalculated to dry basis before comparison with other analyses of dried samples.

REFERENCE NO: A077

Source: Young, Edward J. 1968. Spectrographic data on cores from the Pacific Ocean and the Gulf of Mexico. *Geochimica et Cosmochimica Acta* 32: 466-471.

Number of analyses stored: One

Sample selection: Nodule

Sample preparation: Not reported

Elements analyzed and analytical method: V, Ti, Zr, Ni, Co, Sc, Cr and La by emission spectrography.

Calibration standards and correction procedures: Pd was used as the internal standard. Accuracy is based on rock standards G1 and W1, "but values much below or above G1 and W1 values will not be covered by the stated precision."

Accuracy and precision: 5-10% relative, based on duplicate analyses.

Comments: Since concentrations of almost all the elements in this nodule differ greatly (by two orders of magnitude for Ni and Co) from those in G1 and W1, this analysis is not likely to be accurate.

REFERENCE NO: A088

Source: Von Gümbel, A. 1888. Die mineralogische-geologische Beschaffenheit der auf der Forschungsreise S.M.S. "Gazelle" gesammelten Meeresgrund-Ablagerungen [The Geological mineralogical analysis of the marine sediments collected on the research voyages of the SMS *Gazelle*]. In *Die Forschungsreise S.M.S. "Gazelle" in den Jahren 1874 bis 1876*, pp. 69-116. Hydrographischen Amt der Admiralität, Berlin.

Number of analyses stored: One

Analyst: A. Schwager

Sample selection: Outer layer of a nodule

Sample preparation: Not reported

Elements analyzed and analytical method: Fe, Mn, Cu, Al, Ca, Si, Ti, Mg, Ba and Na by wet chemistry.

Accuracy and precision: Not reported

REFERENCE NO: A165

Source: Goldberg, E. D. 1954. Marine Geochemistry 1: Chemical scavengers of the sea. *Journal of Geology* 62: 249-265.

Number of analyses stored: 11

Analyst: Author

Sample selection: Nodules free from any visible clay or foreign mineral grains.

Sample preparation: Dissolved in HF, dried, and dissolved in 6N HCl.

Elements analyzed and analytical method: Mn, Ni, Co, Cu, Al, P, Fe, Ti and Zr by colorimetry using Beckman Model DU spectrophotometer.

Calibration standards and correction procedures: Reagents used as standards.

Accuracy and precision: Not reported

Comments: These samples probably contained some surface moisture; therefore, reported values would be low by up to 15%.

REFERENCE NO: A166

Source: Barnes, S. S. 1967. The formation of oceanic ferromanganese nodules. Ph.D. dissertation, University of California, San Diego.

Number of analyses stored: 64

Analyst: Author

Sample selection: Whole nodules, fragments or cross sections.

Sample preparation: Dried overnight in oven at 100°C after having been ground to fine powder. Mixed with La_2O_3 (heavy element absorber) and H_3BO_3 (binder) and pressed in a mold.

Elements analyzed and analytical method: Mn, Fe, Ni, Cu, Co and Pb by x-ray fluorescence.

Calibration standards and correction procedures: Rb was used as the internal standard. Pulse height discrimination was used to isolate Co and Fe peaks from interfering peaks. Some corrections using experimental working curves were applied to Fe, Mn and Co to account for inter-element effects. Standard curves were made from standards prepared in exactly the same manner as samples from reagent grade oxides of the various elements. Fe_2O_3 and MnO_2 were added to the standards to approximate the nodule matrix.

Accuracy and precision: Not reported

Comments: Many of the analyses find Mn concentrations of 40-50% much higher than reported by any other investigators. In fact, Mn values are so high that in many cases the sum of the metal oxides exceeds 100%. Ni is also suspiciously high (1.8-2.5%) in some cases. All analyses from this source are likely to be inaccurate and should be disregarded.

REFERENCE NO: A178

Source: Skorniyakova, N. S. and P. F. Andrushchenko. 1970. Ferromanganese nodules in the Pacific Ocean [in Russian]. In *Sedimentation in the Pacific Ocean [in Russian]*, ed. P. L. Bezrukov, vol. 6, pts. 1 and 2, pp. 203-268. P. P. Shirshov Institute of Oceanology, Akademiia Nauk.

Number of analyses stored: 50

Analyst: Exogenic Division, Institute of the Geology of Ore Deposits, Akademiia Nauk

Sample selection: Various layers of nodules; most samples identified.

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Ni, Co, Cu, Si, Al, Mg, Ca, Na, K, Ti, Ba and P by wet chemistry. Not all elements determined for all samples. Analytical methods described in detail in Reference No. A205.

Accuracy and precision: Not reported

REFERENCE NO: A179

Source: Horn, D. R., M. N. Delach and B. M. Horn. 1973. *Metal content of ferromanganese deposits of the oceans*. National Science Foundation, Office for the International Decade of Ocean Exploration Technical Report No. 3, NSF GX-33616.

Number of analyses stored: 159

Analyst: Kennecott Copper Corp.

Sample selection: Nodules and crusts, some sample types not specified; presumably bulk analyses.

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni, and sometimes Si and Ca, by various methods, usually wet chemistry or atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A189

Source: Cronan, D. S. and J. S. Tooms. 1969. The geochemistry of manganese nodules and associated pelagic deposits from the Pacific and Indian Oceans. *Deep-Sea Research* 16: 335-359.

Number of analyses stored: 10

Analyst: D. S. Cronan

Sample selection: Nodules and crusts

Sample preparation: Same as for Reference No. A240.

Elements analyzed and analytical method: Mn and Fe by wet chemistry; Ni Co, Cu, Pb, Ba, Mo, V, Cr and Ti by emission spectrography. Methods described in detail in A240.

Calibration standards and correction procedures: Same as for A240.

Accuracy and precision: 12-17% precision based on replicate analyses for emission spectrography. Accuracy not discussed.

Comments: Most analyses presented here were included in Cronan's 1967 dissertation and are coded as A240. See comments for A240.

REFERENCE NO: A195

Source: Glasby, G. P., J. S. Tooms and J. R. Cann. 1971. The geochemistry of manganese encrustations from the Gulf of Aden. *Deep-Sea Research* 18: 1179-87.

Number of analyses stored: 5

Sample selection: Mn encrustations on rocks

Sample preparation: Same as for Reference No. A217

Elements analyzed and analytical method: Mn and Fe by atomic absorption; Ni, Co, Cu, Pb, Mo, V, Si, Cr, Ti, Zr and Zn by emission spectrography. Detailed discussion of analytical methods in A217.

Calibration standards, correction procedures, accuracy and precision: Same as for A217.

REFERENCE NO: A197

Source: Mero, John L. 1965. *The Mineral Resources of the Sea*. Amsterdam: Elsevier Publishing Co.

Number of analyses stored: 163

Analyst: Author

Sample selection: Mostly whole nodules or nodule cross sections; some crusts.

Sample preparation: Not reported. Samples apparently were not dried, and results are given on a total-weight-of-sample basis.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Zn, Sr, Mo, Ba, Pb, Al, Si, Ca and Ti by x-ray fluorescence (General Electric XRD-5 with tungsten target).

Calibration standards and correction procedures: Standards were made from pure oxide forms of the elements in nodules mixed in proportion to the amounts of these elements generally found in the manganese nodules. Chemically analyzed standards of natural nodules were also used. As a final check, the method of additions was used.

Accuracy and precision: "When applied to chemically analyzed nodules, to three significant figures in most cases which was within the limits of accuracy of the chemical analyses performed." Menard (see Reference No. A261) suggests that these analyses are accurate to the number of significant figures listed except that "due to the x-ray interaction effects, the copper and cobalt assays are probably correct to only one significant figure."

Comments: Although analyses are not normalized to a dry weight-basis, water is relatively transparent to x-rays and the inclusion of about 15% surface moisture would lower results by no more than 2-3%; if standards were also undried, the effect could be nil or even go in the other direction.

REFERENCE NO: A198

Source: Pachadzhnov, D. N., G. A. Bandurkin, A. Migdisov and Yu. P. Girin. 1963. Data on the geochemistry of manganese nodules from the Indian Ocean. *Geochemistry* 5: 493-499.

Number of analyses stored: 2

Analyst: N. V. Yeremeyera (major elements)

Sample selection: Outer layers and nuclei of nodules

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Si, Ti, Al, Mg, Ca and P; method not specified. La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tu, Yb and Lu (determined as hydroxides and oxalates after preliminary enrichment) by x-ray spectrography; reported as percentage of total rare earth content. Nb and Ta by spectrochemical method. V and Th by "methods described in the literature" (see source for reference). Na and K by flame photometry.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A200

Source: Ahrens, L. H., J. P. Willis and C. O. Oosthuizen. 1967. Further observations on the composition of manganese nodules with particular reference to some of the rarer elements. *Geochimica et Cosmochimica Acta* 31: 2169-2180.

Number of analyses stored: 31

Sample selection: Half or whole nodules; most samples described. Observable nuclei removed.

Sample preparation: Ground to pass 120 mesh sieve.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Zn, Pb and Ca by x-ray fluorescence (Phillips PW 1540); Cd, Sn and Bi by combination of ion-exchange pre-enrichment and

emission spectrography; Tl by emission spectrography alone. For x-ray fluorescence, the $K\alpha$ lines were used for all elements except Pb, for which the $L\alpha$ line was used. Zn and Pb were determined on unmixed powders; for other elements, a matrix mixture of Li_2CO_3 -starch (1:1) and a matrix to sample ratio of 19:1 was used. Analytical procedures are described in papers referred to in source.

Calibration standards and correction procedures: Artificial standards used.

Accuracy and precision: "The coefficient of variation. . . ranged from 1 to 10% and varied with the concentration of the element" for x-ray fluorescence. For combined ion-exchange spectrographic procedures the coefficient of variation was about 20%, while it was 8-10% for the spectrographic procedure alone.

Comments: Since nuclei were removed, the reported results are higher than for bulk nodule analysis. If the nuclei were small, however, the difference could be negligible. For some analyses, Co determinations are somewhat higher than those of other investigators for samples from the same locations.

REFERENCE NO: A201

Source: Willis, J. P. and L. H. Ahrens. 1962. Some investigations on the composition of manganese nodules, with particular reference to certain trace elements. *Geochimica et Cosmochimica Acta* 26: 751-764.

Number of analyses stored: 19

Sample selection: Various parts of nodules; samples described. Observable nuclei removed before analysis.

Sample preparation: Samples powdered, dried 2 hours at 120°C, weighed, heated to red heat for 5 minutes, and weighed again to determine loss on ignition; 0.075 g of ignited sample mixed with 0.15 g carbon/Pd mix containing 0.02% Pd (the internal standard).

Elements analyzed and analytical method: Fe, Si, Mg, Co, Ni, Mo, V, Ti and Tl by emission spectrography (Hilger E478 spectrograph). Analytical procedure described in detail in source.

Calibration standards and correction procedures: Synthetic standards were prepared from a base mixture containing 53% MnO₂, 37% Fe₂O₃ and 10% SiO₂. Source contains complete description of standards.

Accuracy and precision: Reproducibility about 5%, as indicated from quadruplicate determinations. Accuracy not discussed.

Comments: Since nuclei were removed, the reported results are higher than for bulk nodule analysis. If the nuclei were small, however, the difference could be negligible.

REFERENCE NO: A202

Source: Grant, John B. 1967. A comparison of the chemistry and mineralogy with the distribution and physical aspects of marine manganese concretions of the southern oceans. Master's thesis, Florida State University.

Number of analyses stored: None

Analyst: N. D. Birell, Newport News Shipbuilding and Drydock Co.

Sample selection: Whole nodules; analyses of these same samples reported in Reference No. A227.

Sample preparation, elements analyzed and analytical method: See A227

Comments: These analyses were not added to the data bank because they were reported in a later publication (A227) after "recalculation to include water." In retrospect, the "water-free basis" used in A202 (after heating to 110°C) was preferable.

REFERENCE NO: A203

Source: Cronan, D. S. and J. S. Tooms. 1967. Geochemistry of manganese nodules from the northwest Indian Ocean. *Deep-Sea Research* 14: 239-249.

Number of analyses stored: 27

Sample selection: Various layers of nodules; all samples identified.

Sample preparation: Crushed and ground, then dried 2 hours at 120°C, then ignited 10 minutes at 850°C.

Elements analyzed and analytical method: Mn and Fe by x-ray fluorescence; Si, Ni, Co, Cu, Pb, Ba, Mo, Cr and Ti by emission spectrography. Analytical techniques probably the same as those described in Reference No. A240.

Calibration standards and correction procedures: Cr was used as an internal standard for x-ray fluorescence; Pd, for emission spectrography.

Accuracy and precision: Precision $\pm 7\%$ at the 95% confidence level for x-ray fluorescence. For emission spectrography, precision varies from method to method but is better than $\pm 30\%$ at the 95% confidence level for the majority of elements. Accuracy not discussed.

Comments: Analyses reported on air-dried (at 120°C) basis. Probably reliable.

REFERENCE NO: A204

Source: Skornyakova, N. S. and P. F. Andrushchenko. 1968. Iron-manganese nodules from the central part of the South Pacific. *Oceanology* 8: 692-701.

Number of analyses stored: 7

Analyst: Exogenic Division, Institute of the Geology of Ore Deposits, Petrology and Geochemistry of the Academy of Sciences

Sample selection: Nodules without nuclei

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Si, Al, Mg, Ca, Na, K, Ti, Pb and V by wet chemistry; method described in detail in Reference No. A205.

Accuracy and precision: Not reported

REFERENCE NO: A205

Source: Skonyakova, N. S., P. F. Andrushchenko and L. S. Fomina. 1962. The chemical composition of iron-manganese concretions of the Pacific Ocean [in Russian]. *Okeanologiya* 2: 264-277.

Number of analyses stored: One

Analyst: Exogenic Division, Institute of the Geology of Ore Bulk Deposits, Petrology and Geochemistry of the Academy of Sciences,

Sample selection: Nodule

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Si, Al, Ti, Ca, Mg and P, sometimes also Na, K, Ba, Pb and Cu by wet chemistry; method described in detail in source.

Accuracy and precision: Not reported

Comments: Most analyses reported in this source are also reported in Reference No. A178 and are coded under that reference number.

REFERENCE NO: A214

Source: Riley, J. P. and P. Sinhaseni. 1958. Chemical composition of three manganese concretions from the Indian and Pacific Oceans. *Journal of Marine Research* 17: 466-482.

Number of analyses stored: 6

Sample selection: Nodules with nuclei and other heterogeneous materials removed.

Sample preparation: Powdered to pass through 80-mesh sieve, boiled in water to remove salts, then dried at 110°C and treated with HCl and HClO₄.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Co, Si, Al, B, Cd, Ca, Cr, Ga, Pb, Mg, Mo, P, Ti, W, V and Zn by wet chemistry; Sb, Ba, Be, Bi, La, Sc, Ag, Sr, Th, Sn, Y and Zr by emission spectrography; K and Na by flame photometry. Acid-soluble and insoluble fractions analyzed separately.

Accuracy and precision: Not reported

Comments: Since nodule nuclei were removed, reported Mn, M, Cu and Co are slightly higher than for bulk nodule analyses. If nuclei were small, however, the difference is probably negligible. Analyses reported are on the acid-soluble fraction. These are included in the data bank, but in addition we have calculated and stored composition of total sample. Because bound water was removed, values will still be about 15% higher than results for comparable samples dried at 110°C.

REFERENCE NO: A217

Source: Glasby, G. P. 1970. The geochemistry of manganese nodules and associated pelagic sediments from the Indian Ocean. Ph.D. dissertation, University of London.

Number of analyses stored: 183

Sample selection: Nodules and crusts

Sample preparation: Heated at 420°(C?) for 4 hours.

Elements analyzed and analytical method: Mn and Fe by atomic absorption; Ni, Co, Cu, Pb, Mo, V, Si, Cr, Ti, Zr and Zn by emission spectrography.

Calibration standards and correction procedures: For atomic absorption, interference effects were investigated by spiking standard solutions. For emission spectrography, standards were prepared using a base mixture of 40%

Mn₃O₄, 40% Fe₂O₃, and 20% SiO₂ plus various concentrations of other metal oxides.

Accuracy and precision: Precision determined by duplicate arcing was, at the 95% confidence level, $\pm 15\%$ for Mn and Fe, better than $\pm 25\%$ for other elements.

REFERENCE NO: A219

Source: Bezrukov, P. L. and P. F. Andrushchenko. 1973. Iron-manganese concretions in the Indian Ocean. *International Geology Review* 15: 342-356.

Number of analyses stored: 5

Analysts: Several, listed in source

Sample selection: Nodules, nuclei not included

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Si, Ti, Al, Ca, Mg, Ba, V, Cr, Mo, W, S, P and CO₂ by wet chemistry.

Accuracy and precision: Not reported

Comments: Some of these analyses were also reported in Reference No. A220 and are coded under that source.

REFERENCE NO: A220

Source: Isaeva, A. B. 1967. Chemical composition of iron-manganese concretions of the Indian Ocean. *Lithology and Mineral Resources* 3: 310-320.

Number of analyses stored: 11

Sample selection: Mostly outer layers of nodules; some nuclei and some whole nodules.

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Si, Bi, Ti, Al, Ca, Mg, V, Cr, Mo, W, Zr, P and S by wet chemistry (gravimetry, volumetry, colorimetry).

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A227

Source: Meylan, M. A. and H. G. Goodell. 1976. Chemical composition of manganese nodules from the Pacific-Antarctic Ocean, Drake Passage and Scotia Sea: Relation to ferromanganese oxide mineralogy and nucleus type. In *Papers Presented at the IDOE Workshop, Suva, Fiji, 1-6 September, 1975: Marine Geological Investigations in the Southwest Pacific and Adjacent Areas*. United Nations Economic and Social Commission for Asia and the Pacific (CCOP/SOPAC Technical Bulletin No. 2), pp. 99-117.

Number of analyses stored: 166

Analyst: Materials Laboratory of Newport News Shipbuilding and Drydock Co.

Sample selection: Mostly crusts; some nodules with nonferromanganese nuclei removed. Most samples described. Samples lightly ground and sand-size or larger detritus removed.

Sample preparation: Some fresh, most air-dried for variable lengths of time. Powder screened to unspecified size.

Elements analyzed and analytical method: Fe, Mn, Cu, Co and Ni by x-ray fluorescence; Ba, Sr, Zr, Ti, Mo, Sn and V by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: $\pm 5\%$ replicable for Fe and Mn (see Goodell, H. G., M. A. Meylan and B. Grant, 1971, *Antarctic Research Series* 15: 27-92). Accuracy not discussed.

Comments: These analyses were originally done on a "water-free" basis; M. Meylan (1971, personal communication) believes "this is essentially L.O.I. at 110°C." The reported H₂O values are in an appropriate range to represent water loss upon heating to 110°C. For this paper, the analyses were recomputed to include the water. For comparison with other analyses, however, these analyses should be converted back to their original values.

Even after recomputation, there are problems with some of these analyses. Many of them, particularly those from the Drake Passage-Scotia Sea region, are characterized by extremely low Mn content, often less than 2%. These samples are not described, and we would have guessed that they were nodule nuclei or samples incorporating large amounts of detrital material. According to Meylan, however, these samples "do represent nodules and not some other material. So the analyses with low Mn content (1-2%) are real, although the repetitious 1.0% may be a peculiarity of the analysis technique."

Cronan (see Reference No. A368) has analyzed samples from some of the same locations and others nearby. He also reports low Mn in the same region, but rarely as low as 2%. Cronan's low Mn analyses generally have much higher Fe content (23-40%) than the analyses from A227, but the same range of Ni, Cu and Co.

The problem with Mn and Fe could be in the resolution of overlapping peaks, a common difficulty with x-ray fluorescence techniques. Or it could be that no correction procedures were applied to account for x-ray absorption and secondary fluorescence. In the former case, analyses of the other elements could be accurate; in the latter case, analyses of all elements from x-ray fluorescence would be dubious and would become progressively more inaccurate as compositions approached the low end of the Mn range. We would use data from A227 as general indicators of nodule grade, but not for studies of inter-element relationships.

REFERENCE NO: A230

Source: Bonatti, Enrico. 1959-1967. Mechanisms of deep-sea volcanism in the South Pacific. In *Researches in Geochemistry*, ed. Philip H. Abelson. 2 vols. New York: John Wiley.

Number of analyses stored: 3

Analyst: A. Joensuu

Sample selection: Mn encrustations on basalts

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Ni, Co, Si, Al and Cr and also sometimes Ca, Mg, K and Cu for some samples. Some samples analyzed by emission spectrography; others analyzed by a combination of x-ray fluorescence and emission spectrography. Details of methods are reported in papers referred to in source.

Calibration standards and correction procedures: Detailed discussion in references.

Accuracy and precision: Precision within 2-12% for emission spectrography. Accuracy not discussed.

Comments: The methods used were developed for silicate rocks containing trace amounts of Mn, Ni and Co; they are not necessarily accurate for analyses of Mn nodules, which differ greatly in composition.

REFERENCE NO: A232

Source: Burns, Roger G. and D. W. Fuerstenau. 1966. Electron-probe determination of inter-element relationships in manganese nodules. *American Mineralogist* 51: 895-902.

Number of analyses stored: One

Sample selection: Nodule cross section

Sample preparation: Polished and carbon-coated; not dried.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Zn, Ti, Ca, Mg and Si by electron microprobe. The analysis reported is the average of a number of point analyses and represents the concentration of the entire sample.

Calibration standards and correction procedures: Standards were TiO_2 , clinopyroxene (for Ca, Mg and Si), muscovite (for K and Al), and pure metals for other elements. No corrections were made for inter-element effects.

Accuracy and precision: "Calibration error arising from differences in average atomic number between specimens and the standards limits the accuracy of the analyses to the range +10% or -5%."

Comments: Given the standards used, we would guess larger errors on the metal determinations due to inter-element effects.

REFERENCE NO: A240

Source: Cronan, D. S. 1967. The geochemistry of some manganese nodules and associated pelagic deposits. Ph.D. dissertation, Imperial College, University of London.

Number of analyses stored: 138

Analyst: Author

Sample selection: Nodules and crusts; some nodule samples analyzed were whole nodules, and others were representative portions such as halves or cross sections. Each sample identified.

Sample preparation: Ground to 80 mesh, heated 10 minutes at 850°C to remove volatiles.

Elements analyzed and analytical method: Mn and Fe by wet chemistry for some samples, x-ray fluorescence for most (ARL Production X-ray Quantometer with tungsten target). Ni, Cu, Co, Pb, Mo, V, Cr, Ba and Ti by emission spectrography (Hilger and Watts large quartz spectrograph). For some samples, Ni and Cu were analyzed by colorimetry to check the accuracy of the other methods. Methods described in detail in source.

For emission spectrography, analytical techniques were a modification of those used by the Applied Geochemistry Research Group in Imperial College (I. Nichol and J. C. Henderson-Hamilton, 1964, *Transactions of the Institution of Mining and Metallurgy* 74: 955-961). To reduce matrix effects, 100 mg of ignited sample was mixed with equal weight of 50% NaCl, 50% C.

Calibration standards and correction procedures: For emission spectrography, 800 ppm Pd was added to samples as an internal standard; working curves were prepared from spectrographically pure materials (method described in detail in source).

For x-ray fluorescence, 10 wt. % Cr_2O_3 was added to 200 mg of sample as an internal standard; final powder was compressed as an inset on a cellulose disk. Mn/Cr ratios of synthetic standards plotted on a working curve were used to determine Mn content. Fe was determined using Mn as a variable internal standard.

Accuracy and precision: Replicate determinations gave ± 10 -15% at one standard deviation for emission spectrography, $\pm 3.5\%$ for x-ray fluorescence. Accuracy not discussed.

Comments: Because bound water was removed from these samples before analysis, the results should be decreased by about 20% before comparison with results on samples dried at 110°C. After such a correction, analyses reported by this source are in the same range as those performed by other investigators for samples from the same locations and are probably reliable.

REFERENCE NO: A242

Source: National Science Foundation, Seabed Assessment Program, IDOE. 1975. *Inter-university Program of Research on Ferromanganese Deposits of the Ocean: Station Summary and Sample logs. Cruise MN-7402, September-October 1974.*

Number of analyses stored: 4

Analysts: B. K. Dugolinsky and J. Greenslate

Sample selection: Bulk nodules

Sample preparation, elements analyzed and analytical method: Greenslate's methods are same as for Reference No. A244. Dugolinsky's methods are same as for Reference No. A356.

Comments: Analyses by Dugolinsky are not stored in the data bank; see A356 for an explanation.

REFERENCE NO: A244

Source: Greenslate, J. 1975. Manganese-biota association in north equatorial Pacific sediments. Ph.D. dissertation, University of California, San Diego.

Number of analyses stored: 49

Analyst: Author

Sample selection: Representative parts of nodules, 1/4 to 2/3 of whole nodules.

Sample preparation: Dried at 110°C to constant weight

Elements analyzed and analytical method: Ca, Ti, Mn, Fe, Ni and Cu by x-ray energy spectrometry

Calibration standards and correction procedures: Well analyzed natural nodule materials

Accuracy and precision: Mn, $\pm 2\%$; Ti, $\pm 10\%$; other elements $\pm 5\%$. Accuracy not discussed.

Comments: Probably reliable except for Ti; Ba $L\alpha$ peak interferes with Ti $K\alpha$ peak. Samples from some of the same locations have been analyzed by M. Fisk (see Reference No. A405) with results in the same range.

REFERENCE NO: A246

Source: Bezrukov, P. L. and P. F. Andrushchenko. 1974. Geochemistry of iron-manganese nodules from the Indian Ocean. *International Geology Review* 16: 1044-1061.

Number of analyses stored: 21

Sample selection and preparation, elements analyzed and analytical method: Same as for Reference No. A205.

Accuracy and precision: Not reported

REFERENCE NO: A247

Source: Frazer, F. W. and J. Ostwald. 1970. Chemical and mineralogical investigations on a suite of deep-sea manganese nodules. Central Research Laboratories, CRL/TC/7/70. (Broken Hill Proprietary Co., Ltd. and the Bureau of Mineral Resources, Shortland, Australia.)

Number of analyses stored: 18

Sample selection: Mn-coated rocks, some nodules

Sample preparation: Ground to -200 mesh, samples dried at 110°C and ignited at 1350°C to determine H_2O^- and H_2O^+ , but analyses are reported on weight-as-received basis.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Al, Ba, Be, Ca, Cr, Mg, Mo, P, S, Si, Ti, V and Zr by emission spectrography; K, Na, Pb, Sr, Zn and Tl by atomic absorption. Analytical methods are described in detail in source.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

Comments: Analyses can be calculated to include H_2O^+ for comparison with analyses of samples dried at 110°C.

REFERENCE NO: A248

Source: Shima, Makoto and Akihiko Okada. 1974. Study on manganese nodules (VIII): Nonhomogeneous chemical distribution of manganese nodule [in Japanese]. *Scientific Report of the Institute of Physical and Chemical Research [in Japanese]* 50: 155-164.

Number of analyses stored: 15

Sample selection: Representative portions of whole nodules

Sample preparation: Ground to unspecified size, heated to 300°C, dissolved in 3N HCl.

Elements analyzed and analytical method: Mn, Fe, Ni, Co, Cu, Zn and Pb by atomic absorption. Ti, V and Bi by emission spectrophotometry (Shimazu GE 100). La, Ce, Nd, Sm, Eu, Tb, Yb and Lu by radiochemical semiquantitative analysis using Ge(Li) detector.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A249

Source: Okada, A. and M. Shima. 1970. Study on the manganese nodule [in Japanese]. *Journal of the Oceanographical Society of Japan* 26: 151-158.

Number of analyses stored: 28

Sample selection: Portions of the Mn-Fe part of nodules; nuclei not included.

Sample preparation: Pulverized, heated to 300°C to remove volatile components, then dissolved in 3N HCl to which several drops of 30% H₂O₂ were added.

Elements analyzed and analytical method: Mn, Fe, Cu, Ni and Co by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

Comments: Analyses reported are for the acid-soluble fraction only. These are included in the data bank, but in addition we have calculated and stored the composition of the total samples. Because bound water was removed, recalculated values will still be about 15% higher than results for comparable samples dried at 110°C.

REFERENCE NO: A250

Source: Glasby, G. P. 1973. Manganese deposits in the southwest Pacific. In *Inter-university Program of Research on Ferromanganese Deposits of the Ocean Floor*, Phase 1 Report, pp. 137-169. National Science Foundation, Seabed Assessment Program, IDOE.

Number of analyses stored: 14

Analyst: C. D. Fein, Hawaii Institute of Geophysics

Sample selection: Thin outer layers of nodules and Mn-coated rocks

Sample preparation: Samples ground, digested in a mixture of HNO₃/HCl/HF, evaporated to dryness, fumed with HClO₄, and finally leached with 8N HCl.

Elements analyzed and analytical method: Fe, Mn, Co, Ni, Cu and Zn by atomic absorption, employing the standard addition method.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Precision determined from 5 replicate analyses is ±29% for Fe, ±9% for Mn, ±32% for Co, ±19% for Ni, ±21% for Cu, and ±8% for Zn at the 95% confidence level. Accuracy not discussed.

REFERENCE NO: A253

Source: Rancitelli, L. A. and R. W. Perkins. 1973. Major and minor elemental composition of manganese nodules. *Inter-university Program of Research on Ferromanganese Deposits of the Ocean Floor*, Phase 1 Report, pp. 1-5. National Science Foundation, Seabed Assessment Program, IDOE.

Number of analyses stored: 26

Analyst: Authors

Sample selection: Nodule rinds, nuclei and cross-sections.

Sample preparation: Powdered and homogenized

Elements analyzed and analytical method: Mn, Fe, Ni, Co, Zn, Cr, V, Sc, La, Sm, Eu, Tb, Hf, Tn, Al, Ba, Na and Sb by neutron activation analysis. Results were based on three spectra: measurements immediately after a short neutron irradiation, together with measurements at periods of 7 and 22 days after a 6-hour irradiation at a thermal neutron flux of 10^{13} n.cm⁻².sec⁻¹.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Mn, Fe, Co, Sc, La, Sm, Al, Na and Sb measured to an accuracy of $\pm 5\%$; most other elements within $\pm 10\%$.

Comments: Probably reliable

REFERENCE NO: A254

Source: Fein, C. D. and M. Morgenstein. 1973. Microprobe analysis of manganese crusts from the Hawaiian Archipelago. In *Inter-university Program of Research on Ferromanganese Deposits of the Ocean Floor*, Phase 1 Report, pp. 85-92. National Science Foundation, Seabed Assessment Program, IDOE.

Number of analyses stored: 8

Sample selection: Various minute portions of Mn crusts; all samples identified.

Sample preparation: Not reported

Elements analyzed and analytical method: Si, Al, Ti, Mg, Ca, Na, K, Fe, Mn, Cr and Ni by electron microprobe (MAC Model 5-SA3). H₂O content reported but not measured; it represents the difference between the sum of the measured elements and 100%.

Calibration standards and correction procedures: Procedures and correction factors as reported by Bence and Albee (1969, *Journal of Geology* 76: 382) and Albee and Ray (1970, *Analytical Chemistry* 42: 1408).

Accuracy and precision: Not reported

REFERENCE NO: A255

Source: Dietz, R. W. 1955. Manganese deposits on the northeast Pacific sea floor. *California Journal of Mines and Geology* 51: 209-220.

Number of analyses stored: 5

Analyst: H. E. Peterson, U. S. Bureau of Mines, Salt Lake City

Sample selection: Nodules and crusts

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co and Ni by wet chemistry

Accuracy and precision: Not reported

REFERENCE NO: A259

Source: Stevenson, J. S. and L. S. Stevenson. 1970. Manganese nodules from the Challenger Expedition at Redpath Museum. *Canadian Mineralogy* 10: 599-615.

Number of analyses stored: 10

Analysts: F. Aumento and J. Stevenson

Sample selection: Bulk nodules and minute areas of Fe-Mn oxide portions.

Sample preparation: For microprobe analysis, cut, mounted in epoxy resin, polished and carbon-coated.

Elements analyzed and analytical method: For bulk nodules, Mn, Fe, Si, Al, Mg, Ca, Na, K, Ti, P and CO₂ by wet chemistry; Ni, Cu, Co, Be, B, Sc, Ti, V, Ge, Sr, Y, Zr, Ag, Sn, Ba, Yb and Pb by emission spectrography. For point analyses, Fe, Mn, Ni, Cu, Co, Si, P and Ti by electron microprobe (Acton M564 Cameca); each value reported is the average of six readings within a small area.

Calibration standards and correction procedures: Standards not reported. For microprobe analyses, "a computer programme containing corrections for drift, deadtime, background, absorption, fluorescence and atomic number was used for reduction of the data."

Accuracy and precision: Not reported

REFERENCE NO: A260

Source: Summerhayes, C. P. 1967. Manganese nodules from the southwestern Pacific. *New Zealand Oceanographic Institute Journal of Geology and Geophysics* 10: 1372-81.

Number of analyses stored: 7

Analyst: Department of Scientific and Industrial Research Chemistry Division, New Zealand Oceanographic Institute, Gracefield

Sample selection: Nodules, crusts and Mn-coated rocks; each sample identified.

Sample preparation: Dried at 110°C

Elements analyzed and analytical method: Fe and Mn by wet chemistry; Ca, Si, Be, B, P, Pb, Al, Ti, Cr, Co, Mg, Mo, Ni and V by emission spectrography, using iron flux technique described in Watters, Todd and Sixtus (1961, *New Zealand Journal of Geology and Geophysics* 4: 270-73).

Calibration standards and correction procedures: Not reported

Accuracy and precision: Probably about $\pm 50\%$ for elements analyzed by spectrography.

REFERENCE NO: A261

Source: Menard, H. W. 1977. Personal communication. Unpublished analyses of Pacific ocean manganese nodules.

Number of analyses stored: 87

Analyst: American Spectrographic Laboratories, San Francisco, California

Sample selection: Whole nodules and parts of nodules; most samples identified.

Sample preparation: Heated one hour at 1000°F before analysis.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, B, Na, Mg, Al, Si, K, Ca, Sc, Ti, V, Cr, Zn, Ga, Sr, Y, Zr, Mo, Ba, La, Yb, Pb and Bi by emission spectrography.

Calibration standards and correction procedures: An internal standard of Pd was used. Analytical results were adjusted so that the oxides of the elements assayed total 100%.

Accuracy and precision: Not reported

Comments: Since all water was removed from these samples, reported results should be reduced by about 20% for comparison with analyses of samples dried at 110°C. Even after such adjustment, most values for Mn and Ni are much higher than those reported by other analysts for samples from the same locations.

REFERENCE NO: A262

Source: Hewett, D. F., M. Fleisher and N. Conklin. 1963. Deposits of the manganese oxides. *Economic Geology* 58: 1-51.

Number of analyses stored: 11

Sample selection: Nodules

Sample preparation: Samples crushed and ground, diluted 1 : 2.64 and 1 : 20.5 with a mixture of 95% pure quartz and 5% Na₂CO₃.

Elements analyzed and analytical method: Co, Ni, Cu, Al, S, Mg, Ca, Na, K, Ti, B, Ba, Be, Bi, Ce, Cr, La, Mo, Nb, Nd, Pb, Sc, Tl, V, Y, Yb, Zn and Zr by emission spectrography; details of technique described in source.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Method is "semiquantitative."

Comments: Results presented on a dry-weight basis.

REFERENCE NO: A264

Source: Maruyama, Shuji and Hideo Takeda. 1974. Ferromanganese nodules. In *Deep sea mineral resources investigations in northwest Pacific, November–December 1972*, ed. H. Takeda, pp. 33-40. Geological Survey of Japan, Cruise Report No. 1.

Number of analyses stored: 11

Sample selection: Bulk analyses of nodules including nuclei

Sample preparation: Not reported

Elements analyzed and analytical method: Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P, Ni, Co, Cu and Ba; method unspecified.

Accuracy and precision: Not reported

REFERENCE NO: A272

Source: Van der Weijden, C. H. 1976. Some geochemical controls on Ni and Co concentrations in marine ferromanganese deposits. *Chemical Geology* 18: 65-80.

Number of analyses stored: 15

Sample selection: Nodules

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Zn and Pb by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

Comments: Samples from most of the same locations were analyzed by Newport News Shipbuilding and Drydock Co. (see Reference No. A227) with results in the same composition range.

REFERENCE NO: A273

Source: Cronan, D. S. and J. S. Tooms. 1968. A microscopic and electron probe investigation of manganese nodules from the northwest Indian Ocean. *Deep-Sea Research* 15: 215-223.

Number of analyses stored: One

Sample selection: A μ^2 area of a nodule cross section, within the central Mn segregation.

Sample preparation: Polished and carbon-coated

Elements analyzed and analytical method: Mn, Fe, Ti, Co, Ni, Cu and Ca by electron microprobe.

Calibration standards and correction procedures: Matrix absorption corrections made after Kelley (1966, *Transactions of the Institution of Mining and Metallurgy*, Section B, 75: 59-73).

Accuracy and precision: Not reported

REFERENCE NO: A275

Source: Smith R. E., J. D. Gassaway and H. N. Giles. 1968. Iron-manganese nodules from Nares Abyssal Plain: Geochemistry and mineralogy. *Science* 161: 780-781.

Number of analyses stored: 3

Sample selection: Nodules

Sample preparation: Samples crushed and washed to remove soluble salts and adherent clay. Ignited at 1000°C and leached with HCl; only the soluble portion was analyzed.

Elements analyzed and analytical method: Fe, Mn, Co, Cr, Cu and Zn by atomic absorption

Calibration standards and correction procedures: Not reported

Accuracy and precision: $\pm 5\%$ of amount present

Comments: Results are reported on a water-free and detrital-free basis and are thus much higher than if samples were bulk nodules dried at 110°C.

REFERENCE NO: A276

Source: Nikolayev, D. S. and E. I. Yefimova. 1963. On the age of iron-manganese concretions from the Indian and Pacific Oceans. *Geochemistry* 7: 703-714.

Number of analyses stored: 20

Sample selection: Middle and outer layers of nodules and crusts

Sample preparation: Not reported

Elements analyzed and analytical method: Mn and Fe in all samples and Ca, Ni and P in some by wet chemistry; U by luminescence method; Ra by emanation method; Th by colorimetry after chromatographic separation from other elements. Source contains detailed description of procedures.

Accuracy and precision: $\pm 20\%$ for U; $\pm 5\%$ for Ra; not reported for other elements.

REFERENCE NO: A277

Source: Hubred, G. L. 1970. *Relationship of morphology and transition metal content of manganese nodules to an abyssal hill*. National Science Foundation, Sea Grant Program, no. 70-5 and Hawaii Institute of Geophysics, no. 70-18.

Number of analyses stored: 11

Analyst: Author

Sample selection: Whole nodules and nodule layers, crusts on basalt. Samples described in source.

Sample preparation: Crushed and dried 24 hours at 80°C, then ground 5 minutes in a miniature ball mill. Dissolved in HF - HClO₄; details of sample preparation in source.

Elements analyzed and analytical method: Mn, Fe, Co, Ni and Cu by atomic absorption "at operating conditions recommended by the manufacturer (Beckman Corp)."

Calibration standards and correction procedures: Initially calibration curves were based on standards prepared with a range of concentrations. An attempt was made to approximate the sample matrix by adding Mn and/or Fe. This method was unsuccessful; thus a standard addition method was adopted. Method described in detail in source.

Accuracy and precision: Based on triplicate analyses, precision at the level of two standard deviations is approximately 10% for Co, Ni and Cu; approximately 5% for Mn and Fe. Accuracy checked by analyzing nodules previously analyzed by other laboratories; results were same within quoted precision.

REFERENCE NO: A282

Source: Noakes, L. C. and H. A. Jones. 1973. Sea floor manganese nodules in the Australian region. In *Report of the Preparatory Meeting for establishment of CCOP/SOPAC and Proceedings of the First and Second Sessions*. Commission for Asia and Far East Committee for Coordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (Document NR/CCOP/SOPAC(2)/CR. Paper 10), pp. 129-133.

Number of analyses stored: 13

Sample selection: Nodules

Sample preparation: Not reported

Elements analyzed and analytical method: Fe, Mn, Ni, Cu, and Co; method not specified.

Accuracy and precision: Not reported

REFERENCE NO: A283

Source: Aumento F., D. E. Lawrence and A. G. Plant. 1968. The Ferro-manganese pavement on the San Pablo Seamount. Geological Survey of Canada Paper 68-32.

Number of analyses stored: 4

Analysts: F. Aumento (x-ray fluorescence), J. J. Lynch, Canadian Geological Survey (colorimetry) and Emission Spectroscopy Group of Canadian Geological Survey (emission spectrography).

Sample selection: Different sections of a manganese pavement

Sample preparation: Not reported, but probably heated before analysis to remove bound as well as surface water (based on reported loss-on-ignition).

Elements analyzed and analytical method: Si, K, Ca, Ti, Mn Fe, Co, Ni and Cu by x-ray fluorescence (dilution with fusion, spiking, and direct comparison); Zn, As and Sb by colorimetry; B, Mg, Al, Sc, V, Sr, Y, Zr, Mo, Ba, Yb and Pb by emission spectrography

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

Comments: Results should be decreased by about 18% to account for loss of bound water.

REFERENCE NO: A284

Source: Lonsdale, Peter (Scripps Institution of Oceanography). 1971. Personal communication.

Number of analyses stored: 5

Analyst: International Nickel Co.

Sample selection: Nodules from the seafloor surface

Sample preparation: Not reported

Elements analyzed and analytical method: Mg, Al, Si, Ca, Mn, Fe, Co, Ni, Cu, Zn and Pb; method not specified. Analyses presented on a dry-weight basis.

Accuracy and precision: Not reported

REFERENCE NO: A290

Source: Schatz, C. E., (Bear Creek Mining Co.). 1965. Personal communication to W. Riedel.

Number of analyses stored: 54

Analyst: R. Spedden, Research Center, Kennecott Copper Corp., Salt Lake City.

Sample selection: Nodules, presumably bulk samples.

Sample preparation: Not reported

Elements analyzed and analytical method: Al, Ca, Co, Cu, Fe, Mg, Mn, Mo, Ni and Ti by atomic absorption; K and Na by flame photometry; P by colorimetry; Si and Ba by emission spectrography.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

Comments: Although most samples are described as nodules, some analyses reporting very low Mn ($\leq 6\%$) with low Fe and high Si are probably Mn-encrusted rocks or sediment balls.

REFERENCE NO: A291

Source: Cronan, D. S. 1973. Manganese nodules in sediments cored during Leg 16, Deep Sea Drilling Project. In *Initial Reports of the Deep Sea Drilling Project*, ed. Ansis G. Kaneps, 16: 605-08. Washington, D. C.: Government Printing Office.

Number of analyses stored: 22

Sample selection: Mostly nodules; one crust

Sample preparation: Ground to powder, dried in a desiccator at room temperature, digested in hot 50% HCl.

Elements analyzed and analytical method: Fe, Mn Co, Ni, Cu, Zn and Pb by atomic absorption (Techtron MK4).

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

Comments: Only the acid-soluble fractions were analyzed; element concentrations in the whole nodules would be less.

REFERENCE NO: A293

Source: Bäcker, H., G. P. Glasby and M. A. Meylan. March 1976. *Manganese nodules from the Southwestern Pacific Basin*. New Zealand Oceanographic Institute Oceanographic Field Report No. 6.

Number of analyses stored: 39

Analyst: Berkhopen Laboratory, Preussag AG, Germany

Sample selection: Fractions of nodules

Sample preparation: Dried at 110°C for 72 hours; pulverized and dried again 24 hours at 110°C; dissolved in HCl with H₂O₂; various dilutions.

Elements analyzed and analytical method: Mn, Fe, Ca, Al, Cu, Ni, Co, Zn, Mo by atomic

absorption; also Al by Na-K-carbonate smelting and Si by gravimetry.

Calibration standards and correction procedures: Because of large matrix effects for Mo, calibration solutions were made from "synthetic manganese nodule" with different amounts of Mo added.

Accuracy and precision: Mn, Fe, Cu, Ni, Co and Zn $\pm 2\%$; CaO $\pm 3\%$; SiO₂ $\pm 1\%$; Al₂O₃ $\pm 5\%$. Compared well with Metallgesellschaft samples, except Fe was 11-13% lower.

Comments: Probably reliable except perhaps for Fe.

REFERENCE NO: A294

Source: Sugimura, Y., Y. Miyake and H. Yanagawa. 1975. Chemical composition of ferromanganese nodules in the western North Pacific. *Papers in Meteorology and Geophysics* 26: 47-54.

Number of analyses stored: 3

Sample selection: Bulk analyses of nodules and crusts

Sample preparation: One or two grams of pulverized manganese concretion was dissolved in a hot solution of 6M HCl; separate treatment for rare earths.

Elements analyzed and analytical method: Mn, Fe, Ni and Co by "spectral analysis by means of permanganate, o-phenanthroline, dimethyl glyoxine, and nitroso-R salt method". Rare earths by x-ray fluorescence.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A296

Source: Goodier, J. Leslie. 1972. How manganese nodules develop. *Oceanology International Offshore Technology* 7, no. 4, pp. 45-48.

Number of analyses stored: 2

Analyst: George Ganung and W. R. Lasko, United Aircraft Research Laboratories

Sample selection: Nodules

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Si, Na, Mg, Ca, K, Ti, Al, V, Pb, Ba, Mo, Zr and Li by atomic absorption and wet chemistry.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A298

Source: Frazer, J. Z., M. B. Fisk, R. W. Fitzgerald and J. Guy. 1975-76. Unpublished analyses.

Number of analyses stored: 119

Analysts: Authors

Sample selection and preparation: Same as for Reference No. A405.

Elements analyzed and analytical method: Mn, Fe, Ni and Cu by x-ray energy spectrometry. The method used was basically the same as for A405, but the instrument was a prototype model of TEFA analyzer with no vacuum system. Because of low count rates, each sample was analyzed for 1000 seconds.

Calibration standards and correction procedures: Calibration curves were based on two natural nodule standards (one high Mn, one moderate Mn) previously analyzed by six different laboratories.

Accuracy and precision: From later comparison of results on some samples exchanged with other laboratories, we believe these analyses for Mn, Ni and Cu may be systematically low and for Fe high by 3-5% of the amount present (see Reference No. A405). Precision on all elements is within $\pm 5\%$ of the amount present.

REFERENCE NO: A301

Source: Korkisch, J., H. Hübner, I. Steffan, G. Arrhenius, M. Fisk and J. Frazer. 1976. Chemical analysis of manganese nodules: Part I. Determination of seven main and trace constituents after anion-exchange separation. *Analytica Chimica Acta* 83: 83-92.

Number of analyses stored: 17

Analysts: J. Korkisch, H. Hübner and I. Steffan

Sample selection: Representative bulk sections of nodules

Sample preparation: Dried 3 days at 110°C and kept in a desiccator. After dissolution in concentrated HCl, elements were adsorbed on a column of the strongly basic ion-exchange resin Darvex I; detailed description of procedure in source.

Elements analyzed and analytical method: Mn, Cu, Co, Zn, Cd, Pb and Ni by atomic absorption (Perkin Elmer 303); U by fluorimetry. (Ni results reported by J. Korkisch in personal communication, 1976).

Calibration standards and correction procedures: For Mn, Cu, Co and Pb, calibration curves were based on suitable standard solutions of the elements in 6M HCl. For Zn and Cd, standard solutions of these elements in 2M HNO₃ were used. More details in source.

Accuracy and precision: Not reported

Comments: The samples analyzed by this method were splits of powders prepared by M. Fisk; other splits of the same samples were analyzed by x-ray energy spectrometry (Reference No. A298). Almost all results by these two methods are within $\pm 6\%$ for Mn, $\pm 25\%$ for Ni, $\pm 10\%$ for Cu. Probably reliable except for Ni.

REFERENCE NO: A303

Source: Korkisch, J. 1976. Personal communication.

Number of analyses stored: 123

Analysts: J. Korkisch, H. Hübner and I. Steffan

Sample selection and preparation: Same as for Reference No. A301

Elements analyzed and analytical method: Mn, Co, Ni, Cu, Zn, Pb, Mo, Cd, Cr, V, Be, Al, Tl, U and Th (not all elements for all samples) by atomic absorption. Methods are reportedly the same as described in A301 except for Ni. For techniques used in Ni determinations, see Korkisch, Steffan and Fisk (1979, *Analytica Chimica Acta* 108: 63-68).

Accuracy and precision: Not reported

Comments: As for A301, samples analyzed were splits of powders prepared by M. Fisk, and other splits of the same samples were analyzed by x-ray energy spectrometry. From results of comparisons with other laboratories, we conclude the reported analyses are generally 10% high for Ni and 15% high for Cu.

REFERENCE NO: A321

Source: Fisk, M. B., R. W. Fitzgerald and J. Z. Frazer. 1976. Unpublished analyses.

Number of analyses stored: 47

Analysts: M. B. Fisk and J. Z. Frazer.

Sample selection and preparation: Same as for Reference No. A405.

Elements analyzed and analytical method: Mn, Fe, Ni and Cu by x-ray energy spectrometry; analytical method and correction procedures same as for Reference No. A298.

Accuracy and precision: See A298

REFERENCE NO: A322

Source: Calvert, S. E. and N. B. Price. 1977. Geochemical variation in ferromanganese nodules and associated sediments from the Pacific Ocean. *Marine Chemistry* 5: 43-74.

Number of analyses stored: 18

Sample selection: Bulk nodules

Sample preparation: Air dried at 100°C; ground in agate to pass 200 mesh sieve; fused in a mixture sample/La₂O₃/Li₂B₄O₇ = 1/1/8; ground to a powder in tungsten carbide, and pressed into a disc with boric acid.

Elements analyzed and analytical method: Si, Al, Ti, Fe, Ca, Mg, K, P, Mn, As, Ba, Ce, Co, Cu, Mo, Ni, Pb, Rb, Sr, Th, Y, Zn and Zr by x-ray fluorescence; C and CO₂ using Leco carbon analyser.

Calibration standards and correction procedures: Synthetic standards were prepared from spectrographically pure oxides. For minor elements, background radiation was used to correct for matrix effects; see paper referenced in source for details.

Accuracy and precision: Accuracy checked for three samples by wet chemistry. Precision is within $\pm 3\%$ but poorer for concentrations < 10 ppm. Authors suggest that a large amount of combined water is present in the samples, producing low totals for the major elements.

Comments: Probably reliable. Since combined water is usually included in samples analyzed, major element totals should not appear low in comparison with other analyses. Moreover, water is relatively transparent to x-rays; thus x-ray fluorescence analyses of dried and undried samples differ only slightly. Samples from most of these same locations have been analyzed by Cronan (Reference No. A240) and Kennecott Research Center (Reference No. A290); values for all elements are generally in same ranges for all three sources.

REFERENCE NO: A323

Source: Piper, D. Z. and M. Williamson. 1977. Composition of Pacific Ocean ferromanganese nodules. *Marine Geology* 23: 285-303.

Number of analyses stored: 16

Sample selection: Bulk nodules.

Sample preparation: Dried for 24 hours at 60°C and dissolved in 6N HCl for atomic absorption.

Elements analyzed and analytical method: Fe, Co, Cr, Sc, Ba and Th by neutron activation analysis. Mn, Ni, Cu and Zn by atomic absorption.

Calibration standards and correction procedures: Elemental determinations by means of additions.

Accuracy and precision: Better than 5% for Mn, Ni, Cu, Zn; better than 10% for other elements as determined by repeated analysis of single sample. Accuracy not discussed.

Comments: Probably reliable. Repeated analyses provide information on precision but not accuracy. However, a number of other investigators have analyzed samples from some of the same stations, and these analyses are within the same general range.

REFERENCE NO: A324

Source: Morgan, C. L. 1975. Nucleation and accumulation of marine ferromanganese deposits. Ph.D. dissertation, University of Wisconsin.

Number of analyses stored: 13

Analyst: Author

Sample selection: Nodules and crusts; bulk samples

Sample preparation: Dried at 110°C, ground to <177 μ , leached in $\text{NH}_2\text{OH HCl}$; residue dissolved in HClO_4 and HCl.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu and Zn by atomic absorption. Method described in detail in source.

Calibration standards and correction procedures: Standards were 1000 ppm commercially available standards.

Accuracy and precision: Accuracy varies for different elements but is within $\pm 4-8\%$ of the amount present. Methods of estimating accuracy are discussed in source. The precision reported includes sample variability for each set of samples as well as experimental variability and is thus not a measure of analytical precision.

Comments: Probably reliable

REFERENCE NO: A326

Source: Marchig, V. and H. Gundlach. 1976. Zur Geochemie von Manganknollen aus dem Zentral Pazifik und ihrer Sedimentunterlage: 1. Manganknollen. *Geologisches Jahrbuch* 16: 59-77.

Number of analyses stored: 98

Sample selection: Bulk nodules; also the 1-5 mm outer layers, middle layers and nuclei of nodules.

Sample preparation: Ground nodules dried 3 days at 105°C, then one gram dissolved in HCl (as reported in Gundlach and Marchig, 1975, Manganknollen von einer Station im äquatorialen Pazifik: Vorläufige mitteilung. Forschungsbericht M75-02 des Bundesministeriums für Forschung und Technologie).

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Zn, Pb and Si by atomic absorption (Perkin Elmer 503).

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A328

Source: Marchig, V. and H. Gundlach. 1976. Zur Geochemie von Manganknollen und ihrer Umgebung. IO 76-109.

Number of analyses stored: 18

Sample selection: Nodules and micronodules

Sample preparation: Not reported, but probably same as for Reference No. A326.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Zn, Pb and Si by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A331

Source: Craig, J. D. 1975. The distribution of ferromanganese nodule deposits in the north equatorial Pacific. Master's thesis, University of Hawaii.

Number of analyses stored: 4

Analyst: "Valdivia scientists and technicians"

Sample selection: Average of several bulk nodules from each location

Sample preparation: Dried in a microwave oven; powdered.

Elements analyzed and analytical method: Mn, Fe, Cu, Ni and Co by "standard atomic absorption methods" performed at sea.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Better than 10%; average deviation of 3% determined by replicate analyses.

Comments: Probably reliable

REFERENCE NO: A332

Source: Friedrich, G. H. W., Kuzendorf, H. and W. L. Plüger. 1974. Ship-borne geochemical investigations of deep-sea manganese-nodule deposits in the Pacific using a radioisotope energy-dispersive x-ray system. *Journal of Geochemical Exploration* 3: 303-317.

Number of analyses stored: 26

Sample selection: Nodule cross sections divided according to macroscopically visible internal structures. Different layers were analyzed, but values reported are the means for each location.

Sample preparation: Crushed to few mm diameter chips; dried at 110°C for one hour or less, then pulverized.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu and Zn by radioisotope energy dispersive x-ray system (EDAX) with 30-mci ²³⁸Pu source aboard *R/V Valdivia*. Analyzed 100 seconds.

Calibration standards and correction procedures: Standards used were 9 nodule samples analyzed by atomic absorption. Constant background was based on count rate in backscatter peak. K β x-ray contributions were subtracted and linear calibration curves used.

Accuracy and precision: Precision within 5% for Co, 3% for other elements

Comments: Probably reliable

REFERENCE NO: A333

Source: Kennecott Exploration, Inc. 1973-1976. Unpublished analyses of nodules from Lamont-Doherty Geological Observatory.

Number of analyses stored: 234

Analysts: B. Crawford and D. Felix.

Sample selection: Nodules and crusts; most sample types identified.

Sample preparation: Same as for Reference No. A334.

Elements analyzed and analytical method: Cu, No, Co, Fe and Mn by atomic absorption (Perkin-Elmer 305B).

Calibration standards and correction procedures: Not reported; probably same as for A334.

Accuracy and precision: Varies, but around 2% accuracy quoted.

Comments: Probably reliable. However, some unidentified samples have very low Mn (<5%) along with low Fe. These samples are probably Mn-encrusted rocks or sediment balls, and their analyses should not be considered to represent nodules.

REFERENCE NO: A334

Source: Greenslate, J., M. Fisk and D. Felix. 1979. Systematics in manganese concretion composition in the northeastern equatorial Pacific. In *La genèse des nodules de manganèse: Colloque No. 289 du C.N.R.S.* Paris: Editions du Centre National de la Recherche Scientifique.

Number of analyses stored: 40

Analyst: D. Felix

Sample selection: Whole nodules or composites of several nodules

Sample preparation: Dried 105-110°C for 24 hours; ground to <125 μ ; dried several additional hours.

Elements analyzed and analytical method: Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Mo and Pb by atomic absorption (Perkin-Elmer 305B). Dissolution methods described completely in source.

Calibration standards and correction procedures: Prepared by dissolving spectrographically pure metals in HCl.

Accuracy and precision: Better than 5%, except Cr, Mo and Pb better than 10%; determined by replicate analyses. Accuracy not discussed.

Comments: Probably reliable

REFERENCE NO: A335

Source: Piper, D. Z. 1976. DOMES Area C: General statement about mineralogy, diagenesis and sediment classification. In *Deep Ocean Mining and Environmental Study, NE Pacific Nodule Province, Site C, Geology and Geochemistry*. U. S. Geological Survey Open-File Report 76-548.

Number of analyses stored: 8

Sample selection: Whole nodules and outer layers; samples identified.

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Cu, Ni and Zn; method not specified.

Accuracy and precision: Not reported

REFERENCE NO: A342

Source: Fisk, M. B., R. W. Fitzgerald and J. Z. Frazer. August-December 1976. Unpublished.

Number of analyses stored: 57

Analysts: M. Fisk and J. Frazer

Sample selection and preparation: Same as for Reference No. A405.

Elements analyzed and analytical method: Mn, Fe, Ni and Cu by x-ray energy spectrometry; analytical method and correction procedures same as for Reference No. A298.

Accuracy and precision: See A298

REFERENCE NO: A343

Source: Skornyakova, N. S. 1976. Chemical composition of ferromanganese nodules of the Pacific [in Russian]. In *Ferromanganese Nodules of the Pacific Ocean [in Russian]*. ed. P. L. Bezrukov. Transactions of the P. P. Shirshov Institute of Oceanology, vol 109, pp. 190-240. *Note:* Analyses in appendix.

Number of analyses stored: 288

Sample selection: Mostly nodules, some crusts. Sections analyzed were usually outer layers or representative bulk samples; most samples identified.

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu and also sometimes Ti by wet chemistry; methods as described in Reference No. A205. Zn and Pb by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A344

Source: Frakes, L. A., N.F. Exon and J. W. Granath. 1979a. Preliminary studies on the Cape Leeuwin manganese nodule deposit off western Australia. *BMR Journal of Australian Geology and Geophysics* 2: 66-99.

_____. 1979b. Chemistry of manganese nodules from the Cape Leeuwin field off western Australia. *Ibid.*, pp. 232-233.

Number of analyses stored: 21

Analysts: (1) Australian Mineral Development Laboratory; Adelaide (2) Bureau of Mineral Resources, Canberra; (3) Monash University, Clayton, Victoria.

Sample selection: Bulk nodules

Sample preparation: Dried at 105°C

Elements analyzed and analytical method: Fe, Mn, Ni, Cu and Co; (1) and (2) by atomic absorption; (3) by x-ray fluorescence.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Accuracy better than 10%, by comparison of results from the three laboratories.

Comments: Probably reliable

REFERENCE NO: A345

Source: Pasho, D. 1977. Personal communication.

Number of analyses stored in data bank: 8

Sample selection: Nodule halves

Sample preparation: Not reported

Elements analyzed and analytical method: Fe, Mn, Ni, Co and Cu by atomic absorption

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A346

Source: Krishnaswami, S. 1976. Authigenic transition elements in Pacific pelagic clays. *Geochimica et Cosmochimica Acta* 40: 425-434.

Number of analyses stored: 11

Sample selection: One-centimeter outer layers of nodules

Sample preparation: For atomic absorption analyses, dried 2 hours at 110°C, digested in HF-HClO₄, residue dissolved in 0.1-0.2 M HCl.

Elements analyzed and analytical method: Fe, Mn, Ni and Cu by atomic absorption; Sc, Co and La by neutron activation; Ti by colorimetry; Th and U by alpha spectrometry.

Calibration standards and correction procedures: Not reported

Accuracy and precision: ±10% precision in duplicated measurements. Accuracy not discussed.

REFERENCE NO: A348

Source: Friedrich, G. H. 1976. Manganese micronodules in deep-sea sediments and their relation to manganese nodules fields. In *Papers Presented at the IDOE Workshop, Suva, Fiji, 1-6 September, 1975: Marine Geological Investigations in the Southwest Pacific and Adjacent Areas*, ed. G. P. Glasby and H. R. Katz. United Nations Economic and Social Commission for Asia and the Pacific (CCOP/SOPAC Technical Bulletin No. 2), pp. 39-53.

Number of analyses stored: 13

Sample selection: Nodules and micronodules

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Ni and Cu for micronodules by electron microprobe. Mn, Fe, Co, Ni, Cu and Zn for macronodules by x-ray energy spectrometry; same method as for Reference No. A332.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Microprobe data "may be used only in a qualified sense because of the well-known difficulties of microprobe analysis of porous ferromanganese oxide material." See A332 for estimate of x-ray energy spectrometry precision.

REFERENCE NO: A349

Source: Monzier, M. 1976. Manganese nodules and encrustations in the vicinity of New Caledonia and the Loyalty Islands. In *Papers Presented at the IDOE Workshop, Suva, Fiji, 1-6 September 1975*, ed. G. P. Glasby and H. R. Katz. United Nations Economic and Social Commission for Asia and the Pacific (CCOP/SOPAC Technical Bulletin No. 2), pp. 124-128.

Number of analyses stored: 6

Analyst: Mr. Job, ORSTROM Laboratory, Noumea

Sample selection: Mn-encrusted rocks, some nodules. Nuclei included when present. Results presented consist of various averages, such as "mean of analysis of 10 nodules without visible nuclei."

Sample preparation: Not specified. No information on drying, but loss-on-ignition specified as ranging from 14-18%.

Elements analyzed and analytical method: Si, Al, Fe, Mn, Ca, Mg, K, Na, Ni, Cr and Cu; method not specified.

Accuracy and precision: Not reported

REFERENCE NO: A350

Source: Halbach, P., M. Özkara and J. Hense. 1975. The influence of metal content on the physical and mineralogical properties of pelagic manganese nodules. *Mineralium Deposita* 10: 397-411.

Number of analyses stored: 5

Sample selection: Nodules

Sample preparation: Dried to constant weight at 110°C.

Elements analyzed and analytical method: Fe, Mn, Ni, Cu, Co, Zn and Ti; method not specified.

Accuracy and precision: Not reported

Comments: Some of these analyses could not be stored in the data bank because the station locations are unknown.

REFERENCE NO: A352

Source: Felix, David. (Kennecott Exploration, Inc.). 1973. Personal communication.

Number of analyses stored: 9

Sample selection and preparation, elements analyzed and analytical method: Same as for Reference No. A333.

Accuracy and precision: Same as for A333.

Comments: Probably reliable

REFERENCE NO: A354

Source: Smith, J. D. and J. D. Burton. 1972. The occurrence and distribution of tin with particular reference to marine environments. *Geochimica et Cosmochimica Acta* 36: 621-629.

Number of analyses stored: 14

Analyst: Authors

Sample selection: Nodules

Sample preparation: Dissolved in HCl + HF. Further detail on solutions in source.

Elements analyzed and analytical method: Mn, Fe, Ca, Co, Ni and Cu by atomic absorption. Sn by a precise spectrophotometric method using phenylfluorone.

Calibration standards and correction procedures: Not reported.

Accuracy and precision: Coefficients of variation were between 1.3 and 1.7%, except 2.7% for Co. A number of other investigators have analyzed nodules from the same or nearby locations. By comparison, analyses reported in A354 seem to be anomalously high, particularly for Mn and Ni. For many of these analyses, combined Mn and Fe are extremely high (68%, for example). These analyses, if they are accurate, must represent only the manganate and iron oxide phases, not bulk nodule composition.

REFERENCE NO: A355

Source: Landmesser, C. W., L. W. Kroenke, G. P. Glasby, G. H. Sawtell, S. Kingman, E. Utanga, A. Utanga and C. Cowan. 1976. Manganese nodules from the South Penrhyn Basin, Southwest Pacific. *South Pacific Marine Geological Notes* 1, no. 3, pp. 17-40.

Number of analyses stored: 13

Analyst: Australian Mineral Development Laboratory.

Sample selection: Bulk samples of nodules, completely described in source. Clay-rich inner zones where included, but where there was a discernable nucleus (three samples), it was removed.

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Ni, Cu, Zn, Co, Mo, Pb, U, Th, Nb, Zr, Ta and W by x-ray fluorescence and atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A356

Source: Dugolinsky, Brent K. 1976. Chemistry and morphology of deep-sea manganese nodules and the significance of associated encrusting protozoans on nodule growth. Ph.D. dissertation, University of Hawaii.

Number of analyses stored: None

Analyst: Author

Sample selection: Whole nodules with "obvious non-manganese nuclear material" removed.

Sample preparation: Cleaned ultrasonically to remove adhering sediment; ground to less than 45 μ ; pressed into SPEX caps at 10,000 psi. Some samples were diluted with boric acid or lithium tetraborate, but most samples were analyzed undiluted.

Elements analyzed and analytical method: Mn, Fe, Ni, Cu, Si, Zn, Mg, Al, K, Ca and Ti by x-ray energy spectrometry (EDAX).

Calibration standards and correction procedures: "Laboratory prepared nodule standards covering the range of elemental compositions for reported nodule analyses" were prepared and yielded linear calibration curves. Composition of standards was determined spectrophotometrically on triplicate 100 mg samples; variation was less than 1%. Elemental concentrations calculated using the EDIT 7/EP computer program which performs corrections for inter-element effects.

Accuracy and precision: Analysis of a standard nodule sample (GRLD 126) was compared with results from five other laboratories. The result for Ni was 21% above the average of the other laboratories, and the result for Cu was 57% higher.

Comments: Dugolinsky (1977, personal communication) reported sudden power loss or power surges with the x-ray tube while these analyses were being performed. Analyses from this source are unreliable and were not added to the data bank, but most of the same samples were re-analyzed by Fisk (Reference Nos. A405 and A422).

REFERENCE NO: A357

Source: Yamakoshi, K. 1971. The origin of nickel component in marine sediments. *Memoirs of the Faculty of Sciences*. Series of Physics, Astrophysics, Geophysics and Chemistry 33, no. 3, pp. 311-323. Kyoto University.

Number of analyses stored: 2

Sample selection: Nodules

Sample preparation: Not reported

Elements analyzed and analytical method: Ni, Fe, Mn: method not specified.

REFERENCE NO: A361

Source: Fujinuki, T., T. Mochizuki and T. Moritani. 1977. Chemical composition of manganese nodules. In *Deep sea mineral resources investigation in the central-eastern part of Central Pacific Basin, January—March 1976*, ed. A. Mizuno and T. Moritani, pp. 162-171. Geological Survey of Japan Cruise Report No. 8.

Number of analyses stored: 70

Sample selection: Whole nodules

Sample preparation: Immersed in running ion-free water to eliminate seawater, air dried 2 days, ground to $<105\ \mu$, then air dried for 3 days.

Elements analyzed and analytical method: Mn and Fe by volumetric analysis; Cu, Ni, Co, Pb, Zn by atomic absorption (Shimodzu AA680). Analytical procedures described completely in source.

Calibration standards and correction procedures: For atomic absorption, concentrations were "determined from a calibration graph, which was prepared using a series of synthetic standard solutions having a composition similar to the sample solution."

Accuracy and precision: Not reported. Standard deviations reported are for average composition at each station, and represent sample variability rather than precision.

Comments: Total water content reported ($H_2O^\pm$) was 17-26%, indicating that some surface moisture remained in the samples (bound water and surface water each are usually about 15% of total samples). Thus reported values for all elements would be about 5-10% lower than actual values for nodules with surface moisture removed by heating to 110°C.

We have analyzed a few samples from the same stations (see Reference No. A437), and even after the Geological Survey of Japan analyses are corrected for water content, they are lower than our analyses for Mn, Fe, Ni and Cu. However, we have not analyzed enough comparison samples to draw any general conclusions.

REFERENCE NO: A364

Source: Heady, H. H. 1967. *Collection and analysis of marine manganese nodules*. U. S. Bureau of Mines Open File Report No. 41.

Number of analyses stored: 9

Sample selection: A ten-pound cut of nodules was hand picked from each dredge haul.

Sample preparation: Pulverized to -100 mesh, dried to constant weight at 110°C.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Si, Al, Ca, Mg, Ti, P, C and S by wet chemistry; Na, K and Li by flame photometry using the addition technique for preparation of standard solutions; V, Mo Pb and Sr by emission spectrography; Zn and Zr by x-ray fluorescence.

Calibration standards and correction procedures: Standards described in source.

Accuracy and precision: Emission spectrography determinations were semiquantitative. Precision of other element measurements not reported.

REFERENCE NO: A365

Source: Brooke, J. N. and A. P. Prosser. 1969. Manganese nodules as a source of copper and nickel—mineralogical assessment and extraction. *Institute of Mining and Metallurgy* 78: C63- C72.

Number of analyses stored: 3

Sample selection: Nodules

Sample preparation: Dried 15 minutes at 110°C, stored over silica gel, digested with hot concentrated HCl.

Elements analyzed and analytical method: Mn, Fe, Co, Ni and Cu by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

Comments: Since these nodules were dried only 15 minutes, they probably contain some moisture; thus results could be low in comparison with samples dried to constant weight at 110°C.

REFERENCE NO: A366

Source: Nohara, M. 1976. Geochemical characteristics in Pacific Ocean manganese nodules and its controlling factors [in Japanese]. *Marine Sciences Monthly* 8: 744-750.

Number of analyses stored: 9

Sample selection: Nodules and one crust

Sample preparation: Not reported; probably same as for Reference No. A361.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu and Zn; method not specified, but is probably same as for A361.

Accuracy and precision: Not reported

REFERENCE NO: A368

Source: Cronan, D. S. 1975. Manganese nodules and other ferromanganese oxide deposits from the Atlantic Ocean. *Journal of Geophysical Research* 80: 3831-3837. *Note:* analytical data in microfiche appendix.

Number of Analyses Stored: 146

Sample selection: Nodules and crusts

Sample preparation: After grinding, samples were dried overnight in a desiccator, digested in hot 50% HCl and kept hot until reaction ceased.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Na, K, Ca, Mg, Yb and Zn by atomic absorption (Techtron Mk4).

Calibration standards and correction procedures: Not reported

Accuracy and precision: Based on replicates of each sample, precision at one standard deviation is better than 4% for Mn, Cr, Mg and Ca; 4.8% for Ni; 7% for Zn; 7.9% for Fe; 8.5% for Cu; 9% for K; 12.6% for Na. Accuracy not discussed.

Comments: Only the material soluble in HCl was analyzed; thus the analyses represent only the detrital-free iron and manganese oxide phases in the samples plus the water content. Detrital content was measured but unfortunately was not reported. These analyses are useful for information about element ratios in the iron and manganese oxide phases or to indicate maximum values, but they cannot be considered representative bulk analyses.

REFERENCE NO: A374

Source: Hathaway, J. C. 1971. *Sample collection and analytical data*. Data File: Continental Margin Program, Atlantic Coast of the United States, vol 2. Woods Hole Oceanographic Institute Reference No. 71-15.

Number of analyses stored: 15

Analysts: F. T. Manheim for most elements; V and Mo by Analytical Laboratories Branch, U. S. Geological Survey, Washington, D. C.

Sample selection: Nodules and crusts

Sample preparation: Samples fluxed with lithium tetraborate at 1000°C; the resulting glass ground, mixed with graphite and pressed into pellets.

Elements analyzed and analytical method: Mn, Fe, Ni, Cu, Co, Si, Al, Ti, Ca, Mg, Sr, K, Na, P, C, Zn and Ba, by emission spectrography; V and Mo (semiquantitative) by unspecified method.

Calibration standards and correction procedures: Correction procedures described in source.

Accuracy and precision: Not reported

Comments: Results are reported on total weight basis and are thus 10-15% lower than if reported on basis of samples dried at 110° C.

REFERENCE NO: A376

Source: Fisk, M. B., J. Z. Frazer and R. W. Fitzgerald. 1977. Unpublished analyses.

Number of analyses stored: 175

Analyst: Authors

Sample selection and preparation, elements analyzed, analytical method and correction procedures: Same as for Reference No. A405.

Accuracy and precision: See A405. Because of errors in sample preparation, some Co values originally reported in A376 were too high. These have since been corrected in the data bank files.

REFERENCE NO: A379

Source: Hoover, Mauricio Porcile. 1967. Studies on the dissolution of Cu, Ni and Co from ocean Mn nodules. Ph.D. dissertation, University of California, Berkeley.

Number of analyses stored: 3

Analyst: Author

Sample selection: Samples selected from 5 pounds of crushed nodules for each location.

Sample preparation: Dissolved in HCl.

Elements analyzed and analytical method: Mn, Fe, Co, Ni and Cu by atomic absorption (Perkin Elmer 303).

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

Comments: Results are presented on a wet basis, and samples average 25% water. It is not known whether results are presented for bulk material or for acid-soluble fractions only.

REFERENCE NO: A380

Source: Frank, D. J., M. A. Meylan, J. D. Craig and G. P. Glasby. 1976. *Ferromanganese Deposits of the Hawaiian Archipelago*. Hawaii Institute of Geophysics, University of Hawaii, UNIHl-Seagrant-Cr-77-01, HIG 76-14.

Number of analyses stored: 32

Analyst: D. J. Frank

Sample selection: Nodules, crusts and Mn-encrusted rocks (crust and substrate together).

Sample preparation: Samples dried under unspecified conditions. Detailed description of dissolution procedures in source.

Elements analyzed and analytical method: Fe, Mn, Al, Co, Cu and Ni by atomic absorption; Ti by x-ray energy spectrometry (EDAX).

Calibration standards and correction procedures: For atomic absorption, standards prepared in 1N HNO₃ from Hartman-Leddon standard reference solutions. For x-ray fluorescence, standards were Fe-Mn oxides previously analyzed by atomic absorption and x-ray fluorescence.

Accuracy and precision: A number of replicate samples were analyzed and some samples reanalyzed as a check on precision. Also, results on Marine Standard Nodule GRLD-126 were compared with those from other laboratories. Overall accuracy and precision averages 5-10%.

Comments: Probably reliable

REFERENCE NO: A381

Source: Fuerstenau, D. W. 1966. Metal recovery from manganese nodules. Office of Research Services, College of Engineering, University of California, Berkeley. Unpublished.

Number of analyses stored: 18

Sample selection: Nodules

Sample preparation: Polished for microprobe analysis; not dried.

Elements analyzed and analytical method: K, Ca, Ti, Mn, Fe, Co, Ni, Cu and Zn by electron microprobe (ARL), using low beam currents to prevent dehydration. Analyses reported are mean compositions for traverses across the nodules. Co, Ni and Cu analyzed also by colorimetry on some of the specimens; method described in source.

Calibration standards and correction procedures: For electron microprobe, pure metals and oxides first used as standards, then the well analyzed nodule DWHD-16 (procedure described in source). No correction procedures reported to account for inter-element effects.

Accuracy and precision: Accuracy of 5-10%. Agreement between electron microprobe and colorimetry analyses is usually within 20% of amount present.

REFERENCE NO: A383

Source: Piper, D. Z. (U. S. Geological Survey, Menlo Park). 1977. Unpublished analyses of samples collected during 1972 *Seascope* cruise.

Number of analyses stored: 96

Sample selection: Nodules, presumably bulk samples

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu and Zn by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A385

Source: Greenslate, J. 1977. Personal communication.

Number of analyses stored: 12

Sample selection: Nodule halves

Sample preparation: Dried at 105°C to constant weight.

Elements analyzed and analytical method: Mn, Fe, N, Cu, Co, Ca, Ti and Si by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: $\pm 1\%$ for Mn; $\pm 5\%$ for Fe, Ni, Cu, and Ca; $\pm 10\%$ for Ti and Si.

REFERENCE NO: A386

Source: Greenslate, J., M. Krutein and D. Pasho, eds. 1978. *Initial report of the Seascope Expedition*, vol. 2, appendix E. U. S. Department of Interior, Bureau of Mines, Spokane, Washington.

Number of analyses stored: 165

Sample selection: Representative samples of nodules

Sample preparation: Dried at 110°C at least 24 hours. Details of sample preparation in source.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu and Mo by x-ray fluorescence and/or wet chemistry. Analytical procedures described in detail in source.

Calibration standards and correction procedures: A synthetic blank was used to zero the spectrophotometer for colorimetric determination of Co, Ni and Cu. NBS steel standards were used as standards for wet chemical analysis of Mn and Fe. Nodule samples previously analyzed by wet chemistry were used as standards for x-ray analysis.

Accuracy and precision: Not discussed. However, results from wet chemistry and x-ray fluorescence seldom differ by more than $\pm 3\%$ of amount present for Mn and Fe, $\pm 10\%$ for Co and Ni, $\pm 15\%$ for Cu.

Comments: Probably reliable.

REFERENCE NO: A388

Source: Willis, J. P. 1970. Investigations on the composition of manganese nodules with particular reference to certain trace elements. Master's thesis, University of Cape Town.

Number of analyses stored: 66

Analyst: Author

Sample selection: Various parts of nodules; each sample identified.

Sample preparation: Ground to pass 120-mesh sieve. Except for estimation of Ti, all analysis carried out on "air-dried" materials.

Elements analyzed and analytical method: Mn, Fe, Ni, Cu, Co, Zn, Mo, Nb, Zr, Y, Sr, Pb, As, Ga, Ca, S, P and Si by x-ray fluorescence; Ti by emission spectroscopy; Ba by atomic absorption. Source contains detailed discussion of analytical techniques and correction procedures.

Calibration standards and correction procedures: Artificial standards were used for Mn, Fe, Ni, Cu and Co.

Accuracy and precision: Precision varies according to concentration; for most elements precision is better than 10%. For trace elements, accuracy is thought to be approximately 10%, "but for some of the major and minor elements, the results may be subject to a systematic bias due to calibration problems." Bias most likely for Mn and Fe.

Comments: Samples probably contained some surface moisture, but this would make very little difference for x-ray fluorescence. Probably reliable except for Mn and Fe.

REFERENCE NO: A389

Source: Yabuki, H. 1971. Fission track analysis of uranium in manganese nodules collected from Pacific Ocean Floor. *Scientific papers* 65, nos. 3-4, pp. 100-104. Institute of Physical and Chemical Research [of Japan].

Number of analyses stored: 16

Sample selection: Mn-Fe phases of nodules separated from silicate phases.

Sample preparation: Heated several hours at 200°C. 10 ml of 3N HCl and a few drops of 30% H₂O₂ added to 50 mg of each sample.

Elements analyzed and analytical method: Mn, Fe, Cu, Ni and Co by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

Comments: Analyses reported are on the acid-soluble fraction. These are included in the data bank, but in addition we have calculated and stored bulk compositions. It is not known how much of the total water would be removed at 200°C, but recalculated values may be slightly higher than results for comparable samples dried at 110°C.

REFERENCE NO: A390

Source: Andrushchenko, N. F., B. P. Gradusov, V. A. Yeroshchev-Shak, R. S. Yanshina and S. Ye. Borisovskiy. 1975. Composition and structure of metamorphosed ferromanganese nodules, new vein formations of manganese hydroxides, and the surrounding pelagic sediments on the Southern Basin of the Pacific Ocean floor. *International Geology Review* 17: 1375-1392.

Number of analyses stored: 3

Sample selection: Bulk nodule and outer layers of nodules

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Si, Ti, Al, Mg, Ca, Na, K, P and Cl; method not specified.

Accuracy and precision: Not reported

REFERENCE NO: A391

Source: Piper, D. Z., W. Cannon and K. Leong. 1977. Composition and abundance of ferromanganese nodules at DOMES Sites A, B and C: Relationship with bathymetry and stratigraphy. In *Deep ocean environmental study: Geology and geochemistry of DOMES sites A, B and C, equatorial North Pacific*, compiled by D. Z. Piper. U.S. Geological Survey Open File Report 77-778.

Number of analyses stored: 67

Sample selection: Whole nodules or cross sections taken from the dominant size class in each box core.

Sample preparation: Samples washed free of sea salts, dried at 110°C, and powdered.

Elements analyzed and analytical method: Ni, Cu, Co, Zn, Fe and Mn determined on acid (6N HCl) soluble fraction by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Precision better than $\pm 2\%$ for each element. Accuracy not discussed.

Comments: Apparently analyses were presented on bulk basis rather than acid-soluble fraction, because in comparison with analyses by other investigators for nodules from the same locations they are usually the same or lower in Mn, Ni and Cu.

REFERENCE NO: A392

Source: International CLB Group. 1977. Personal communication.

Number of analyses stored: 85

Analysts: Three different laboratories, not specified

Sample selection: "It is assumed that these assays were run on a standard sampling of the entire contents of each bag."

Sample preparation: Some dried at 105°C; some dried for one hour at 125°C; some report "ignition loss" possibly indicating drying at higher temperatures; for some assays it is unknown whether assays were run on a dry-weight or as-is basis.

Elements analyzed and analytical method: Mn, Fe, Co, Ni and Cu for all samples; S, Si, Al, Ca, Mg, Mo, P, Na, K, Ba, Zn and/or Pb for some. Some samples analyzed by atomic absorption; for most, method not specified.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A393

Source: International CLB Group. 1977. Personal communication.

Number of analyses stored: 16

Sample selection: Composites of several nodules representing bulk of material at each location.

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Co, Ni and Cu; usually Fe and Si. Method not specified.

Accuracy and precision: Not reported

REFERENCE NO: A394

Source: Moritani, T., T. Mochizuki, S. Terashima and S. Maruyama. 1979. Metal contents of manganese nodules from the GH77-1 Area. In *Deep sea mineral resources investigation in the central-western part of central Pacific Basin, January—March 1977*, ed. T. Moritani, pp. 206-217. Geological Survey of Japan Cruise Report No. 12.

Number of analyses stored: 118

Sample selection: Nodules

Sample preparation, elements analyzed and analytical method: Same as for Reference No. A361.

Accuracy and precision: See Reference No. A361.

REFERENCE NO: A398

Source: Greenslate, J. 1974. Personal communication.

Number of analyses stored: 3

Analyst: Author

Sample selection: Nodule halves

Sample preparation: Dried at 105°C to constant weight.

Elements analyzed and analytical method: Mn, Fe, Ni, Cu, Ca and Ti by x-ray energy spectrometry; analytical method and calibration standards probably same as for Reference No. A244.

Accuracy and precision: Probably same as for A244.

Comments: Probably reliable except for Ti; Ba $L\alpha$ peak interferes with Ti $K\alpha$ and cannot be separated from Ba in x-ray energy spectrometry.

REFERENCE NO: A402

Source: LeClaire, L., M. Clocchiatti, P. J. Gianesini and J. P. Caulet. 1977. Dépôts metallifères dans l'océan Indien austral: données nouvelles sur la genèse et la prospection des champs de nodules. *Bulletin BRGM*, (Second series), Section II, no. 1, pp. 13-42.

Number of analyses stored: 2

Analyst: MM. Michard and Renard, Laboratoire de Géochimie des Eaux.

Sample selection: Nodules

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Cu, Ni, Co, Zn and Pb, probably by atomic absorption.

Accuracy and precision: Not reported

REFERENCE NO: A405

Source: Frazer, J. Z., M. B. Fisk, J. Elliott, M. White and L. Wilson. 1978. *Availability of copper, nickel, cobalt and manganese from ocean ferromanganese nodules*. Scripps Institution of Oceanography Reference No. 78-25.

Number of analyses stored: 300

Analyst: M. B. Fisk

Sample selection: Nodules or crusts. The sections selected for analysis usually represent the bulk nodule or crust (including nucleus if any): for example, whole or half or quarter nodules or cross-sections. In some cases nuclei were removed or various non-representative portions were analyzed (top or bottom layers, inner or outer layers). In all cases, the sample section analyzed has been identified.

Sample preparation: Samples dried at 110°C for at least 36 hours, ground to pass through a 74 μ sieve, pressed undiluted into pellets under 24,000 psi, redried for another 12 hours at 110°C, and stored in a desiccator until analysis.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Ca, Zn and Pb by x-ray energy spectrometry (ORTEC 611A TEFA) operated at 35 kV with Mo-filtered radiation from a Mo anode. Operating conditions were chosen to minimize deadtime. Samples and standards were analyzed in vacuum 400 seconds, with standards analyzed between each set of 10 samples to monitor drift.

Calibration standards and correction procedures: Empirical methods were used to subtract out background and interfering K β peaks. Corrections for inter-element effects were based on linear working curves derived from four natural nodule samples which had previously been analyzed by several other laboratories plus nine secondary standards prepared by adding pure metal oxides to splits of two natural standards. Secondary standards were prepared in order to increase the applicable range of compositions to 10-35% Mn. Corrections to Ni and Co measurements were based on amounts of Mn and Fe in the samples. An additional empirical correction was performed for samples with high Ca content (>4%) because Ca strongly absorbs Mn K α radiation.

Accuracy and precision: Precision at the 95% confidence level is within 0.4 wt % for Mn, 0.2 wt % for Ca and Fe, 0.02-0.04 wt % for other elements. Based on inter-laboratory comparisons (blind analyses of the same samples covering a wide range of compositions by the authors and academic, government and industrial laboratories) accuracy is estimated to be within 5% of the amount present for Mn and Fe and 10% for other elements. Accuracy decreases, however, as element concentrations approach or exceed the limits of the normal range (see source for limits).

The accuracy of these analyses depends on accurate knowledge of the composition of the two primary standards used. Inter-laboratory comparisons indicate that the reported values for these standards may be 3-5 % low for Mn, Ni and Cu and high by the same percentage for Fe. This would imply similar systematic errors for all analyses reported in this source. The question cannot be resolved, however, until accepted international nodule standards (such as those presently being prepared by F. Flanagan of the U. S. Geological Survey) are available.

Because of faulty sample preparation, a few Co values were too high as originally reported. These have since been corrected for the analyses stored in the Sediment Data Bank.

REFERENCE NO: A407

Source: Felix, D. (Kennecott Exploration, Inc.) 1978. Personal communication.

Number of analyses stored: 4

Sample selection and preparation, elements analyzed and analytical method: Same as for Reference No. A333

Accuracy and precision: See A333

REFERENCE NO: A409

Source: Deepsea Ventures, Inc. 1965. Unpublished analyses of nodules from Scripps Institution of Oceanography archives.

Number of analyses stored: 14

Analyst: Newport News Shipbuilding and Drydock Co.

Sample selection: Nodules with "large inclusions of core materials removed"

Sample preparation: Air dried 2 hours at 200°C

Elements analyzed and analytical method: Mn, Cu, Fe, Ni and Co by emission spectrography.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported.

Comments: Loss-on-ignition values reveal at least some bound water was removed by the drying procedure; thus reported results may be slightly higher than if samples had been dried at 110°C.

REFERENCE NO: A411

Source: Calvert, S. E., N. B. Price, G. R. Heath and T. C. Moore, Jr. 1978. Relationship between ferromanganese nodule composition and sedimentation in a small survey area of the equatorial Pacific. *Journal of Marine Research* 36: 161-183.

Number of analyses stored: 19

Sample selection: "In addition to visually representative subsamples taken from individual nodules, more than one subsample was taken from some nodules from parts that clearly contained more or less aluminosilicate."

Sample preparation: Same as for Reference No. A322

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Si, Al, Ti, Ca, Mg, K, P, As, Ba, Ce, Mo, Pb, Rb, Sr, Th, Y, Zn and Zr by x-ray fluorescence; analytical method and correction procedures same as for A322.

Accuracy and precision: Precision within 5% for concentrations >10 ppm.

Comments: Probably reliable

REFERENCE NO: A413

Source: Piper, D. Z. 1974. Rare earth elements in ferromanganese nodules and other marine phases. *Geochimica et Cosmochimica Acta* 38: 1007-1022.

Number of analyses stored: 35

Sample selection: Nodules

Sample preparation: Not reported

Elements analyzed and analytical method: La, Ce, Sm, Eu, Yb, Lu, Nd and Tb by neutron activation analysis using TRIGA reactor.

Calibration standards and correction procedures: Normalized on element-by-element basis to standard which was unweighted average of REE contents of shales from North America,

Europe and Russia (M. A. Haskin and L. A. Haskin, *Science* 154: 507-509, 1966).

Accuracy and precision: Variations observed for triplicate analyses are 5% for La, Ce, Sm and Eu; 8% for Yb and Lu; 10% for Nd and Tb.

REFERENCE NO: A414

Source: Meylan, M. A., G. P. Glasby, J. C. McDougall and J. R. Singleton. 1978. *Manganese Nodules and Associated Sediments from the Samoan Basin and Passage*. New Zealand Oceanographic Institute Oceanographic Field Report No. 11.

Number of analyses stored: 9

Analyst: M. A. Meylan

Sample selection: Whole nodules

Sample preparation: Dried at 80°C, ground to a fine powder using mortar and pestle, mixed 1:1 by weight with boric acid powder, and pressed into pellets at approximately 10,000 psi.

Elements analyzed and analytical method: Mn, Fe, Ni, Cu and Co by x-ray energy spectrometry (EDAX) using 100-second count, 19 kV, 60 μ a.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Mn $\pm$ 10%, Fe $\pm$ 15%, Ni $\pm$ 40%, Cu $\pm$ 25%, Co $\pm$ 60%.

Comments: Analytical techniques and correction procedures used may have been the same as for Reference No. A356. If this was the case, errors are probably systematic rather than random and reported Ni and Cu values are high by about the amount of error cited.

REFERENCE NO: A415

Source: LeClaire, L. 1978. Fichier concrétions métallifères et sédiments associés de l'Océan Indien. *Actions Concertées "Nodules Polymétalliques,"* Conventions Nos. 76.7 et 77.7.1449. Laboratoire de Géologie du Muséum d'Histoire Naturelle.

Number of analyses stored: One

Analyst: Centre National pour l'Exploitation des Océans, Centre Océanologique de Bretagne

Sample selection: Nodule

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni and Cu; method unspecified.

Accuracy and precision: Not reported

REFERENCE NO: A416

Source: LeClaire, L. and E. A. Perseil. 1978. Minéralogie, composition chimique et milieux de sédimentation de concrétions polymétalliques dans l'Océan Indien. In *La genèse des nodules de manganèse: Colloque No. 289 du C.N.R.S.*, pp. 23-38. Paris: Editions du Centre National de la Recherche Scientifique.

Number of analyses stored: 44

Sample Selection: Nodules and crusts

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni and Cu; method not specified.

Accuracy and precision: Not reported

Comments: Values reported appear to be the average of separate analyses of several nodules at each site.

REFERENCE NO: A418

Source: Andersen, M. E. 1977. Accumulation rates of manganese nodules and sediments: An alpha track method. Master's thesis, University of California, San Diego.

Number of analyses stored: 18

Analyst: J. Greenslate

Sample selection: Nodules; probably halves or cross sections

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni and Cu by atomic absorption

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A419

Source: Addy, S. K. 1978. Personal communication.

Number of analyses stored: 340

Analyst: Kennecott Research Center (nodules from Lamont-Doherty Geological Observatory, analyzed 1967-68)

Sample selection: Nodules, micronodules, and Mn-coated sediment; all samples identified.

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni and Cu by wet chemistry

Accuracy and precision: Not reported

Comments: Some samples described as nodules or micronodules have extremely low Mn content (<6%). These probably contain large amounts of extraneous materials and may actually be Mn-coated rocks or sediments.

REFERENCE NO: A422

Source: Fisk, M. B., J. Z. Frazer, J. S. Elliott and L. L. Wilson. 1979. *Availability of copper, nickel, cobalt and manganese from ocean ferromanganese nodules (II)*. Scripps Institution of Oceanography Reference No. 79-17.

Number of analyses stored: 216

Analyst: M. Fisk

Sample selection and preparation, elements analyzed, analytical method and correction procedures: Same as for Reference No. A405.

Accuracy and precision: See A405

REFERENCE NO: A424

Source: Fewkes, R., W. MacFarland, W. Reinhart and R. Sorem. *Development of a reliable method for evaluation of deep sea manganese nodule deposits*. U. S. Department of the Interior, Bureau of Mines Final Report, Contract No. G0274013-MAS.

Number of analyses stored: 159

Analyst: W. Reinhart

Sample selection: Whole nodules selected to represent major size classes in each box core.

Sample preparation: Samples ground, pelletized and dried 4 hours at 110°C.

Elements analyzed and analytical method: Mn, Fe, Ni, Cu, Co and Zn by x-ray fluorescence (Phillips PW 1410-10).

Calibration standards and correction procedures: "Analyzed standards" used.

Accuracy and precision: $\pm 5\%$ of amount present.

Comments: Probably reliable

REFERENCE NO: A425

Source: Usui, A., S. Takenouchi and T. Shoji. 1976. Distributions of metal elements in manganese nodules and formation mechanism of constituent minerals, with special reference to nodules from Komabashi-Daini Seamount [in Japanese]. *Mining Geology* 26: 371-384..

Number of analyses stored: 9

Sample selection: Nodules, presumably bulk samples; also small volumes of 10Å manganate and δ -MnO₂ in nodules.

Sample preparation: For bulk analyses, heated 30-minutes at 350°C. For point analyses, impregnated with resin and carbon-coated.

Elements analyzed and analytical method: Bulk analyses of Ni and Cu by atomic absorption, Co by colorimetry, Fe by both methods and Mn by unknown method. Point analyses on 10Å manganates and δ -MnO₂ of Mn, Fe, Ni and Cu by electron microprobe.

Calibration standards and correction procedures: For electron microprobe, standards were Mn₃O₄, NiO and CuFeS₂.

Accuracy and precision: For bulk analyses, precision is $\pm 5\%$ for Fe, $\pm 3\%$ for Mn and Co, $\pm 2\%$ for Ni, and $\pm 1\%$ for Cu.

REFERENCE NO: A426

Source: Preussag Aktiengesellschaft. 1979. Personal communication on station locations, sediment descriptions and nodule chemistry for cruise VA-07 Indian Ocean.

Number of analyses stored: 36

Sample selection: Nodules

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu and Zn; method not specified. Most results reported are means of analyses of several nodules.

Accuracy and precision: Not reported

Comments: Probably reliable

REFERENCE NO: A433

Source: Colley, N. M., D. S. Cronan and S. A. Moorby. 1979. Some geochemical and mineralogical studies of recently collected ferromanganese oxide deposits from the north-west Indian Ocean. In *La genèse des nodules de manganèse: Colloque No. 289 du C.N.R.S.*, pp. 13-22. Paris: Editions du Centre National de la Recherche Scientifique.

Number of analyses stored: 110

Analyst: N. Colley

Sample selection: Manganese crusts; samples drilled out at points of varying depth within the specimens using a hand drill with 2 mm stainless steel bit.

Sample preparation: Ground in agate, dried in a desiccator to constant weight, subjected to standard HF/HNO₃/HClO₄ attack.

Elements analyzed and analytical method: Fe, Mn, Co, Pb, Ni, Cu, Zn, Al, Ti, Ca, Mg, Cd and Li by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Generally better than 10% and usually better than 5% except for Cd and Li, which had precisions generally worse than 15% because their concentrations were near the detection limits.

Comments: Probably reliable

REFERENCE NO: A435

Source: Siddiqui, H. N., D. R. Das Gupta, N. R. Sengupta, P. C. Shrivastava and T. K. Hallik. 1978. The manganese-iron nodules from the Indian Ocean. *Indian Journal of Marine Sciences* 7: 239-253.

Number of analyses stored: 13

Analyst: Geological Survey of India

Sample selection: Inner and outer layers of nodules; some whole nodules.

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Ni, Cu, Co, Mo, Zn, Ti, Pb, Sr, Ba, P, Al, Ca, Na, K, Si, C and Cr by wet chemistry; method described in detail in source. Moisture removed by heating to 110°C estimated from separate samples.

Accuracy and precision: Not reported

Comments: Before comparison with analyses of samples dried at 110°C, reported values should be increased by about 20% to compensate for included moisture.

REFERENCE NO: A437

Source: Frazer, J. Z. and M. B. Fisk. 1980. Appendix A, this work.

Number of analyses stored: 291

Analysts: Authors

Sample selection and preparation, elements analyzed, analytical method and correction procedures: Same as for Reference No. A405.

Accuracy and precision: See A405

REFERENCE NO: A438

Source: Siegel, M. and M. B. Fisk. In preparation. Geochemical studies of manganese nodules from the northeastern equatorial Pacific.

Number of analyses stored: 101

Analyst: M. Fisk

Sample selection and preparation, elements analyzed, analytical method and correction procedures: Same as for Reference No. A405.

Accuracy and precision: See A405

REFERENCE NO: A441

Source: Sorem, R. K. and R. H. Fewkes. 1979. *Manganese Nodules: Research and Methods of Investigation*. New York: IFI/Plenum.

Number of analyses stored: 48

Analyst: Some by W. R. Reinhart; others by outside laboratories.

Sample selection: Generally nodule halves; samples described.

Sample preparation: Not reported; probably same as for Reference No. A448.

Elements analyzed and analytical method: Mn, Fe, Ni, Cu, Co and Zn, and sometimes also Al, Ca, Mg, Na, K and Si, by x-ray fluorescence.

Calibration standards and correction procedures: Not reported; probably same as for A448.

Accuracy and precision: "Believed to be accurate within $\pm 10\%$ of the amount present."

Comments: Probably reliable

REFERENCE NO: A444

Source: Sorem, R. K., W. R. Reinhart, R. H. Fewkes and W. D. McFarland. 1979. Occurrence and character of manganese nodules in DOMES sites A, B, and C, east equatorial Pacific Ocean. In *Marine Geology and Oceanography of the Pacific Manganese Nodule Province*, ed. James L. Bischoff and David Z. Piper. New York: Plenum Press. *Note:* analytical data in microfiche appendix.

Number of analyses stored: none

Analyst: W. Reinhart

Sample selection: Nodule halves

Sample preparation: Pulverized, pelletized at 2000 kg/cm², and dried for 4 hours at 110°C.

Elements analyzed and analytical method: Mn, Fe, Ni, Cu, Co and Zn by x-ray fluorescence (Phillips PW 1410-10).

Calibration standards and correction procedures: Standards were nodules analyzed by three other laboratories.

Accuracy and precision: Precision better than 5% of amounts present.

Comments: No analyses from this source were added to the data bank, because they were recalculated and presented in Reference No. A448, which states that the analyses "differ slightly from analyses reported earlier [in A444]. This difference reflects an improvement in our analysis procedure resulting from the use of more accurate calibration standards." Values of Cu, Co and Zn are identical for the two sources, and Ni values are about 2% lower in A444. At the high-Mn end of the range (Mn >30%), Mn values in A444 are about 12% higher and Fe values are 6-22% higher. At the low-Mn end of the range (Mn <10%), values reported in A444 are 40-50% lower for Mn, and about 6% higher for Fe.

REFERENCE NO: A445

Source: Marchig, V. and H. Gundlach. 1979. Changes in chemical composition of some Pacific manganese nodules during their growth. In *Marine Geology and Oceanography of the Pacific Manganese Nodule Province*, ed. James L. Bischoff and David Z. Piper. New York: Plenum Press.

Number of analyses stored: 71

Sample selection: Nodules and micronodules from 21 different box cores within a 20' x 20' area; locations from which individual box cores were collected are not reported. Samples analyzed were nodule cross sections plus portions representing their centers, inner laminated zones and loose outer layers.

Sample preparation: Dissolved in 1:1 diluted HCl.

Elements analyzed and analytical method: Mn, Fe, Co, Ni, Cu, Al, Mg, Ca, Zn and Pb by atomic absorption; Si for some samples by gravimetry.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

REFERENCE NO: A446

Source: Andrews, J. E. and G. H. W. Friedrich. 1979. Distribution patterns of manganese nodule deposits in the northeast equatorial Pacific. *Marine Mining* 2: 1-43. *Note:* station locations from map in U. F. Stackelberg. Sedimentation, haituses and development of manganese nodules: Valdivia Site 13/2, northern central Pacific. In *Marine Geology and Oceanography of the Pacific Manganese Nodule Province*, ed. J. L. Bischoff and D. Z. Piper. New York: Plenum Press.

Number of analyses stored: 119

Sample selection: Nodules (one crust); reported results presumably represent bulk nodules for each location.

Sample preparation: Not reported

Elements analyzed and analytical method: Mn, Fe, Ni and Cu; method not specified.

Accuracy and precision: Not reported

REFERENCE NO: A448

Source: Fewkes, R. H., W. D. McFarland, W. R. Reinhart and R. K. Sorem. 1980. *Evaluation of metal resources at and near proposed deep sea mine sites. August 15, 1978 to September 29, 1979.* U. S. Bureau of Mines.

Number of analyses stored: 365

Analyst: W. Reinhart

Sample selection and preparation: Same samples for which analyses were reported in Reference No. A444.

Elements analyzed and analytical method: Mn, Fe, Ni, Cu, Co and Zn by x-ray fluorescence (Phillips PW 1410-10).

Calibration standards and correction procedures: Not reported

Accuracy and precision: $\pm 10\%$ of amount present for each element.

Comments: Probably reliable. Some analyses presented in this source were reported previously and are included in the data bank under Reference No. A424.

REFERENCE NO: A451

Source: Skornyakova, N. S., P. L. Bezrukov, E. S. Vasilevskaya and V. V. Gordeev. 1979. Ferromanganese concretions from the eastern Indian Ocean [in Russian]. *Litologiya i Poleznye Iskopaemye* 3: 3-18.

Number of analyses stored: 53

Sample selection: Nodules and crusts; some whole nodules with nuclei removed and some inner and outer layers.

Sample preparation: Not reported

Elements analyzed and analytical method: Mn and Fe by wet chemistry; Co, Ni and Cu by atomic absorption.

Calibration standards and correction procedures: Not reported

Accuracy and precision: Not reported

III. RESOURCE AREA UPDATES

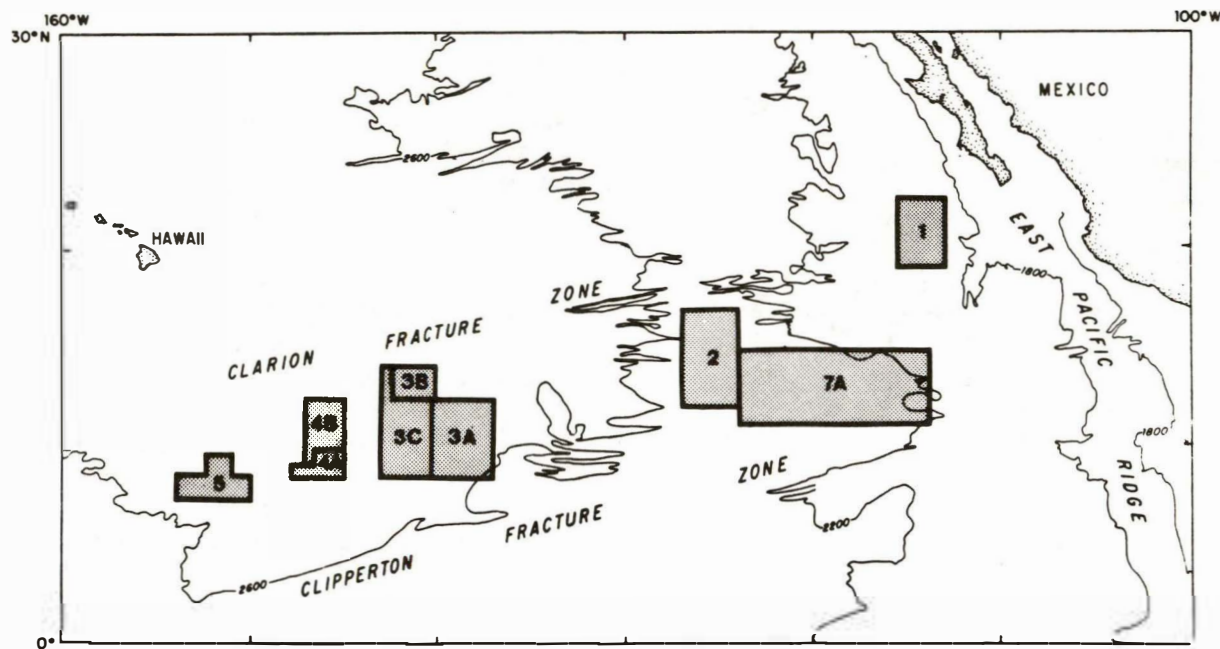


Fig. 2. Locations of resource areas in the northeastern equatorial Pacific.

Eight areas in the northeastern equatorial Pacific between the Clarion and Clipperton Fracture Zones (see Fig. 2) have been studied previously^{4,5}. Of those, only Areas 1-5 and Area 7A appeared to show any promise for seabed mining.

This section consists of updated studies of these areas based on data that has become available since our previous reports. Area maps are included where there are significant numbers of new data. Nodule analyses for these areas added to our files since August, 1978, are listed in Appendix A of this report and in Appendix B of

SIO Reference 79-17⁶. It may be noted that, although the amount of data on nodule composition has increased dramatically within the last two years and thus our confidence in our estimates has increased, average composition for most of these areas is about the same as previously reported. The greatest obstacle to estimating the resource potential of these areas is lack of adequate data on nodule abundance and seafloor topography.

⁴See footnote 1, page 7.

⁵J. Z. Frazer and M. B. Fisk, Reports to the Bureau of Mines on Grant G0254024 (1976) and Grant G0264024 (1977).

⁶M.B. Fisk, J. Z. Frazer, J. S. Elliott and L. L. Wilson, Availability of copper, nickel, cobalt and manganese from ocean ferromanganese nodules (II) (Scripps Institution of Oceanography Reference 79-17, unpublished, 1979).

AREA 1

Areal extent: 90,000 km² located within 19-22.25°N 113-115.5°W, as shown in Fig. 3. The inner portion, Area 1A, comprises about 6,000 km². Most of Area 1 is within 200 miles of Clarion Island.

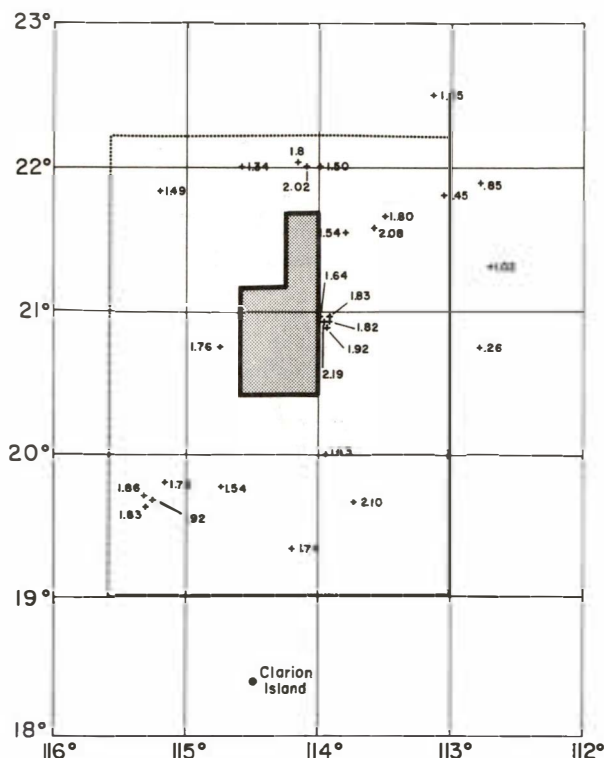


Fig. 3. Distribution of Ni + Cu in nodules from Area 1B. The shaded inner portion is Area 1A.

New information available: Data on manganese nodules in Area 1 were previously provided to Bureau of Mines in 1976. Since that time the number of analyses for Area 1 and its surroundings has more than doubled. Most of the new analyses are for two groups of stations centered at approximately 19.7°N, 115.3°W and 20.9°N, 114°W sampled by the *R/V Seascop* expedition in 1972. These locations were outside of the previous Area 1 boundaries, but we are now able to extend those boundaries because the new data indicate that nodule grade is rather uniform over a larger area.

Nodule abundance: Abundance has been measured at only three locations within Area 1,

and the mean of these is only 3.2 kg/m². However, it has been estimated⁷ that at least within Area 1A the nodules cover 20-50% of the ocean floor between the seamounts. The nodules from this region are rather large oblate spheroids about 6 cm in diameter. Assuming a wet density of 1.95 g/cc after Greenslate⁸, the 20-50% coverage range would translate to 8.5-21 kg/m².

Nodule grade: Area 1A (the shaded inner area in Fig. 3) has been intensively sampled, and analyses are available for 73 different locations. For the much larger outer portion, Area 1B, analyses are available for only 38 locations. Ni + Cu grade at these outer locations is shown in Fig. 3.

Average nodule composition for each sub-area is shown in Table 1. Composition differences between the two areas are statistically insignificant except for copper. Although there are some changes from the average grades reported in 1976, particularly for cobalt, the change in total Ni + Cu + Co grade is only +3% for both sub-areas. Frequency distributions for element concentrations in Area 1 nodules are shown in Fig. 4. Approximately 3/4 of the nodules contain Ni + Cu in the range of 1.5-2%. This is too low to meet the grade criterion for first-generation mining but high enough for the deposits here to be considered submarginal resources.

Conclusions: Area 1 is located in a seamount province characterized by rugged topography. The nodule deposits sampled occur in the valleys at depths of 3500-4000 m. Nodules may also occur on the seamounts, but no data for these locations are available. By analogy with other regions one would expect any seamount deposits to be lower in nickel and copper but higher in cobalt than the valley deposits.

Although typical nodule grade in Area 1 is well below the 2.27% Ni + Cu stated as a requirement for first-generation mining⁹, the location of

⁷John Mero, personal communication, 1975.

⁸See footnote 3, page 12.

⁹J. T. Kildow, M. B. Bever, V. K. Dar and A. E. Capstaff, Assessment of economic and regulatory conditions affecting ocean minerals resource development (Massachusetts Institute of Technology report to the U.S. Department of Interior, unpublished, 1976).

Table 1. Average Nodule Composition in Area 1

Element	Inner Area 1A				Outer Area 1B			
	Number of Analyses	Grade (Wt %)	Standard Deviation	Change from 1976 Average	Number of Analyses	Grade (Wt %)	Standard Deviation	Change from 1976 Average
Mn	119	25.5	2.9	-4%	102	25.2	3.7	+3%
Fe	90	10.3	2.3		100	10.1	2.5	
Co	55	0.16	0.10	+23%	100	0.14	0.12	+17%
Ni	119	1.10	0.23	+6%	102	1.06	0.24	-3%
Cu	111	0.66	0.15	-4%	88	0.72	0.24	+9%
Cu/Ni	111	0.61	0.11		87	0.68	0.24	
Ni+Cu	111	1.76			88	1.78		
Ni+Cu+Co		1.92				1.92		
Ni+Cu/3+2Co		1.64				1.58		

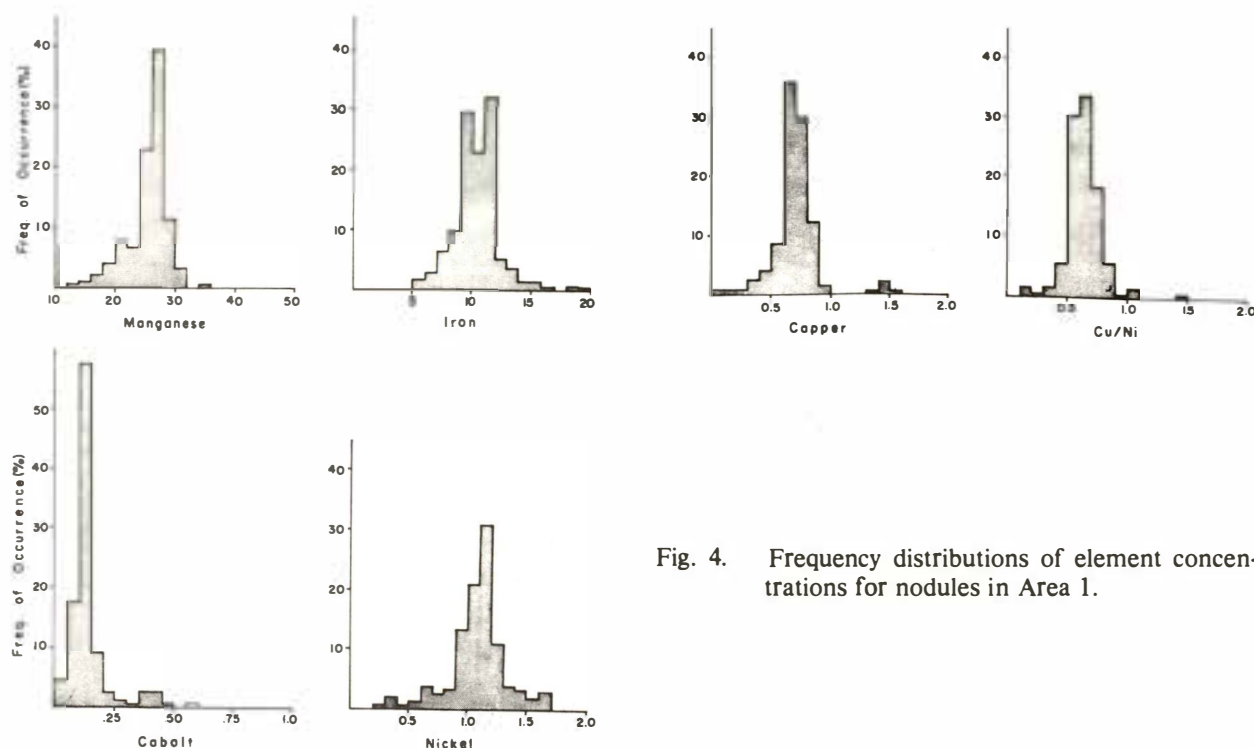


Fig. 4. Frequency distributions of element concentrations for nodules in Area 1.

these nodule deposits may to some extent offset this factor. Most of the area is within 200 miles of a Mexican island, so mining here would not be subject to international treaty provisions. The nodules occur at depths about 1000 m shallower than in other economically promising areas within the Clarion-Clipperton Zone, and this area is closer to land than most. The cost-saving effects of these factors must be analyzed before the resource value of these deposits can be established.

Table 2. Average Nodule Composition in Area 2

Element	Number of Analyses	Grade (Wt %)	Standard Deviation	Change from 1978 Average	Deviation from Area C Average*
Mn	475	26.3	3.9	-1%	-1%
Fe	473	7.0	1.5	-1%	
Co	397	0.27	0.07	0	0
Ni	475	1.31	0.19	-1%	-1.5%
Cu	475	1.01	0.24	-6%	-1.5%
Cu + Ni		2.32	0.40	-3%	
Cu + Ni + Co		2.59		-2%	
Ni + Cu/3 + 2Co		2.19			

*As reported by Fewkes et al, 1980.

AREA 2

Areal extent: 12-17°N, 124-127°W, 180,000 km². This area includes DOMES Site C.

New information available since August, 1978: No new locations within this area have been sampled since our last update, and all new analyses are from the same stations as those for which nodules had previously been analyzed. Many new nodule analyses and measurements of nodule abundance have been performed at Washington State University^{10,11,12} on box core samples collected by *R/V Oceanographer*, and these data have been added to our files. Some additional analyses of nodules from IDOE Manganese

Nodule Project cruises have been performed in our laboratory. There are now 475 analyses available for Area 2, 80% more than were available in 1978.

Nodule abundance: Fewkes et al¹¹ have determined nodule abundance in their Area C, which includes DOMES Site C and the surrounding area between 13.5-16.5°N, 124.5-127°W, to be 10.2 wet kg/m². This determination was based on the study of 12 camera stations and 19 box cores. New abundance measurements for 12 grab samples from within this same area¹³ give an average of 10.7 kg/m². Because nodules have been observed in almost all bottom samples collected from Area 2, we estimate that an average abundance of 10.5 kg/m² is likely to be found throughout the whole area.

Nodule grade: Average nodule composition for Area 2 is shown in Table 2. Even with many more analyses, the average composition is approximately the same as reported previously, indicating that there is little information to be gained by further analyses of nodules from the parts of this area which have already been heavily sampled. Average Ni + Cu is well above the required 2.27% grade, and only 10% of the samples show Ni + Cu less than the 1.8% cutoff grade.

¹⁰R. H. Fewkes, W. D. McFarland, W. R. Reinhart and R. K. Sorem, Development of a Reliable Method for Evaluation of Deep-sea Manganese Nodule Deposits. (U. S. Department of Interior, Bureau of Mines Final Report, Contract No. G-274013-MAS., 1979.)

¹¹R. H. Fewkes, W. D. McFarland, W. R. Reinhart and R. K. Sorem, Evaluation of Metal Resources at and near Proposed Deep-sea Mine Sites (U. S. Department of the Interior, Bureau of Mines Final Report, Contract No. GO274013-MAS, 1979.)

¹²R. K. Sorem, W. R. Reinhart, R. H. Fewkes and W. D. McFarland, Occurrence and character of manganese nodules in DOMES Sites A, B, and C, equatorial Pacific Ocean. In *Marine Geology and Oceanography of the Pacific Manganese Nodule Province*, ed. J. L. Bischoff and David Z. Piper (New York: Plenum Press, 1979), pp. 475-527. Note: analytical data in microfiche appendix

¹³D. Z. Piper, K. Leong and W. F. Cannon, Manganese nodule and surface sediment compositions: DOMES Sites A, B, and C. In *Marine Geology and Oceanography of the Pacific Manganese Nodule Province*, ed. J. L. Bischoff and David Z. Piper (New York: Plenum Press, 1979), pp. 437-474.

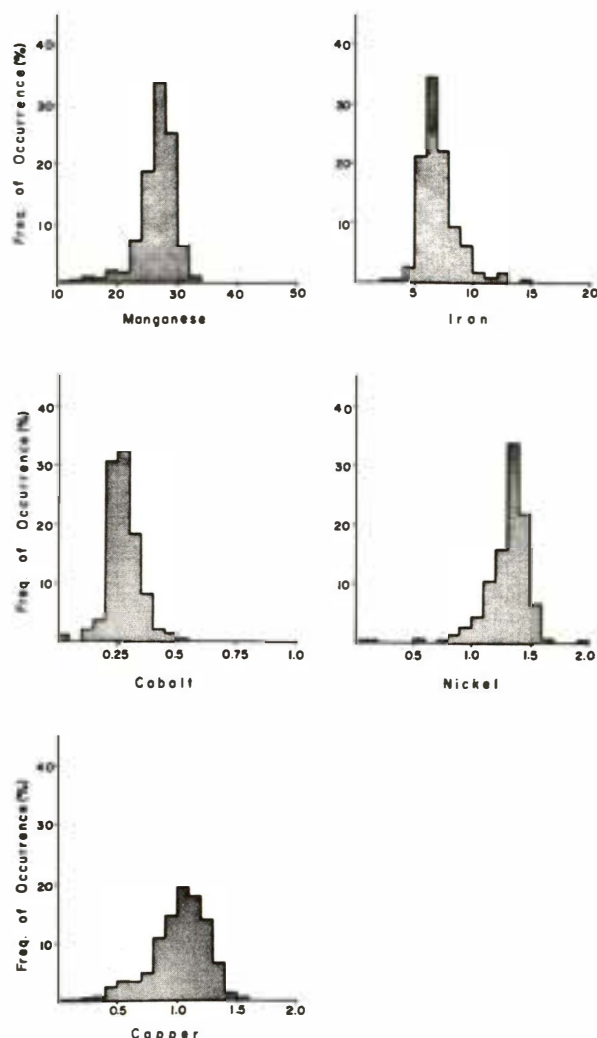


Fig. 5. Frequency distributions of element concentrations for nodules in Area 2.

Frequency distributions for element concentrations in Area 2 (Fig. 5) show approximately normal distributions and suggest that this area contains a single nodule population. Available data do not indicate any parts of the area where nodule grade is especially high or low.

Conclusions: Unchanged since 1978. This area is the most promising for seabed mining of all the areas studied, as it is the only one which has been shown to contain abundant nodule deposits ($>10 \text{ kg/m}^2$) of high grade. According to Fewkes et al.¹⁴, the area contains about 70% more Ni + Cu per km^2 than the other two areas they studied.

¹⁴See footnote 11, page 58.

The question to be answered is the size of the minable area within Area 2. Most of the sampling has been concentrated within $14.5\text{--}15.5^\circ\text{N}$, $125\text{--}126.5^\circ\text{W}$; however, the scattered samples collected around this smaller area show similar high grades of nickel and copper. Area 7A (see below), directly to the east, has average nodule composition and distributions of element concentrations almost identical to Area 2 and shows indications of abundant nodule deposits.

AREA 3

Areal extent: Area 3 as previously discussed included approximately $455,000 \text{ km}^2$ between $8\text{--}13^\circ\text{N}$, $137\text{--}145^\circ\text{W}$. This area has been extended somewhat and divided into three sub-areas based on the amount of information available and geographic variations in nodule composition (see Fig. 6). Area 3A is approximately $169,000 \text{ km}^2$ between $8.5\text{--}12.5^\circ\text{N}$, $137\text{--}140.5^\circ\text{W}$. The much smaller Area 3B includes about $54,000 \text{ km}^2$ between $12.5\text{--}14^\circ\text{N}$, $139.5\text{--}142.5^\circ\text{W}$. Area 3C is the remainder of the area for which almost no analytical data are available.

New information available since August, 1978: 298 new nodule analyses have been obtained for Area 3, increasing the number of available data to 2.8 times as many as in 1978. All but nine of the new analyses are for samples from Area 3A. Almost all were performed either in our laboratory or at Washington State University^{14,15}. Some are additional assays for locations from which nodules had already been analyzed, but more than 2/3 of them are for nodules from 46 new locations within Area 3A.

Information on nodule abundance from 24 box cores in Area 3A collected by *R/V Oceanographer* Cruise RP8-75 has recently been published by Piper et al.¹⁶. This increases by 75% the number of abundance measurements for this area obtained from box cores and grab samples.

¹⁵R. K. Sorem and R. H. Fewkes, *Manganese nodules research data and methods of investigation* (New York: IFI/ Plenum, 1979).

¹⁶See footnote 13, page 58.

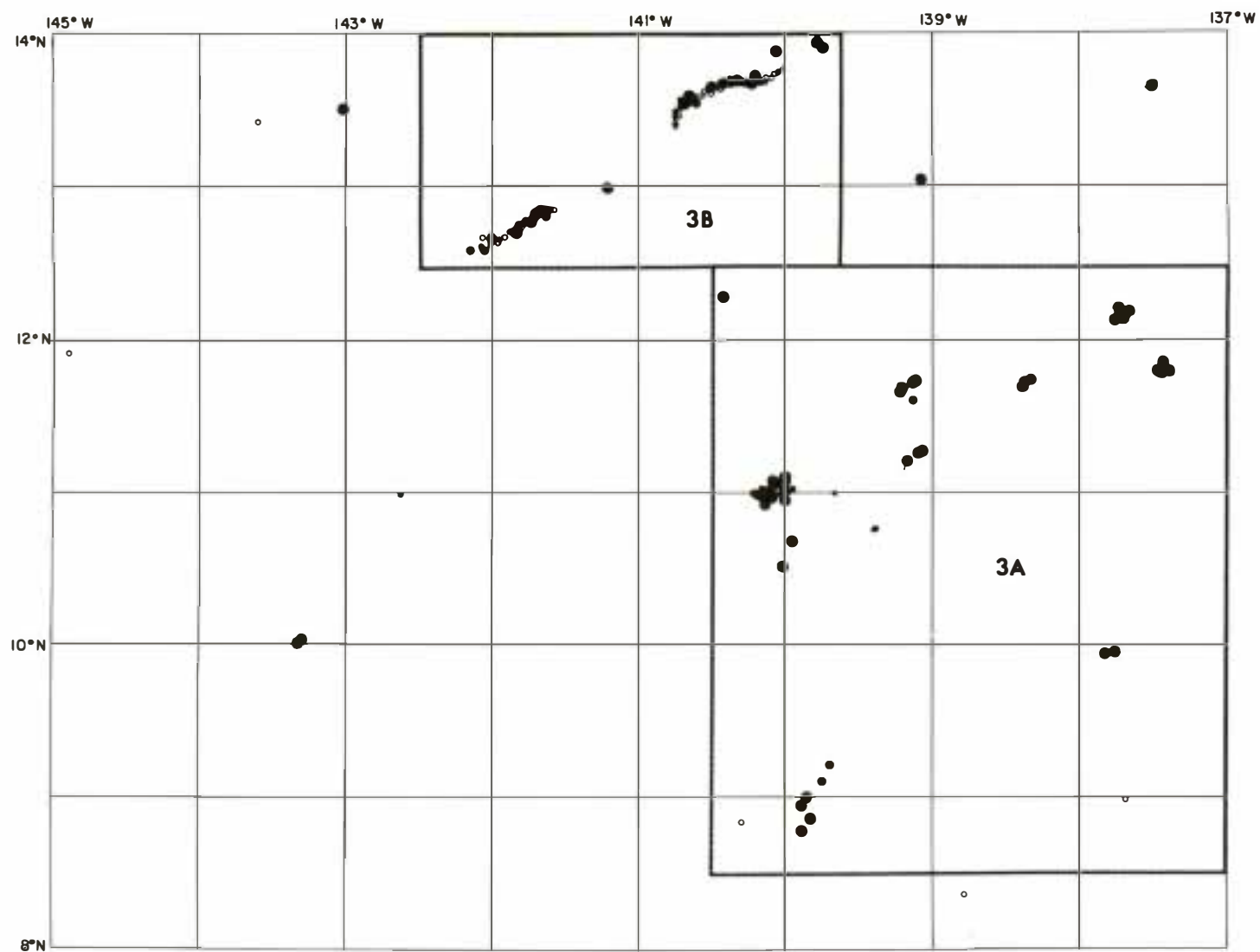


Fig. 6. Distribution of nodule grade in Area 3.

- = Ni + Cu $\geq 2.5\%$
- = Ni + Cu 2.27-2.49%
- = Ni + Cu 1.8-2.26%
- = Ni + Cu $< 1.8\%$

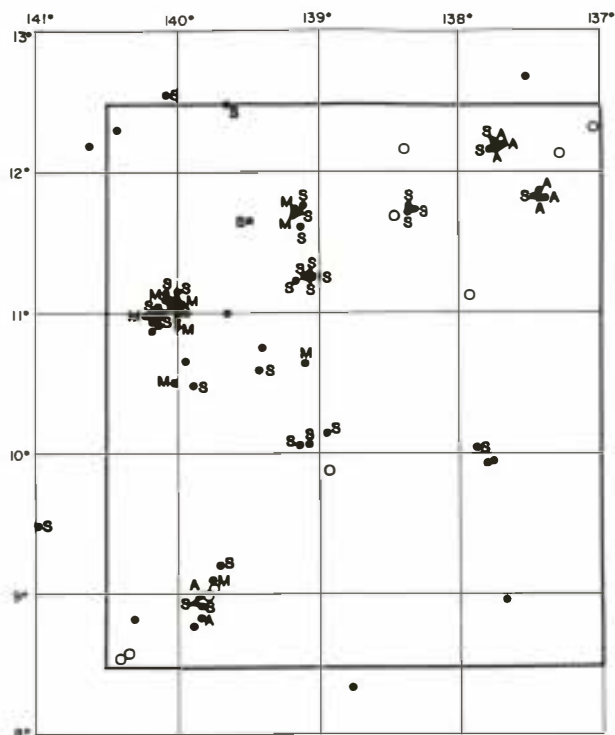


Fig. 7. Nodule distribution in Area 3A (outlined with dotted line). Solid circles indicate locations where nodules were observed; hollow circles are locations where nodules were absent. Abundance estimates from grab samplers, box cores and seafloor photographs are indicated by A = abundant (estimated $>10 \text{ kg/m}^2$ or $>50\%$ seafloor coverage), M = moderate (estimated $5\text{--}10 \text{ kg/m}^2$ or $20\text{--}50\%$ coverage), S = sparse (estimated $<5 \text{ kg/m}^2$ or $<20\%$ coverage).

Nodule abundance: Fig. 7 shows nodule distribution in Area 3A. Average abundance determined from 55 box cores and grab samplers is 5.3 kg/m^2 . Of these, 24% indicated $>10 \text{ kg/m}^2$, while 58% indicated $<5 \text{ kg/m}^2$.

We previously studied more than 2000 seafloor photographs taken by cameras mounted on the Scripps Institution of Oceanography Deep-Tow instrument in a 100 km^2 area centered at 11°N , 140°W ¹⁷. We found that even this very small area could be divided into two distinct sections based on topography and nodule abundance. In the northeast section, which was relatively flat with few slopes of more than five degrees, average abundance was 5.3 kg/m^2 . Fifty-six percent

of the photographs there showed abundances $<5 \text{ kg/m}^2$, and only 6% showed $>10 \text{ kg/m}^2$. In the southwest section, which was characterized by nearly vertical scarps 5-80 meters in height, relatively dense nodule coverage was more frequent although the nodules themselves were generally much smaller (1-2 cm in diameter rather than 4-5 cm). Only 40% of these photographs indicated abundances $<5 \text{ kg/m}^2$, while 17% showed $>10 \text{ kg/m}^2$. The average for the southwest section was 7.2 kg/m^2 . The overall average of $5\text{--}6 \text{ kg/m}^2$ for Area 3A differs significantly from the 3.8 estimated by Fewkes et al; our estimate is based on a larger data set.

The data indicate that at least some parts of Area 3A contain nodule deposits abundant enough for first generation mining. Our study of seafloor photographs indicates that nodule abundance is related to local topography, with the most abundant deposits occurring at the tops of slopes or at their bases. This is a different distribution pattern from that observed by Andrews and Friedrich¹⁸ for an area about 500 km to the west (see Area 4A below). Those authors did, however, note as we did that nodule abundance is related to topographic features and that the sparsest deposits generally occur on the valley floors. Based on the available data, grade and abundance do not seem to be correlated in Area 3A.

The only abundance data for Area 3C are for three grab samples from a single locality; their average is 13.5 kg/m^2 . Nodules were observed at 2/3 of the 18 locations sampled in Area 3C, but these are too few sites from which to draw conclusions about nodule abundance. No measurements are available for Area 3B, but it was a test site for the Continuous Line Bucket (CLB) system, so one might assume that nodules are at least moderately abundant there.

Nodule grade: Area 3A has the highest average Ni + Cu + Co grade (2.89%) as well as the highest average nickel-equivalent grade of all the areas studied. Only 7% of the analyses indicate grades below the cutoff value of 1.8% Ni + Cu. High-grade nodules are distributed throughout

¹⁷See footnote 1, page 7.

¹⁸J. E. Andrews and G. H. W. Friedrich, Distribution patterns of manganese nodules deposits in the northeast Equatorial Pacific, *Marine Mining* 2(1979): 1-43.

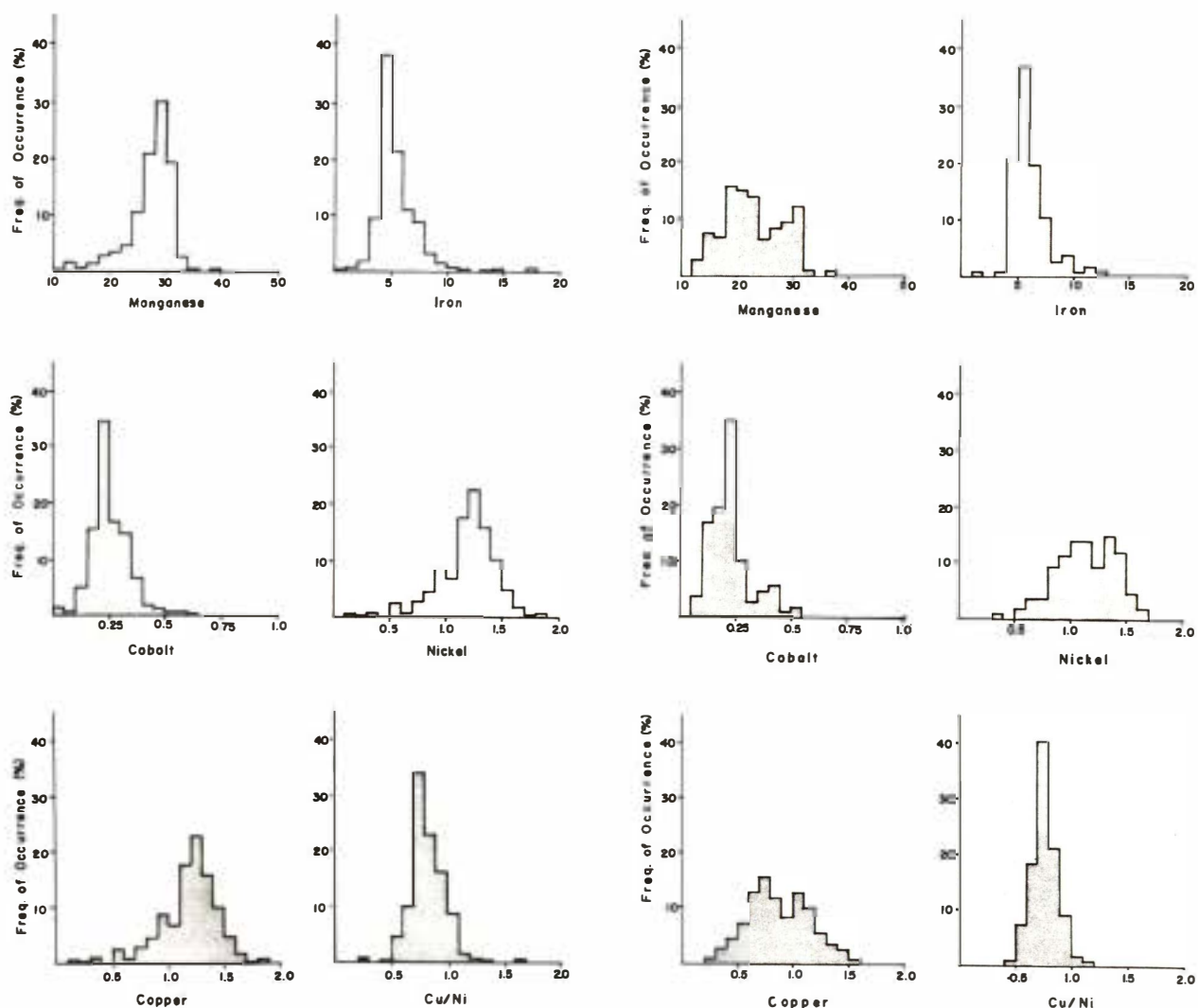


Fig. 8. Frequency distributions of element concentrations for nodules in Area 3. See graphs on left for area 3A, on right for area 3B.

Table 3. Average Nodule Composition in Area 3.

Element	Number of Analyses	Area 3 Grade (wt.%)	Standard Deviation	Number of Analyses	Area 3B Grade (wt.%)	Standard Deviation
Mn	414	27.1	4.4	108	22.8	5.5
Fe	416	5.5	2.2	106	6.1	1.7
Co	377	0.25	0.09	109	0.23	0.09
Ni	418	1.46	0.27	109	1.13	0.26
Cu	418	1.18	0.26	109	0.87	0.28
Cu/Ni	418	0.82	0.16		0.76	0.12
Cu+Ni		2.64			2.00	
Cu+Ni+Co		2.89			2.23	
Ni+Cu/3+2Co		2.35			1.87	

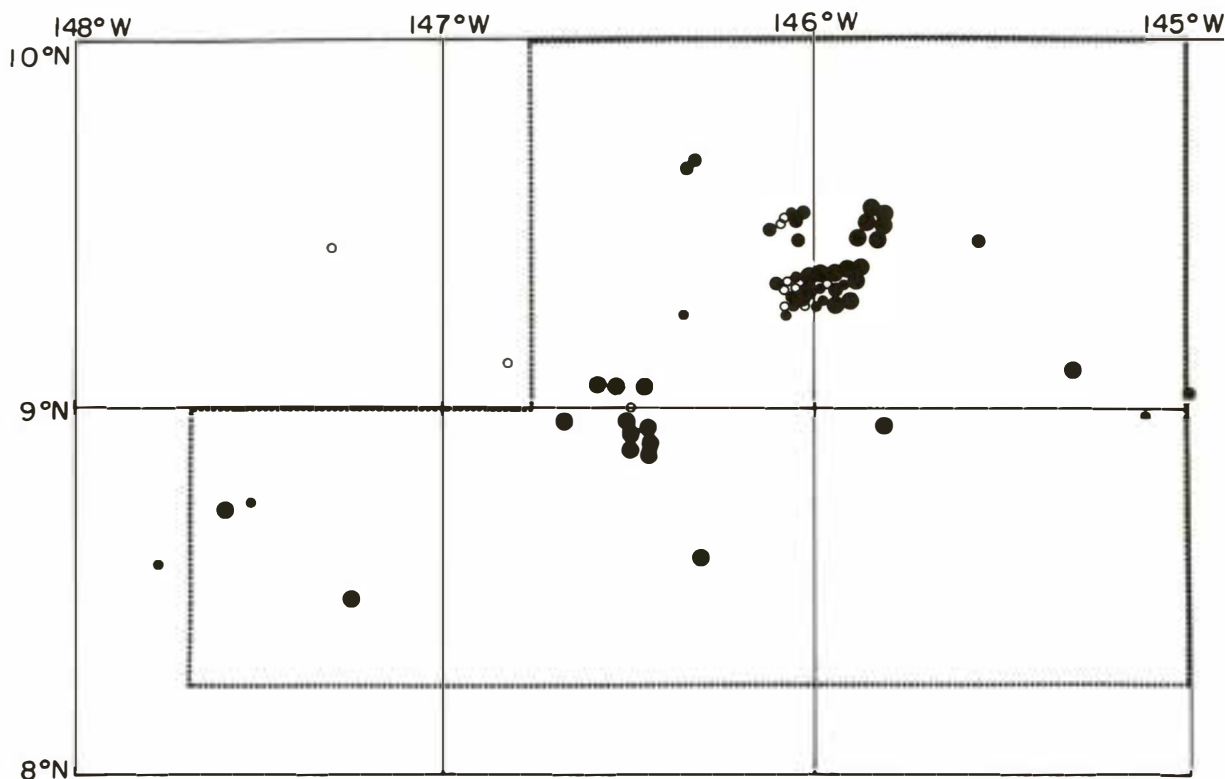


Fig. 9. Grade distribution of nodules in Area 4A (outlined with dotted line).

- = Ni + Cu $\geq 2.5\%$
- ◐ = Ni + Cu 2.27-2.49%
- = Ni + Cu 1.8-2.26%
- = Ni + Cu < 1.8%

the area (see Fig. 6). Average grade in Area 3B is slightly below the grade required for paramarginal resources but high enough for this area to be considered a submarginal resource. Average composition for both of these sub-areas is shown in Table 3, and frequency distributions for the elements are in Fig. 8.

The distributions of manganese, nickel and copper for Area 3B are bimodal, indicating that two distinct types of nodules occur there. Nodules in the high-grade group are not as high in nickel and copper as typical nodules from Area 3A. They instead resemble in composition nodules from Area 2. The composition variations in Area 3B may be related to local topography as in Area 4A (see below), but this cannot be confirmed without additional data.

Conclusions: Although average nodule abundance in Area 3A is at about the minimum required for paramarginal resources, its extremely

high grade makes it a promising resource area. Further exploration is needed, particularly in the southeastern part of the area, to determine where the deposits are abundant enough to mine. Area 3C should also be explored to determine whether it contains high-grade nodule deposits.

AREA 4A

Areal extent: Area 4 as previously discussed included approximately 123,000 km² between 8-12.5°N, 145-147°W. We have divided this area into two sections, 4A and 4B, on the basis of the amount of information available. In this update we will consider only 4A, the southern part of Area 4 for which many analytical data are available. Area 4A, which has been extended to include an area to the west where nodule grade seems to be high, includes 49,000 km² between 8.25-10°N, 145-147.5°W as shown by the dotted outline in Fig. 9.

Table 4. Average Nodule Composition in Area 4A

Element	Number of Analyses	Grade (Wt %)	Standard Deviation	Change from 1978 Average
Mn	215	27.2	3.7	+2%
Fe	212	6.8	2.3	+13%
Co	86	0.21	0.07	-5%
Ni	216	1.32	0.26	-6%
Cu	216	1.02	0.25	-4%
Cu/Ni	216	0.78	0.15	
Cu + Ni	216	2.34	0.49	-5%
Cu + Ni + Co		2.55		-5%
Ni + Cu/3 + 2Co		2.08		

New information available since August, 1978: Andrews and Friedrich¹⁹ have published nodule analyses and abundance measurements for 118 grab samplers and box cores collected by the *Valdivia* in 1976. We have analyzed a number of additional nodules from MN-7401 grab samples collected from within Area 4A.

Nodule abundance: Measurements of nodule abundance have been made at two localities within Area 4A: MN-7401 Station 6 (around 9°N, 146.5°W) and *Valdivia* Site 13/2 (centered at about 9.4°N, 146°W). These data have been studied intensively by Andrews and Friedrich, who found nodule abundance definitely related to topographic features. At Station 6 the lowest densities (2-4 kg/m²) occurred at slope base and in the center of the valley, while highest densities (9-18 kg/m²) were found on slopes. At Site 13/2 they found a similar pattern of nodule distribution. On a low abyssal hill, nodule coverage was greater on the upper slopes (5-10 kg/m²) than on the lower areas (0-5 kg/m²). On three larger peaks of 400-500 m relief, nodule coverage was generally 15-20 kg/m².

Nodules at Site 13/2 occur in two distinct facies. The nodules from the abundant deposits in the areas of submarine peaks were polynucleate or single nodules with smooth surfaces, whereas those from areas with low rolling abyssal hill topography were larger discoidal nodules with rough bottom surfaces and knobby equatorial rims at the sediment-water interface.

Nodule grade: On the basis of five times as many analyses as were available previously, the average nodule grade for Area 4A is 5% lower than previously estimated (see Table 4). At 2.34% Ni + Cu it is still above the 2.27% grade requirement for first generation mining, but 20% of the nodules analyzed were below the cutoff grade of 1.8% Ni + Cu.

Fig. 9 shows the distribution of Ni + Cu grade throughout Area 4A, and Fig. 10 shows the frequency distribution of element concentrations. It can be seen from Fig. 10 that nodules from Area 4A do not constitute a single population on the basis of composition. Andrews and Friedrich showed that at Site 13/2 the two nodule facies are chemically quite distinct. The rough discoidal nodules from the abyssal hill areas are highest in manganese (26-33%), nickel (1.2-1.8%) and copper (0.9-1.3%), similar in composition to the nodules typical of Area 3A. The smooth nodules from submarine peaks are lowest in these elements (manganese 24-26%, nickel 0.8-1.0%, copper 0.6-0.7%). On the flanks of the peaks is a transition zone with a mixture of the two facies and intermediate compositions. The average nodule composition shown in Table 4 corresponds to nodules at the low end of the nickel range for the rough facies.

Conclusions: The inverse correlation between grade and abundance appears to be significant in Area 4A ($r = -.32$ for Site 13/2; $r = -.78$ for Station 6); therefore, grade and abundance averaged over the whole area cannot be used to predict its economic potential. As Andrews and

¹⁹See footnote 18, page 61.

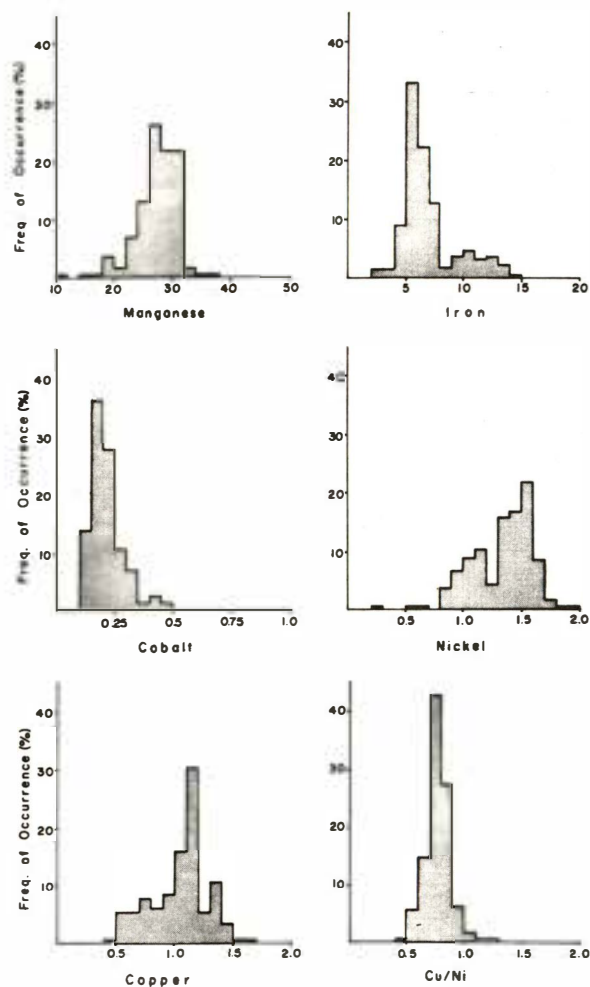


Fig. 10. Frequency distributions of element concentrations for nodules in Area 4A.

Friedrich pointed out, defining minable deposits within such an area will require much detailed work. Target areas will be the those moderately dense deposits with high grade characteristic of the upper slopes of the low abyssal hills or transitional deposits on the lower slopes and at the bases of the larger features where moderately high nodule densities ($5\text{--}15\text{ kg/m}^2$) are sometimes associated with acceptable Ni + Cu grade. The minable areas ultimately defined will probably be only a small fraction of the area.

AREA 5

Areal extent: Area 5 includes the $82,000\text{ km}^2$ area between $7\text{--}10^\circ\text{N}$, $150\text{--}154^\circ\text{W}$, outlined by dotted lines in Fig. 11. The northern and southern boundaries have been changed from those

reported in 1978 in order to omit sections where grades are low or no data are available and to include an adjacent area with high-grade nodules. The eastern half of Area 5 is within the region surrounding DOMES Site A which Fewkes et al²⁰ studied as Area A.

New information available since August, 1978: Seventy-five new analyses of nodules collected in this area by *R/V Oceanographer* have been reported by Fewkes et al along with measurements of nodule abundance from seafloor photographs and box cores.

Nodule abundance: Fig. 11 shows the distribution of nodule abundance in Area 5. The data suggest that nodule deposits are most abundant in the eastern part of the area and decrease in abundance toward the west. Between $150\text{--}151^\circ\text{W}$ the average abundance, based on data for 24 locations, is 9.1 kg/m^2 ; and more than half the locations have $10\text{--}22\text{ kg/m}^2$. Between $151\text{--}152^\circ$ (16 locations) the average is 3.8 kg/m^2 , and the highest reported abundance is 9.4 kg/m^2 . West of 152° the average for six locations is only 2.4 kg/m^2 , with 6.25 the highest reported.

Seafloor photographs from Area 5 fail to confirm this trend. More than half the photograph locations from the western half show nodules covering more than 20% of the sea floor, whereas in the eastern half only 40% show coverage $>20\%$. Since almost all the available box-core and grab data are for the eastern half, the apparent trend of abundance decreasing to the west may be an artifact of the small data set for the area $152\text{--}154^\circ$.

Nodule grade: With an average of 2.64% Area 5 has a Ni + Cu grade as high as any of the areas studied. Based on 22% more analyses than were available for the 1978 update, and with changed boundaries to eliminate low-grade areas, this is 5% higher than we reported previously (see Table 5). As shown in Fig. 12, high Ni + Cu grades occur throughout the area.

It can be observed from the frequency distributions in Fig. 13 that the concentrations of most elements are distributed normally, but copper shows a bimodal distribution. In samples with especially high copper content ($>1.4\%$), the

²⁰See footnote 11, page 58.

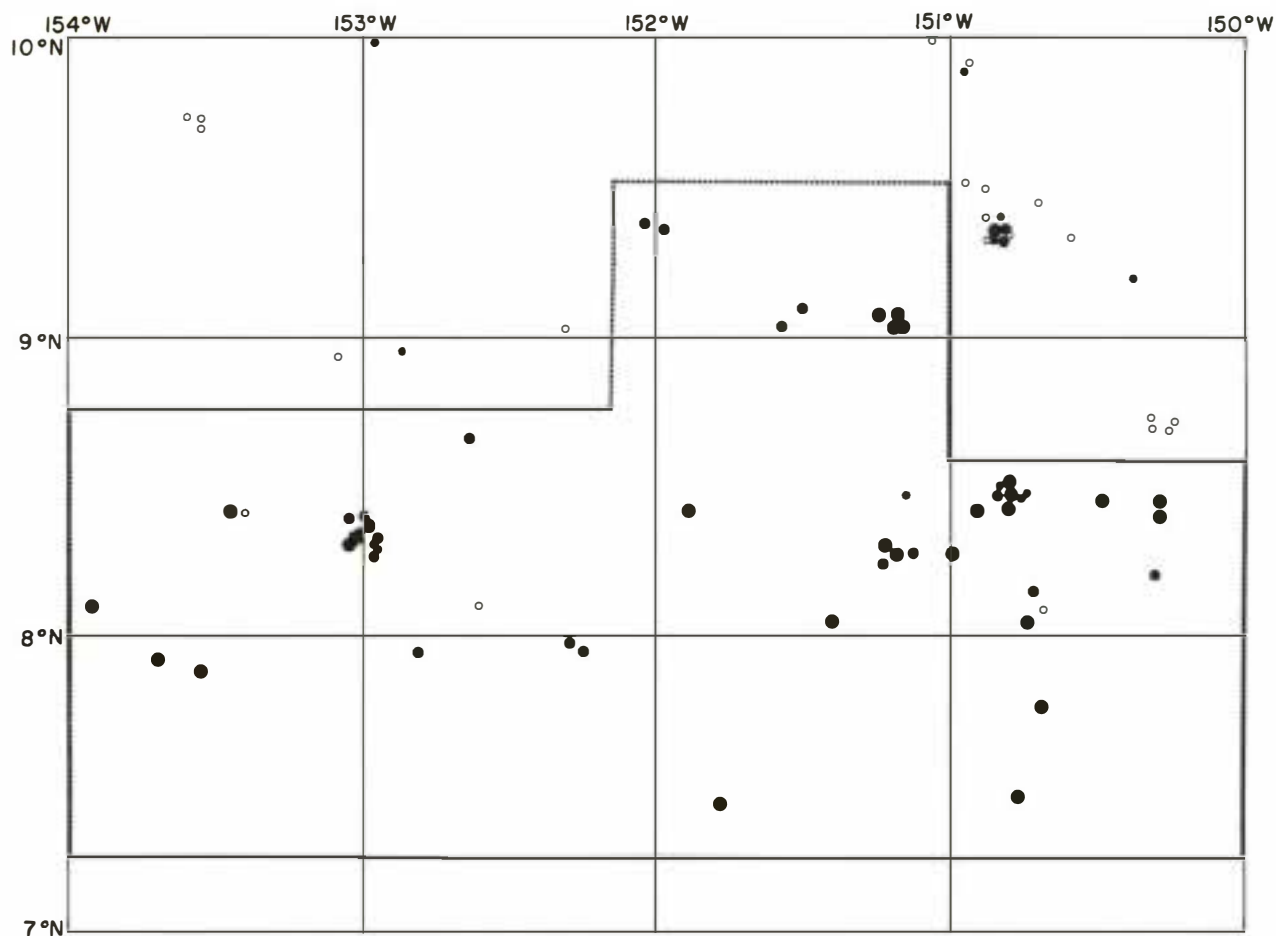


Fig. 12. Distribution of nodule grade in Area 5 (outlined with dotted line).

- = Ni + Cu $\geq 2.5\%$
- ◐ = Ni + Cu 2.27-2.49%
- = Ni + Cu < 1.8%

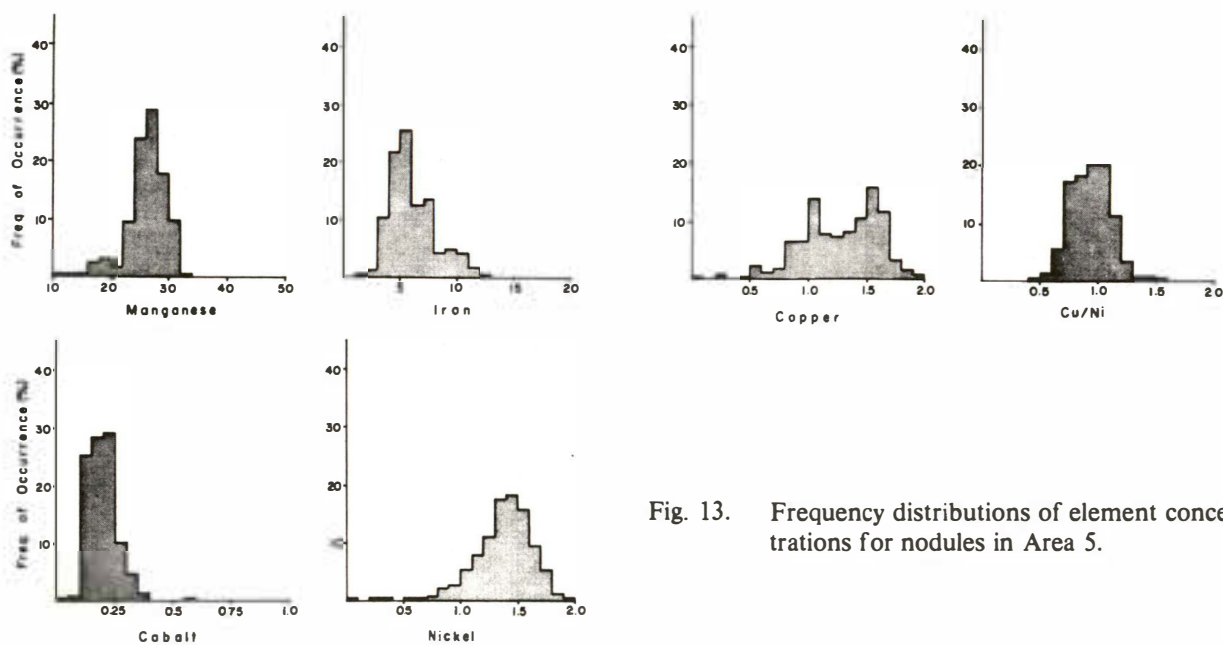


Fig. 13. Frequency distributions of element concentrations for nodules in Area 5.

Table 5. Average Nodule Composition in Area 5

Element	Number of Analyses	Grade (Wt %)	Standard Deviation	Change from 1978 Average*	Deviation from Area A Average**
Mn	263	25.9	4.2	+4%	+10%
Fe	261	6.1	2.0	-5%	
Co	258	0.20	0.06	0	-13%
Ni	263	1.36	0.26	+5%	+14%
Cu	262	1.28	0.34	+6%	+27%
Cu/Ni	262	0.94	0.17		
Cu + Ni	262	2.64	0.57	+5%	
Cu + Ni + Co		2.84		+5%	
Ni + Cu/3 + 2Co		2.18			

*The change in average composition from that reported in 1978 is due primarily to the redefinition of the Area 5 northern boundary. This boundary was changed to include an adjacent area with high grades and eliminate parts of the area with generally low grades.

**As reported by Fewkes et al, 1980. Area A includes the eastern half of Area 5 and extends eastward to 149°W.

Cu/Ni ratio is also high, often ≥ 1 . Cu/Ni ratios >0.8 are quite rare outside of Area 5 except in the Central Indian Basin²¹. Nodules with high copper and high Cu/Ni are not concentrated in particular localities within the area but are scattered throughout and frequently occur in the same grab sampler or box core with nodules that have lower copper for the same amount of nickel. This bimodal copper distribution is not due to systematic analytical inaccuracies, since both types of compositions have been found by all investigators.

Average manganese, nickel and copper in Area 5 are significantly greater than in the Area A studied by Fewkes et al. This is because nodule grades are generally lower in the eastern part of their Area A but high throughout all parts of Area 5.

Conclusions: With an average Ni + Cu + Co of 2.84% and 90% of the nodules containing $>1.8\%$ Ni + Cu, grade in Area 5 is well above the minimum for paramarginal resources and is almost as high as in Area 3A. However, because the exceptionally high grade here is due primarily to high copper content, the economic value of the nodules expressed as nickel-equivalent grade is considerably lower in Area 5 than in Area 3A and about the same as in Area 2.

The available data suggest that nodule deposits abundant enough for first-generation mining occur only in the eastern fourth of Area 5, too small an area to constitute a mine site. The abundant deposits may also continue to the east of 150°, but no data are available and nodule grade is lower there. Further exploration is required to determine nodule abundance west of 151°.

²¹J. Z. Frazer and L. L. Wilson, Manganese Nodule Deposits in the Indian Ocean (Scripps Institution of Oceanography Reference 79-18, unpublished, 1979).

AREA 7A

Areal extent: 11-15°N, 113.9-124°W, 500,000 km².

New information available since August, 1978: Twenty-one new nodule analyses have become available including analyses at six new locations. Almost all of these analyses were performed in our laboratory. No new information on nodule abundance has been reported.

Nodule abundance: Although very few abundance measurements have been made from grab samplers or seafloor photographs, these indicate that parts of Area 7A may contain nodule deposits of >10 kg/m². A high percentage of the samples collected from this area did contain nodules, suggesting further that abundant deposits may be found here.

Nodule grade: On the basis of 50% more analyses than were available for the 1978 update, average nodule composition is approximately the same as reported then (see Table 6). Fig. 14 shows frequency distributions of element concentrations. The distribution of nodule compositions in Area 7A is very similar to that of Area 2, which is adjacent on the west

Conclusions: Unchanged from 1978. Although Area 7A has not been much explored, unless perhaps by mining companies who keep their results proprietary, the available data indicate that it contains potential mine sites. This area should be explored more intensively.

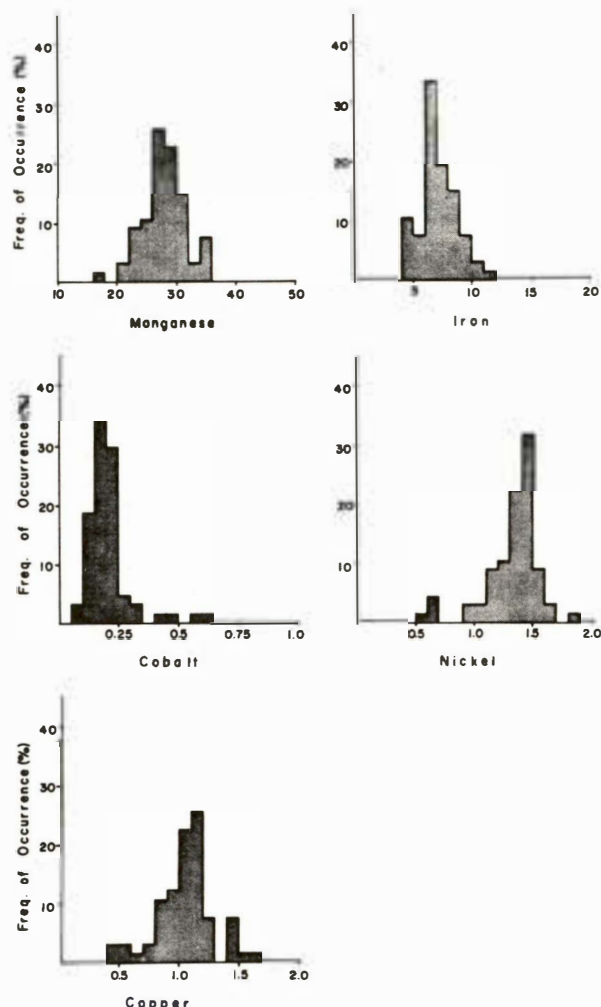


Fig. 14. Frequency distributions of element concentrations for nodules in Area 7A.

Table 6. Average Nodule Composition in Area 7A

Element	Number of Analyses	Grade (Wt %)	Standard Deviation	Change from 1978 Average
Mn	66	27.8	4.3	-3%
Fe	66	7.3	2.2	+3%
Co	64	0.20	0.10	+12%
Ni	66	1.32	0.24	-1.5%
Cu	66	1.05	0.23	0
Cu + Ni		2.37	0.42	-1%
Cu + Ni + Co		2.57		0
Ni + Cu/3 + 2Co		2.07		

IV. AREA DATA SUMMARIES FOR RESOURCE EVALUATION

Most prospecting for manganese nodule resources has occurred in the region of the northeastern equatorial Pacific between the Clarion and Clipperton Fracture Zones, and most detailed evaluations of seabed mineral resources have concerned that region. Although it appears probable that other regions of the ocean contain nodule deposits that will eventually become mineral resources, so far no paramarginal resources (first-generation mine sites) have been confirmed elsewhere.

In 1979 we reported on possible resource areas in the Indian Ocean²². We identified one area in the Central Indian Basin that might be a possible first-generation mine site, but more information is needed to establish its actual resource potential. We identified four additional areas that could be submarginal resources at best. We concluded that no other areas in the Indian Ocean are candidates for nodule mining at least within the next 50 years.

During this past year we have studied data for some areas in the Pacific Ocean and one in the South Atlantic. Data for most of these areas is too sparse to allow for even preliminary resource estimates. However, the available information is sufficient to indicate which of the areas warrant further exploration.

AREA 14: CAPE BASIN

Description: The Cape Basin is located in the Atlantic off the southwest coast of South Africa between 24° - 40°S, 5°W - 20°E (see Fig. 15). It has been suggested by Holser²³ as a possible resource area. The basin is bounded to the south by the Cape Rise, a northeast trending chain of

seamounts that according to Emery²⁴ may have been volcanoes. On the north is Walvis Ridge, which extends about 2800 km southwest to the flank of the mid-Atlantic Ridge. Emery suggested that Walvis Ridge resulted from uplift of oceanic basin along north-trending faults that have been sites of local vulcanism.

Water depth in the basin is approximately 4800 m except in a few depressed areas where it exceeds 5200 m. The western section of the basin has undulating topography that has been eroded considerably by currents of Antarctic Bottom Water, which flow northward at the base of Walvis Ridge and then south along the continental margin of Africa. Surficial sediment from the eastern part of the basin is foraminiferal. Sediments from the erosional depression consists of brown clay; however, sedimentation in this area has been dominated by carbonate turbidities²⁵.

Nodule abundance: Figure 15 shows locations in this region where the seafloor was sampled and indicates where nodules were recovered. Nodule abundance has not been measured at any of the locations; however, estimates of nodule coverage are available from 109 seafloor photographs and are shown in Fig. 15. Only 10% of these show nodules covering >20% of the seafloor, and 85% show no nodules. Nodules were observed in only 20% of the cores and dredges collected from this area. There appear to be some patches of more abundant nodules at the base of Walvis Ridge and the continental rise, probably due to current activity there; however, nodule grades are low in these areas.

²²See footnote 21, page 68.

²³A. F. Holser, Manganese nodule resources and mine site availability (Ocean Mining Administration staff study, 1976).

²⁴K. O. Emery, E. Uchupi, C. O. Brown, J. Phillips and E. S. W. Simpson, Continental margin of western Africa: Cape St. Francis to Walvis Ridge (Southwest Africa), *American Association of Petroleum Geologists Bulletin* 59 (1975): 3-59.

²⁵B. D. Bornhold and C. P. Summerhayes, Scour and deposition at the foot of the Walvis Ridge in the northernmost Cape Basin, South Atlantic, *Deep-Sea Research* 24 (1977): 743-752.

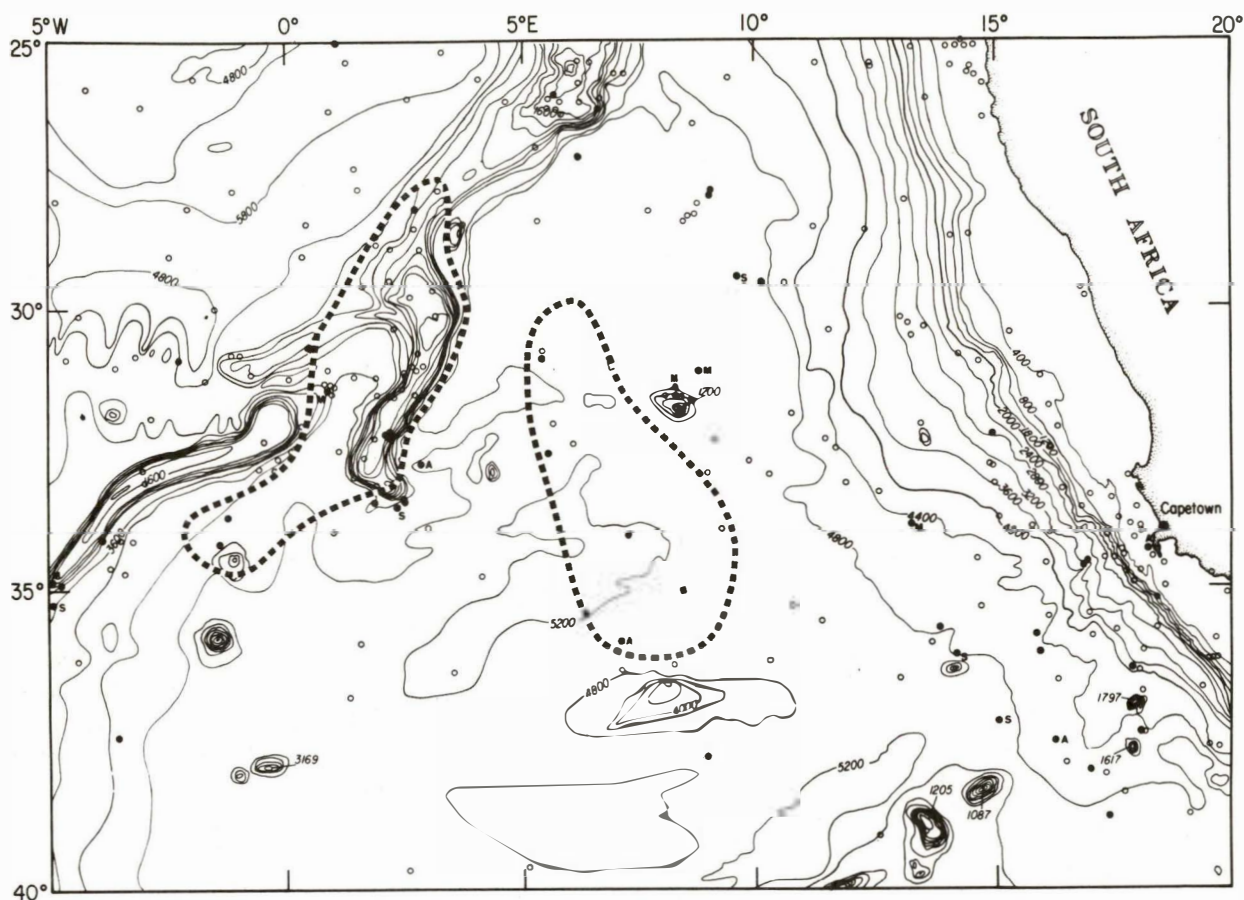


Fig. 15. Nodule distribution in Area 14. Solid circles indicate locations where nodules were observed; hollow circles are locations where nodules were absent. Abundance estimates from grab samplers, box cores and seafloor photographs are indicated by A = abundant (estimates >10 kg/m² or >50% seafloor coverage), M = moderate (estimated 5-10 kg/m² or 20-50% coverage), S = sparse (estimated <5 kg/m² or <20% coverage). Contours in meters.

Nodule grade: Fig. 16 shows nickel-equivalent grade (Ni + Cu/3 + 2Co) for the Cape Basin and surrounding areas. Two areas, delimited by dashed lines, appear to contain deposits of possible submarginal resource grade (nickel-equivalent >1.32%), but neither has an average grade high enough for first-generation mine sites. Average composition of nodules in these two areas are shown in Table 7.

Area 14A, about 275,000 km² on Walvis Ridge, contains nodules high in cobalt, generally 0.44-0.84%. Nickel content here is only moderate, and copper content is low. In Area 14B, about 226,000 km² in the basin, nodules are more similar in composition to those from the Clarion-Clipperton Zone but slightly lower in nickel and much lower in copper.

Conclusions: From data available in our Sediment Data Bank we must conclude that there is little likelihood of finding minable nodule deposits in Cape Basin. However, very little information is available, and the area is quite large. Further exploration might be useful but should have a low priority.

If cobalt were the prime target, Area 14A might be of interest. Composition of nodules here is very similar to those from Area 12 around the Seychelles Islands in the Indian Ocean²⁶. Note, however, that Area 12 lies within a 200-mile economic zone whereas Area 14A does not.

²⁶See footnote 21, page 68.

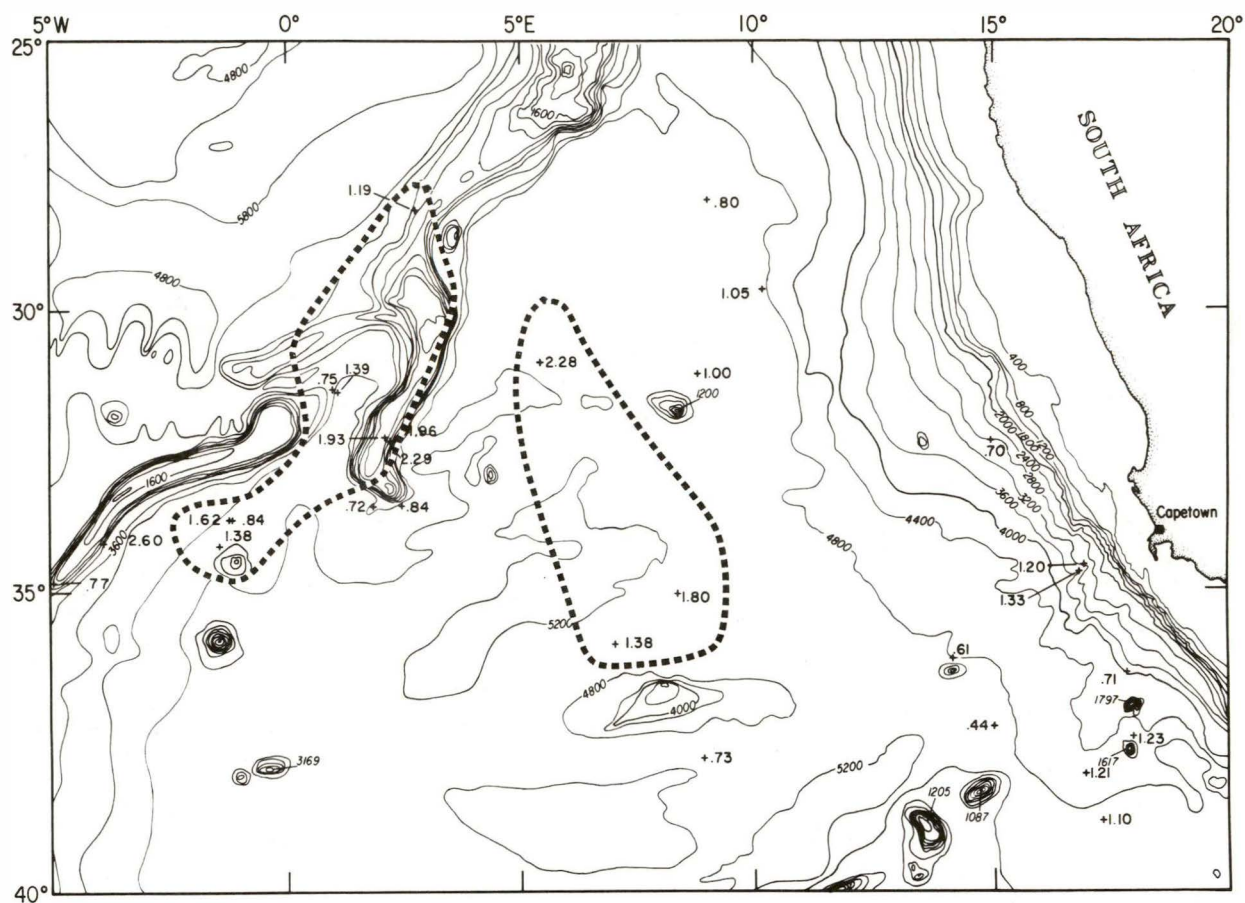


Fig. 16. Nickel-equivalent grade ($\text{Ni} + \text{Cu}/3 + 2\text{Co}$) for nodules in the Cape Basin. Areas outlined with dotted lines are Areas 14A (on Walvis Ridge) and 14B (in the basin). Contours in meters.

Table 7. Average Nodule Composition in Area 14

Element	Area A		Area B	
	Grade ^a (Wt%)	Standard Deviation	Grade ^b (Wt%)	Standard Deviation
Mn	19.2	3.5	22.6	5.5
Fe	17.5	3.5	10.4	3.9
Co	0.58	0.22	0.20	0.05
Ni	0.39	0.15	1.19	0.27
Cu	0.11	0.07	0.49	0.23
Cu + Ni	0.50	0.26	1.68	0.36
Cu + Ni + Co	1.07	0.29	1.88	0.44
Cu/Ni	0.29	0.19	0.41	0.15

^aBased on 16 analyses from 10 locations.

^bBased on 6 analyses from 3 locations.

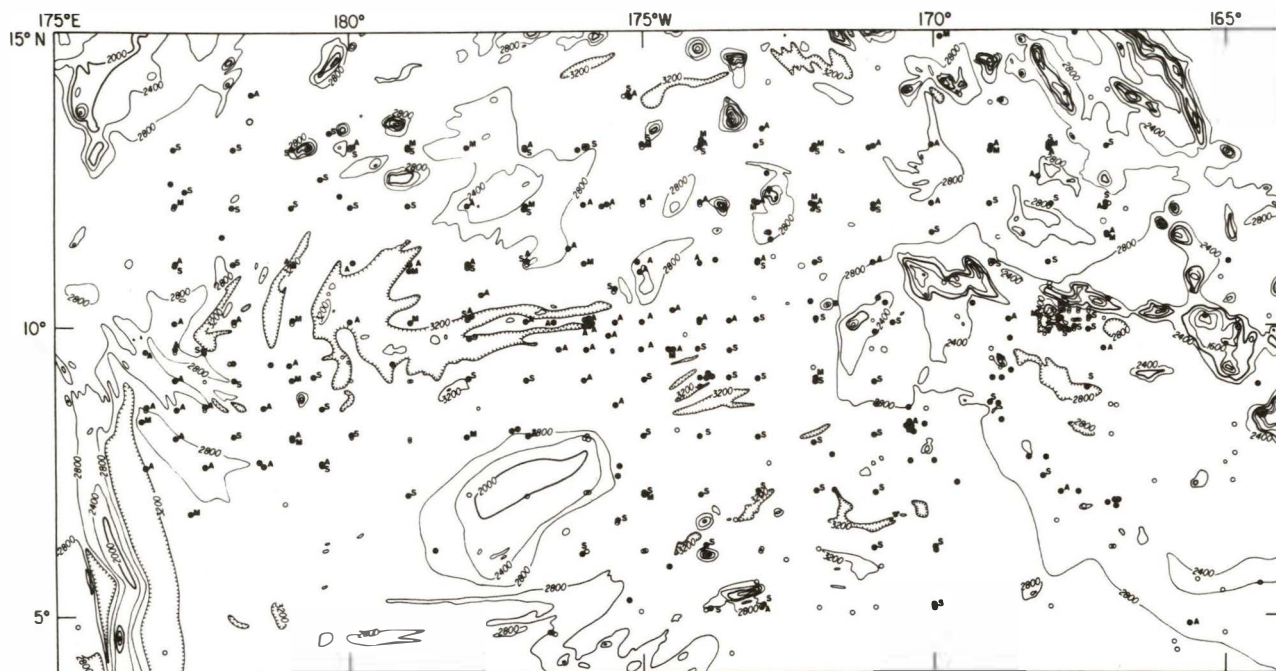


Fig. 17. Nodule distribution in Area 15. Solid circles indicate locations where nodules were observed; hollow circles are locations where nodules were absent. Abundance estimates from grab samplers, box cores and seafloor photographs are indicated by A = abundant (estimated >10 kg/m² or $>50\%$ seafloor coverage), M = moderate (estimated 5-10 kg/m² or 20-50% coverage), S = sparse (estimated <5 kg/m² or $<20\%$ coverage). Contours in fathoms.

AREA 15: CENTRAL PACIFIC BASIN

Description: Area 15 within the Central Pacific Basin includes approximately 2.8 million km² at 4-15°N, 164°W-175°E (see Fig. 17). It is situated southwest of the Hawaiian Islands and bounded by the Marshall Islands on the west and the mid-Pacific mountains on the north. The eastern section is a relatively flat abyssal plain with water depths of about 5000 m. The central section has deep basins with water depths ranging from 5600 to 5900 m and seamounts arranged in the NWW-SEE direction. The western section includes Magellan Rise, which is about 1800 m above the seafloor, and the Northern Seamounts, which are about 1000 m high relative to the seafloor. Surficial sediments throughout most of this area are pelagic clay or siliceous clay. The Magellan Rise and seamount areas are calcareous ooze.

Information available: For Area 15 we have available the results of more thorough exploration than for any other area. Five cruises of the Geological Survey of Japan²⁷ have conducted intensive geological and geophysical surveys and

have sampled at 618 locations, for the most part in a regular 110-km grid. Most of the Japanese sampling was done with freefall grabs for which both chemical analyses of nodules and estimations of nodule abundance have been published.

²⁷A. Mizuno and J. Chujo, eds., *Deep sea mineral resources investigation in the eastern Central Pacific Basin, Cruise GH74-5, August–October 1974* (Geological Survey of Japan Cruise Report No. 4, 1975). A. Mizuno and T. Moritani, eds., *Deep sea mineral resources investigation in the central-eastern part of Central Pacific Basin, Cruise GH76-1, January–March 1976* (Geological Survey of Japan Cruise Report No. 8, 1977). T. Moritani, ed., *Deep sea mineral resources investigation in the central-western part of Central Pacific Basin, Cruise GH77-1, January–March 1977* (Geological Survey of Japan Cruise Report No. 12, 1979). K. Tsurusaki and K. Handa, Studies on the investigation techniques and instruments for deep sea floor mineral resources, Hakurei-Marui Research Cruise GH78-1, *Mining and Safety* 24(1976), no. 11. K. Handa and K. Tsurusaki, Studies on the investigation techniques and instruments for deep sea floor mineral resources, Hakurei-Marui Research Cruise GH79-1 [in Japanese], *Mining and Safety* 25(1979), no. 11.

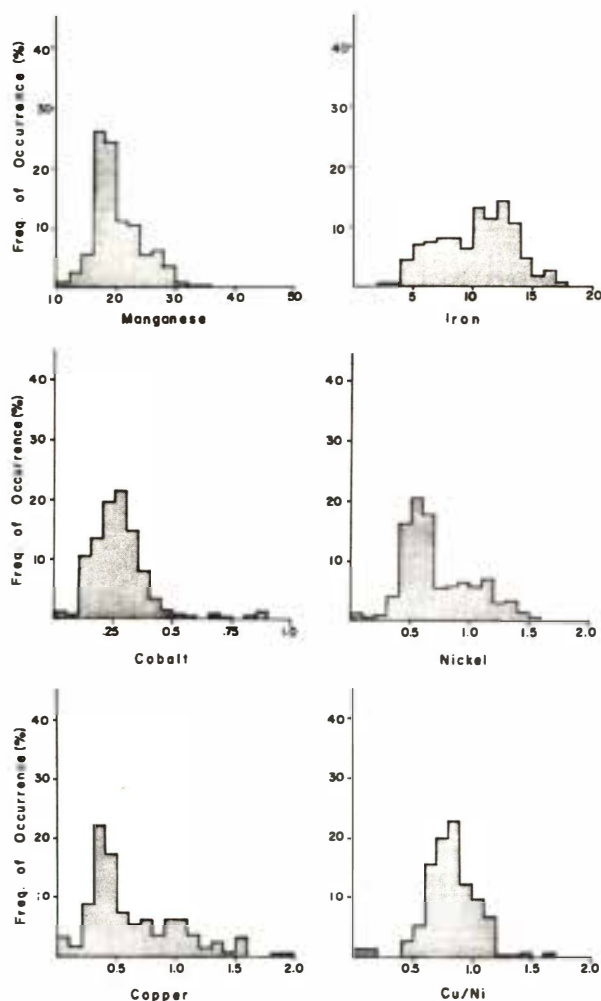


Fig. 19. Frequency distributions of element concentrations for nodules in Area 15.

in association with siliceous clay; smooth nodules, with pelagic clay.²⁹

Conclusions: The inverse correlation between Ni + Cu and abundance is quite marked in Area 15 ($r = -0.75$). Although this area was once thought on the basis of limited data to be a promising area for seabed mining, this no longer appears to be the case. Mizuno and Moritani³⁰ have summarized the situation as follows: "At least in the area east of 180°, the general ten-

dency is that the densely populated area has an extremely low Ni + Cu content and the sparsely distributed area has a high Ni + Cu content. In general, nodules below the mining cutoff grade/concentration are distributed throughout the entire area and nodules above the cutoff grade/concentration are scattered in limited areas." They suggest that the maximum areal extent of the high grade and abundance areas is perhaps about 10,000 km².

AREA 16

Description: Area 16 includes approximately 600,000 km² between 0-6°S, 154-162°W, in the South Pacific (see Fig. 20). Two islands occur within this region: Jarvis, claimed by the United States, and Malden, claimed by the United States and Great Britain. Most of the area is characterized by seamounts, but between the two islands there is a basin about 5000 m in depth. McKelvey and Wright³¹ first pointed out the economic potential of nodule deposits in this basin.

Available data: The sea floor has been sampled at 95 locations within the area. Twenty-nine nodule analyses, almost all of them performed in our laboratory, are available for 22 locations. No measurements of nodule abundance have been made, and no seafloor photographs are available.

Nodule abundance: Nodules were recovered in 76% of the 25 dredges and grab samples but only 24% of the 70 cores taken in this area. We can draw no conclusions about nodule abundance from these data.

Nodule grade: Fig. 20 shows the geographical distribution of Ni + Cu grade in nodules from this area. In the 85,000 km² area of the basin within the dotted outlines (Area 16A), nodule grade is 2.54% Ni + Cu, well above the minimum requirement for paramarginal resources. Nodules in the surrounding seamount area (16B) contain less than half this concentration of Ni + Cu. Table 8 shows average nodule compositions for each of these two areas.

²⁹A. Mizuno and T. Moritani, *Deep sea mineral resources investigation in the central-eastern part of Central Pacific Basin, Cruise GH76-1, January-March 1976* (Geological Survey of Japan Cruise Report No. 8, 1977), p. 18.

³⁰See footnote 28, page 75.

³¹V. E. McKelvey and N. A. Wright, *Metal content of manganese nodules in part of the southeastern equatorial Pacific* (U. S. Geological Survey Open-File Report 80-373, 1980).

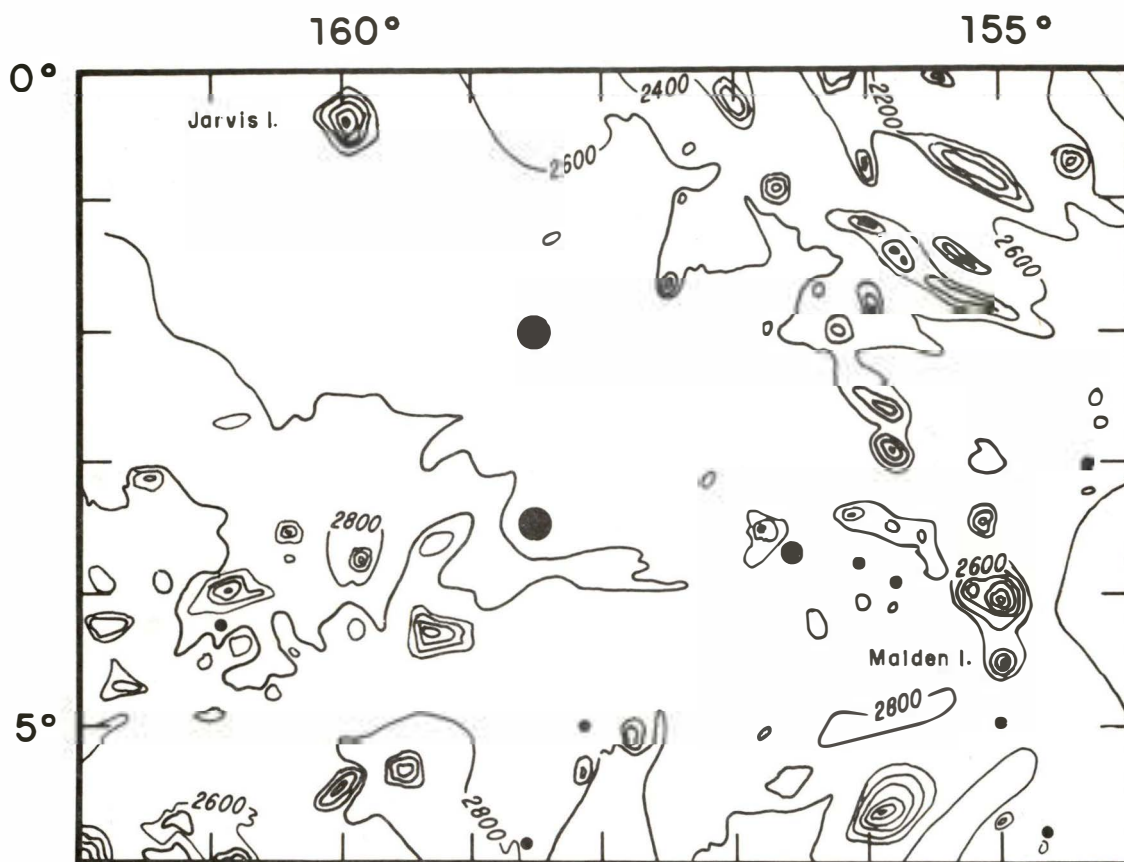


Fig. 20. Grade distribution of nodules in Area 16. Contours in fathoms.

- = Ni + Cu $\geq 2.27\%$
- = Ni + Cu 1.8-2.26%
- = Ni + Cu $< 1.8\%$

Table 8. Average Nodule Composition in Area 16

Element	Inner Area 16A		Outer Area 16B	
	Grade ^a (Wt. %)	Standard Deviation	Grade ^b (Wt. %)	Standard Deviation
Mn	28.7	5.2	16.7	6.6
Fe	6.3	1.0	11.1	5.4
Co	0.16	0.05	0.20	0.11
Ni	1.23	0.24	0.65	0.30
Cu	1.31	0.14	0.43	0.28
Cu/Ni	1.07	0.14	0.69	0.26
Cu+Ni	2.54		1.08	
Cu+Ni+Co	2.70		1.28	
Ni+Cu/3+2Co	1.99		1.19	

^aBased on 10 analyses from 8 locations.

^bBased on 19 analyses from 14 locations

As in Area 5 to the northeast, nodules in Area 16A have especially high Cu/Ni ratios with an average ratio >1 . Cu/Ni ratios in the surrounding Area 16B are, in contrast, close to the ocean-wide average.

Conclusions: Since nodule grade usually tends to be relatively constant over large areas, even

the few analyses available for Area 16A may be sufficient evidence that nodule deposits in this basin are generally high-grade. This area is especially promising for seabed mining because it is entirely within a 200-mile Exclusive Economic Zone. Exploration should be undertaken to determine nodule abundance and define the typical grade.

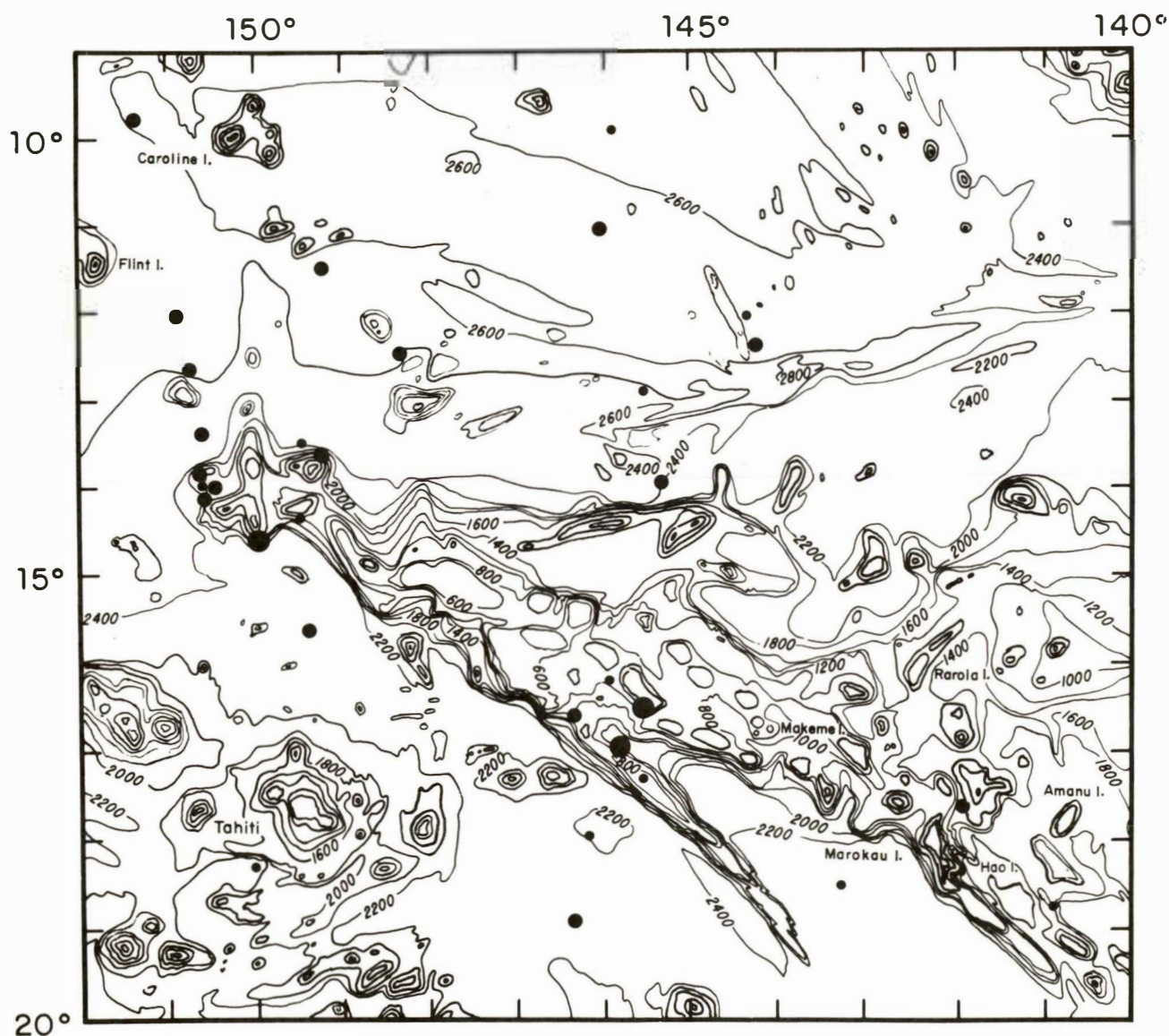


Fig. 21. Nickel-equivalent grade for nodules in Area 17. Contours in fathoms.

- = $\text{Ni} + \text{Cu}/3 + 2\text{Co} \geq 1.98\%$
- = $\text{Ni} + \text{Cu}/3 + 2\text{Co} \text{ } 1.32\text{--}1.98\%$
- = $\text{Ni} + \text{Cu}/3 + 2\text{Co} < 1.32\%$

AREA 17: TUAMOTU ARCHIPELAGO

Description: Area 17 in the South Pacific includes approximately 1.5 million km² between 9-11°S, 140-152°W (see Fig. 21). Within this region are the French Tuamotu Islands and Tahiti and the Caroline Islands, which are presently part of the Trust Territory of the Pacific. Most of this region lies within 200 miles of some island.

It appears that a branch of the Antarctic Bottom Current flows through Aitutaki Passage and thence into the basins to the north of the Tuamotus³². Calcareous turbidites characterized by >60% calcium carbonate are frequent at the base of the Tuamotu Archipelago, while pelagic clays rich in zeolites are the most common sediment type in the deep basin to the north³³.

Available data: Pautot and Melguen³³ have studied the abundance and grade of manganese nodules from this region, but unfortunately their work was based on data from the CNEXO/Société Le Nickel group and AFERNOD (Association Française pour l'Etude et la Recherche des Nodules Polymétalliques), which remain confidential. In the Sediment Data Bank we have information from 35 seafloor photographs and 99 analyses of nodules and crusts from 31 locations.

Nodule abundance: Nodules were observed in only 10% of the seafloor photographs from this region, and the two grab samplers from which abundance was calculated both indicated <2 kg/m². Half of the 64 dredges and grab samplers and 24% of the 98 cores contained nodules. These data suggest that nodules here are much less abundant than in any of the northeastern equatorial Pacific areas studied. Further information is required to confirm this, however.

³²G. Pautot and M. Melguen, *Deep bottom currents, sedimentary hiatuses and polymetallic nodules* (CCOP/SOPAC Technical Bulletin No. 2, 1976), pp. 54-61.

³³G. Pautot and M. Melguen, Influence of deep water circulation and sea-floor morphology on the abundance and grade of central South Pacific manganese nodules. In *Marine geology and oceanography of the Pacific manganese nodule province*, ed. J. L. Bischoff and D. Z. Piper (New York: Plenum Press, 1979), pp. 621-649.

Pautot and Melguen reported that in this region nodules are absent at depths <3000 m and are most abundant between 4350 and 4900 m water depth. However, 29% of the stations in the data bank at which nodules were observed are at depths <3000 m. A few of the samples collected from these shallow water locations are manganese crusts, but most are nodules.

Nodule grade: As shown in Table 9, average nickel and copper content of nodules in Area 17 is too low to be economically interesting. On the other hand, cobalt content is high enough to place the nickel-equivalent value for some of the locations well above the minimum for paramarginal resources. Fig. 22 shows the frequency distributions of the elements in nodules from this area.

Table 9. Average Nodule Composition in Area 17

Element	Grade* (Wt. %)	Standard Deviation
Mn	18.6	6.3
Fe	14.5	4.6
Co	0.58	0.48
Ni	0.54	0.25
Cu	0.26	0.19
Cu/Ni	0.50	0.24
Cu+Ni	0.80	
Cu+Ni+Co	1.34	
Ni+Cu/3+2Co	1.79	

*Based on 99 analyses from 31 locations.

In almost 20% of the nodules and crusts analyzed the reported cobalt content is >1%, ranging up to 2.5%. Most of these very high cobalt values were found by investigators³⁴ who heated samples to 850°C or above before analysis, thus removing bound water and other

³⁴D. S. Cronan, The geochemistry of some manganese nodules and associated pelagic deposits (Ph.D. dissertation, Imperial College, University of London, 1967). H. W. Menard, personal communication on unpublished analyses of the composition of Pacific seafloor manganese nodules (1977).

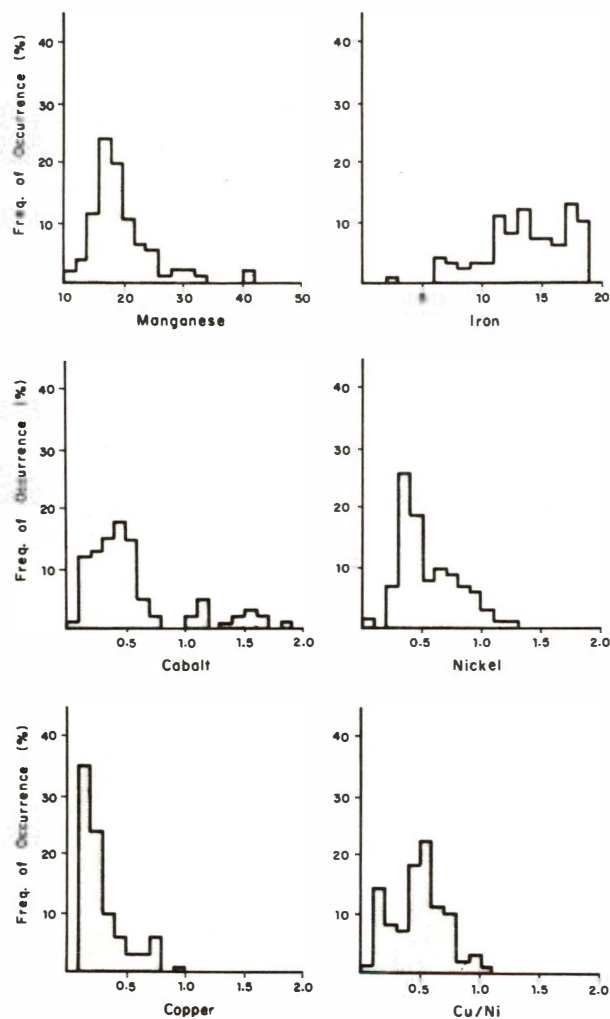


Fig. 22. Frequency distributions of element concentrations for nodules in Area 17.

volatiles. These analyses should be adjusted downwards by about 20% before comparison with analyses performed after standard drying procedures (see Section II above). After such adjustment, average cobalt for this area is 0.53% and average nickel-equivalent grade is 1.6%, still within the limits for submarginal resources.

Conclusions: Parts of the area around the Tuamotu and Caroline Islands could perhaps be considered submarginal resources if cobalt becomes a primary target for miners, but there are certainly no first-generation mine sites here. It is impossible to evaluate the future economic potential of a shallow seamount area such as this, since presently conceived mining techniques are designed for abyssal plains with gentle relief.

APPENDIX A

STATION LOCATIONS AND CHEMICAL COMPOSITION OF SAMPLES ANALYZED AT S.I.O. SEDIMENT DATA BANK, 1979-80

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT. SAMPLED	DIMENSIONS (CM)	XMN	XFE	XCO	XNI	XCU	XZN	XPB
1570001	ET21-RS13	43.967S	120.100W	C	4009	NODULE, WHOLE	32X21X21	18.7	8.5	0.08	1.00	0.59	0.11	0.07
1570029	ELI-CPH24-21	41.917S	124.900W	C	4326	NODULE, WHOLE	28X25X24	21.0	12.2	0.13	0.92	0.39	0.08	0.09
2310013	SCAN-80-G	24.882S	143.453W	C	4658	NODULE FRAGMENTS		20.0	11.4	0.21	0.95	0.51	0.09	0.07
2310033	SCAN-81-G	20.610S	147.528W	C	4570	NODULE, HALF	17	20.3	15.4	0.51	0.60	0.30	0.07	0.09
2320008	SCAN-75-G	24.583S	154.867W	C	4066	NODULE, HALF	30X21X19	15.2	20.1	0.39	0.32	0.20	0.06	0.12
2320019	SOTW 38G	24.812S	157.488W	C	4901	NODULE, HALF	19X12X10	19.5	16.7	0.58	0.52	0.31	0.07	0.12
2660018	SCAN-77-FG	12.423S	134.158W	C	4175	NODULE FRAGMENTS		10.2	15.3	0.37	0.79	0.41	0.09	0.03
2670071	AMPH-126P	11.983S	144.367W	C	4875	CRUST, OUTER LAYER	30X20X10	17.2	13.1	0.25	0.38	0.38	0.06	0.06
2670070	AMPH-125P	11.983S	144.367W	C	4972	NODULE FRAGMENTS	23X18X7	18.1	8.4	0.15	1.15	0.78	0.04	0.04
2670201	AMPH-116P	11.433S	149.283W	C	5106	NODULE, HALF	20X19X11	17.2	14.5	0.18	0.79	0.50	0.09	0.06
2680041	SCAN-72-G	18.997S	155.005W	C	4605	NODULE, HALF	28X28X27	16.0	19.1	0.54	0.27	0.18	0.06	0.12
2690197	STYX-IX 02HX	11.917S	169.533W	C		CRUST	34X33X14	15.9	16.1	0.69	0.29	0.01	0.03	0.17
2700166	STYX-IV-5G	10.250S	175.183W	C	3829	NODULE, HALF	22X21X21	16.7	21.8	0.21	0.19	0.15	0.06	0.11
2770043	0000-57P	15.667S	112.733E	C	3660	NODULE FRAGMENTS		20.6	17.6	0.19	0.38	0.32	0.08	0.17
3040069	STYX-27FF	3.750S	156.050W	G	5065	NODULE, HALF	37X35X19	15.6	9.5	0.08	0.70	0.06	0.09	0.04
3050056	STYX-72FF	3.800S	160.100W	G	5217	NODULE, QUARTER	60X50X15	25.1	11.6	0.20	1.04	0.74	0.12	0.04
3050137	STYX-IX 03HX	8.017S	166.583W	C		NODULE FRAGMENTS	20X10X10	15.8	12.9	0.25	0.51	0.39	0.07	0.07
3050075	STYX-43G	4.233S	166.283W	C	5451	NODULE, QUARTER	43X33X28	18.2	17.7	0.30	0.43	0.30	0.06	0.09
3050080	SOTW 1FF-A	7.250S	168.475W	C	5686	NODULE, WHOLE	5X5X9	21.4	7.6	0.14	1.20	1.06	0.17	0.03
3050134	STYX-IV-11G	7.667S	168.550W	C	5423	NODULE FRAGMENTS	31X29X28	16.0	16.1	0.28	0.39	0.28	0.06	0.08
3050135	STYX-IV-10G	8.750S	168.917W	C	5021	NODULE, QUARTER	46X33X32	16.8	19.4	0.31	0.21	0.15	0.05	0.11
3060056	STYX-IV-7G	9.617S	170.817W	C	4162	NODULE, HALF	31X30X22	14.7	20.4	0.17	0.17	0.15	0.07	0.11
3060057	STYX-IV-12G	7.683S	170.850W	C	5440	NODULE, HALF	33X29X28	13.2	21.5	0.16	0.15	0.06	0.10	0.00
3070035	MSN-17GA	7.050S	174.150E	C	5530	NODULE, QUARTER		17.8	19.9	0.25	0.37	0.32	0.06	0.10
3350124	RISE-III-D3	6.825N	103.917W	D	2055	CRUST FRAGMENTS		12.8	20.6	0.07	0.17	0.04	0.06	0.04
						NODULE, QUARTER	78X50X26	38.3	0.0	0.00	0.04	0.00	0.01	0.00
						NODULE FRAGMENTS	41X31X24	33.4	0.0	0.00	0.06	0.08	0.06	0.00
						CRUST FRAGMENTS	54X38X19	42.6	0.0	0.00	0.00	0.00	0.00	0.00
3390072	EWOT 22FF	7.618N	133.988W	C	4630	NODULE, HALF	22X17X10	15.3	9.6	0.14	0.97	0.85	0.49	0.02

SEQ NUMBER	SIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZMN	ZFE	ZCC	ZNI	ZCU	ZZN	ZPB
3390187	SS72-72DB	8.98CN	145.11CW	C	4940	NCD & MICROCD, HALF NODULE, QUARTER NODULE, QUARTER	34X29X22 49X35X33 70X65X50	18.7 30.6 29.4	11.6 5.1 5.5	0.28 0.17 0.15	0.84 1.51 1.24	0.54 1.35 0.97	0.07 0.14 0.13	0.11 0.04 0.03
3390189	SS72-70DB	8.955N	145.807W	D	5030	NODULE, QUARTER NODULE, QUARTER	40X40X20 45X35X28	28.6 28.1	4.2 4.5	0.16 0.16	1.59 1.65	1.44 1.32	0.16 0.15	0.03 0.04
3390190	SS72-74DB	9.657N	146.332W	C	5033	NODULE, HALF	26X22X22	28.4	6.2	0.28	1.60	1.15	0.13	0.05
3390192	SS72-69DB	8.965N	146.668W	C	5101	NODULE, QUARTER	50X43X30	29.5	5.3	0.16	1.30	1.11	0.12	0.04
3390193	SS72-65DB	8.740N	147.532W	D	5123	NODULE X-SECTION	70X70X35	28.5	7.5	0.20	1.18	0.82	0.12	0.05
3390194	SS72-66DB	8.727N	147.590W	D	5055	NODULE, HALF NODULE X-SECTION	44X36X30 70X60X50	28.2 31.0	5.2 5.5	0.15 0.13	1.51 1.42	1.22 1.12	0.15 0.17	0.04 0.03
3390197	SS72-68DB	8.575N	147.778W	D	5125	NODULE, HALF	29X22X14	27.9	4.8	0.12	0.68	0.48	0.14	0.03
3400249	80C75-46-3	9.317N	150.875W	C	4900	NODULE FRAGMENTS NODULE FRAGMENTS NODULE, WHOLE	35 40 27	24.5 24.5 24.1	12.2 12.3 13.8	0.29 0.29 0.33	1.04 0.93 1.18	0.60 0.57 0.51	0.09 0.08 0.08	0.08 0.08 0.10
3400269	SS72-63DB	8.273N	150.993W	D	4830	NODULE, HALF NODULE, HALF	21X17X11 35X30X27	27.9 27.4	6.1 7.2	0.19 0.18	1.65 1.46	1.37 1.25	0.16 0.15	0.04 0.05
3400272	SS72-60DB	8.098N	152.603W	C	5033	MICRONOD IN SED, HALF MICRONOD IN SED, WHOLE	36X28X21 22X20X19	15.9 21.4	8.1 10.5	0.14 0.18	0.98 1.00	0.70 0.74	0.09 0.09	0.05 0.06
3400017	WAK-E18FF-2	9.272N	152.970W	C	5160	NODULE, HALF	21X20X13	25.3	8.4	0.24	1.36	1.05	0.12	0.06
3400274	SS72-59DB	8.095N	153.915W	C	5000	NODULE X-SECTION	22X22X18	27.4	5.9	0.13	1.45	1.56	0.14	0.04
3400275	SS72-58DB	7.83CN	154.822W	C	4905	NODULE, HALF NODULE, HALF	34X23X21 24X24X13	27.0 27.2	6.8 7.0	0.17 0.16	1.47 1.50	1.46 1.39	0.13 0.13	0.05 0.04
3400277	SS72-57DB	7.80CN	156.317W	C	5125	NODULE, HALF	32X28X19	25.7	7.7	0.20	1.36	1.38	0.12	0.05
3410220	SS72-53DB	6.783N	166.883W	D	4671	NODULE, WHOLE NODULE, WHOLE	15X15X11 19X18X10	24.8 24.7	12.1 12.5	0.23 0.29	0.92 0.98	0.66 0.66	0.10 0.11	0.07 0.07
3420006	LSGP-93P	9.817N	170.983W	C	4875	NODULE FRAGMENTS		22.9	9.6	0.27	1.10	0.90	0.11	0.06
3420223	GH771-G394	6.962N	175.007W	G	5940	NODULE, HALF	32X22X20	26.6	8.3	0.20	1.21	1.17	0.11	0.04
3420241	GH771-G402	9.497N	175.968W	C	6160	NODULE X-SECTION	65X48X35	17.1	14.4	0.27	0.46	0.32	0.06	0.08
3420261	GH771-G397	5.985N	176.025W	C	5371	NODULE, HALF NODULE, HALF	14X13X12 13X12X12	26.6 25.7	5.9 5.4	0.17 0.13	1.31 1.51	1.53 1.57	0.16 0.15	0.03 0.02
3420262	GH771-G387	8.983N	176.028W	G	6035	NODULE, HALF	31X25X17	19.9	11.6	0.22	0.82	0.72	0.08	0.06
3420267	GH771-G385	7.99CN	176.983W	G	5120	NODULE FRAGMENTS	40X34X31	20.9	12.5	0.26	0.81	0.62	0.09	0.07
3430010	PRDA-99P	3.163N	179.350E	C	5391	NODULE FRAGMENTS	16X12X8	17.7	17.1	0.04	0.33	0.42	0.08	0.06

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZMN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB
3430015	NOVA-A 7G	9.317N	177.983E	C	5658	NODULE, HALF	37X30X25	20.7	12.3	0.23	0.78	0.64	0.08	0.07
3470013	PRJA-11P	6.133N	136.183E	C	4600	NODULE FRAGMENTS		18.6	14.3	0.01	0.68	0.42	0.09	0.07
3710145	RISE-III-D24	13.022N	100.817W	D	2308	NODULE, OUTER LAYER NODULE FRAGMENTS NODULE, OUTER LAYER		15.7 16.5 30.9	20.4 20.1 8.5	0.29 0.14 0.03	0.57 0.31 0.51	0.20 0.12 0.30	0.08 0.05 0.10	0.06 0.05 0.02
3710146	RISE-III-D25	13.022N	100.817W	C	2350	NODULE, HALF NODULE FRAGMENTS		22.0 13.7	20.7 20.8	0.29 0.15	0.35 0.15	0.13 0.13	0.05 0.05	0.09 0.05
3710147	RISE-III-D26	13.033N	100.833W	D	2589	NODULE, HALF NODULE, HALF	27X23X15 21X20X17	15.3 22.0	13.0 13.8	0.00 0.00	0.58 0.68	0.31 0.29	0.13 0.17	0.03 0.03
3710149	RISE-III-C28	13.767N	101.872W	D	1693	CRUST FRAGMENTS FRAGMENTS FRAGMENTS		22.0 15.4 18.8	18.3 21.6 20.9	0.57 0.44 0.81	0.43 0.21 0.28	0.11 0.07 0.07	0.06 0.05 0.04	0.12 0.13 0.14
3710148	RISE-III-D27	13.783N	101.875W	C	1638	FRAGMENTS		9.5	16.3	0.28	0.18	0.01	0.05	0.01
3710152	RISE-III-D19	14.717N	102.558W	C	2260	FRAGMENTS NODULE FRAGMENTS NODULE, HALF	51X37X33	13.5 20.3 15.0	22.0 20.4 22.1	0.09 0.32 0.00	0.19 0.36 0.21	0.14 0.12 0.13	0.05 0.05 0.06	0.05 0.09 0.05
3710153	RISE-III-D20	14.725N	102.575W	D	1843	CRUST FRAGMENTS CRUST FRAGMENTS		7.9 19.8	13.3 19.6	0.28 0.52	0.13 0.31	0.01 0.08	0.04 0.05	0.08 0.12
3710154	RISE-III-C11	12.525N	103.200W	D	2077	NODULE, QUARTER CRUST FRAGMENTS	82X57X28	16.9 17.1	19.4 21.4	0.23 0.25	0.40 0.28	0.12 0.09	0.05 0.05	0.06 0.08
3710155	RISE-III-C7	11.517N	103.217W	C	2183	NODULE FRAGMENTS NODULE FRAGMENTS		14.7 13.9	24.0 23.9	0.09 0.16	0.19 0.21	0.13 0.12	0.06 0.06	0.06 0.05
3710156	RISE-III-C8	11.500N	103.225W	D	2450	NODULE FRAGMENTS NODULE FRAGMENTS NODULE, HALF NODULE FRAGMENTS NODULE, QUARTER	59X53X32 52X42X30	13.2 12.9 18.2 12.6 12.3	23.2 23.4 20.4 24.4 23.7	0.00 0.00 0.08 0.00 0.00	0.16 0.15 0.52 0.14 0.13	0.16 0.16 0.25 0.13 0.14	0.06 0.05 0.11 0.07 0.06	0.04 0.04 0.04 0.05 0.05
3710157	RISE-III-D9	11.517N	103.242W	C	2352	NODULE, QUARTER	56X38X17	4.1	15.3	0.02	0.06	0.03	0.05	0.03
3710158	RISE-III-D12	12.517N	103.258W	C	2302	NODULE, HALF	63X41X29	14.3	25.2	0.00	0.18	0.16	0.06	0.05
3710160	RISE-III-C13	12.533N	103.283W	D	2251	NODULE FRAGMENTS		13.4	21.5	0.12	0.19	0.05	0.05	0.05
3710159	RISE-III-C6	11.500N	103.292W	C	2703	NODULE, HALF NODULE, HALF FRAGMENTS CRUST FRAGMENTS NODULE FRAGMENTS	45X35X25 37X29X27	13.8 14.0 16.2 13.3 14.7	23.6 21.2 20.8 23.7 24.0	0.10 0.02 0.09 0.01 0.02	0.15 0.30 0.32 0.17 0.23	0.13 0.16 0.20 0.16 0.12	0.06 0.07 0.08 0.06 0.07	0.05 0.04 0.04 0.04 0.05
3710167	RISE-III-C5	11.497N	103.957W	D	2635	MN COATED ROCK W/O NUCLEUS	43X30X28	11.8	20.9	0.00	0.13	0.11	0.05	0.04
3710057	BNFC 196X	10.727N	108.542W	C	3172	NODULE, HALF	60X45X32	23.3	13.2	0.13	1.04	0.58	0.12	0.03

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEF (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	2PN	2FE	2CO	2K1	2CU	2ZN	2PB
3710034	SCAN-98-G	16.450N	109.223W	C	3474	NODULE, HALF	42X30X22	20.2	15.7	0.01	0.72	0.44	0.10	0.04
3710095	BNFC 17P	11.177N	109.605W	C	3522	NODULE, HALF NODULE, HALF	50X40X20 20X17X14	27.7 21.6	9.3 12.5	0.09 0.05	1.28 1.02	0.85 0.52	0.18 0.12	0.03 0.04
3720042	BNFC 53P	11.870N	110.002W	C	3851	NODULE FRAGMENTS		27.3	11.3	0.07	1.21	0.71	0.17	0.05
3720011	TRI-7GD	14.467N	111.833W	C	3644	NODULE, HALF	20X15X10	24.9	12.4	0.10	1.11	0.74	0.12	0.05
3720048	BNFC 58PG	13.535N	114.345W	C	4003	NODULE FRAGMENTS		28.3	10.4	0.13	1.38	0.77	0.15	0.05
3720100	SS72-37CC	19.663N	115.305W	C	3768	NODULE, QUARTER		27.2	8.3	0.14	1.15	0.81	0.16	0.04
3720101	SS72-38CC	19.695N	115.328W	C	3768	NODULE, QUARTER NODULE, QUARTER	49X26X23 25X17X10	26.6 27.1	8.8 8.6	0.13 0.16	1.19 1.30	0.78 0.82	0.18 0.19	0.05 0.04
3720083	BNFC 63BX-B	14.547N	117.270W	C	4079	NODULE, HALF	24X15X5	28.3	9.6	0.17	1.40	0.92	0.14	0.06
3720055	BNFC 62P	14.607N	117.293W	C	4035	MIN ENCRUSTED SED, WHOLE	40X30X22	8.8	7.0	0.05	0.58	0.57	0.07	0.03
3720057	BNFC 73P	14.557N	117.303W	C	3964	NODULE, HALF	33X29X27	27.3	9.4	0.10	1.26	0.95	0.14	0.05
3720056	BNFC 73PG	14.557N	117.303W	C	3964	NODULE, WHOLE	15X15X10	28.2	8.4	0.19	1.45	0.96	0.22	0.05
3720060	BNFC 71FF	14.533N	117.320W	C	3964	NODULE, HALF	20X20X10	24.6	10.4	0.26	1.23	0.87	0.12	0.06
3720061	BNFC 70FF	14.530N	117.327W	C	3988	NODULE, WHOLE	27X23X10	26.6	8.7	0.19	1.40	0.91	0.14	0.05
3720066	BNFC 68FF	14.527N	117.353W	C	4083	NODULE FRAGMENTS	24X19X11	29.2	8.3	0.17	1.51	0.93	0.18	0.04
3720067	BNFC 77FF	14.612N	117.360W	C	4087	NODULE, HALF	27X20X18	29.6	7.2	0.14	1.37	1.01	0.21	0.04
3730044	BNFC 84PG	15.093N	120.748W	C	4207	NODULE, WHOLE	23X20X13	27.6	6.5	0.18	1.26	1.13	0.27	0.04
3730047	BNFC 86PG	14.585N	121.062W	C	4295	NODULE	40X30X15	28.8	6.9	0.21	1.43	1.01	0.21	0.04
3730114	80C75 25-51	14.242N	124.975W	C	4561	NODULE, WHOLE NODULE, WHOLE NODULE, WHOLE NODULE, WHOLE	20X18X15 20X19X8 21X14X12 19X18X12	29.8 30.4 28.2 26.7	6.0 6.8 6.1 6.1	0.14 0.23 0.14 0.16	1.49 1.63 1.59 1.49	1.25 1.22 1.34 1.24	0.17 0.15 0.17 0.16	0.05 0.06 0.05 0.05
3730143	SS72-90B	15.132N	125.132W	C	4298	NODULE X-SECTION NODULE FRAGMENTS	18X15X13 25X20X16	30.1 29.9	6.7 5.5	0.27 0.17	1.50 1.44	1.20 1.30	0.18 0.15	0.05 0.04
3730145	SS72-130E	15.043N	125.138W	C	4300	NODULE, HALF	30X15X15	27.9	7.0	0.29	1.48	1.06	0.14	0.05
3730148	SS72-60C	15.100N	125.167W	C	4390	NODULE FRAGMENTS NODULE FRAGMENTS	25X20X18 27X20X17	28.9 32.7	7.1 4.4	0.27 0.16	1.32 1.43	1.00 1.26	0.16 0.24	0.05 0.03
3730129	80C75-58-61	15.343N	125.447W	C	4414	NODULE FRAGMENTS NODULE, HALF	52	24.8 27.6	7.0 5.9	0.31 0.21	1.38 1.36	1.03 1.19	0.13 0.14	0.06 0.05
3730130	80C75-58-60	15.297N	125.473W	C	4375	NODULE FRAGMENTS		27.0	9.3	0.29	1.34	0.87	0.12	0.07
3730133	80C75-57-57	15.297N	125.922W	C	4520	NODULE, HALF	27	29.6	8.6	0.31	1.56	1.00	0.13	0.08

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZPN	ZFE	ZCC	ZNI	ZCU	ZZN	ZPB
						NODULE, HALF	21	26.9	8.2	0.32	1.42	0.94	0.12	0.08
3730172	SS72-17DB	13.142N	128.602W	C	4710	NODULE, CLARTER NODULE, HALF	42X30X22 40X35X24	29.7 30.9	5.6 5.5	0.19 0.20	1.48 1.50	1.16 1.23	0.17 0.17	0.04 0.04
3740008	JYNU-50P	18.267N	131.767W	C	5210	NODULE FRAGMENTS	30X26X13	25.3	11.0	0.44	1.12	0.74	0.08	0.08
3740012	JYNU-49P	17.167N	132.833W	C	5188	NODULE, HALF	40X10X10	14.3	10.2	0.17	0.18	0.24	0.04	0.09
3740053	SCAN-98-PG	19.933N	139.867W	C	5038	NODULE, HALF	22X20X10	23.1	10.5	0.31	1.20	0.75	0.09	0.07
3740132	MN7601-20G09	11.067N	139.997W	C	4873	NODULE, HALF NODULE, WFOLE	24X19X18 12X10X9	29.9 29.9	3.5 7.9	0.20 0.42	1.30 1.72	1.39 1.01	0.15 0.16	0.03 0.06
3740133	MN7601-20G10	11.067N	139.998W	C	4873	NODULE, WFOLE	11X11X9	29.1	4.8	0.39	1.40	1.40	0.20	0.04
3750192	MN7601-20G12	11.048N	140.047W	C	4780	NODULE, HALF	18X13X11	30.8	4.0	0.19	1.71	1.49	0.22	0.03
3750446	K79-05 99 BC	11.012N	140.067W	C	4900	NODULE, WFOLE NODULE, WFOLE	19X16X16 13X11X10	29.7 15.7	3.2 5.4	0.14 0.28	1.46 1.29	1.35 1.15	0.24 0.13	0.03 0.04
3750128	MN7503-01G14	11.043N	140.070W	G	4895	NODULE, HALF NODULE, WFOLE NODULE, WFOLE NODULE, WFOLE NODULE, WFOLE	12X11X10 7X6X5 7X5X4 13X10X7 12X11X11	26.6 18.4 10.4 24.5 27.4	4.5 5.0 7.4 8.5 5.0	0.26 0.25 0.18 0.51 0.30	1.48 1.21 0.71 1.10 1.47	1.32 1.11 0.78 0.90 1.18	0.17 0.18 0.11 0.15 0.21	0.03 0.03 0.02 0.11 0.04
3750129	MN7503-01G15	11.037N	140.078W	G	4932	NODULE, HALF NODULE, HALF	19X17X15 19X11X7	28.9 27.8	4.8 6.9	0.24 0.30	1.44 1.26	1.44 0.78	0.16 0.16	0.03 0.06
3750453	K79-05 101BC	11.012N	140.080W	C	4920	NODULE, CLARTER	60X45X28	29.4	4.5	0.19	1.41	1.29	0.17	0.04
3750193	MN7601-20G13	11.095N	140.082W	C	4781	NODULE W/C NUCLEUS NODULE, WFOLE	19 12X11X10	33.4 33.2	4.7 4.8	0.20 0.31	1.54 1.90	1.25 1.42	0.21 0.20	0.04 0.04
3750194	MN7601-20G14	11.093N	140.082W	G	4781	NODULE, WFOLE	11X10X8	30.7	4.6	0.29	1.85	1.36	0.19	0.04
3750125	MN7503-01G11	11.035N	140.088W	G	4909	MN COATED ROCK, HALF NODULE FRAGMENTS NODULE, WFOLE NODULE, HALF NODULE, HALF	29X24X19 20X10X3 10X10X9 13X13X12 21X14X13	20.2 21.0 27.7 31.5 26.1	2.6 11.3 7.0 4.9 5.6	0.13 0.38 0.36 0.22 0.20	0.89 0.68 1.02 1.31 1.25	0.81 0.55 0.96 1.19 1.29	0.18 0.12 0.21 0.20 0.18	0.02 0.02 0.04 0.03 0.03
3750478	K79-05 85 BC	11.010N	140.088W	C	4910	NODULE, HALF	16X13X11	28.0	4.2	0.19	1.40	1.37	0.22	0.03
3750486	K79-05 54 BC	11.012N	140.088W	C	4910	NODULE, HALF	24X18X15	27.1	4.2	0.21	1.46	1.43	0.18	0.03
3750480	K79-05 73 BC	11.013N	140.088W	C	4910	NODULE, HALF	25X25X14	20.0	4.2	0.16	1.07	0.98	0.17	0.03
3750479	K79-05 75 BC	11.012N	140.088W	C	4910	NODULE, WFOLE	10X10X9	19.2	5.1	0.32	1.10	1.23	0.14	0.04
3750126	MN7503-01G12	11.035N	140.090W	C	4909	NODULE, HALF NODULE, HALF NODULE W/C NUCLEUS NODULE W/C NUCLEUS	18X18X16 16X15X12 24X23X14 44X39X17	21.5 28.6 26.5 26.9	6.0 5.0 5.8 6.7	0.29 0.23 0.23 0.29	1.35 1.55 1.45 1.43	1.13 1.24 1.19 0.92	0.13 0.15 0.14 0.15	0.03 0.03 0.03 0.05

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	XMN	XFE	XCC	XNI	XCU	XZN	XPB
3750122	MN7503-01G08	10.982N	140.092W	C	4937	NODULE, HALF NODULE, HALF NODULE, HALF NODULE, HALF NODULE, WHOLE	10X9X8 9X7X7 25X20X10 14X12X11 12X9X8	25.9 26.6 30.1 30.5 29.4	3.5 5.3 5.0 5.2 4.1	0.27 0.26 0.26 0.31 0.25	1.47 1.16 1.43 1.53 1.58	1.28 1.12 1.37 1.33 1.37	0.18 0.13 0.20 0.16 0.20	0.04 0.03 0.04 0.04 0.03
3750121	MN7503-01G07	10.980N	140.092W	G	4932	NODULE, HALF NODULE, HALF NODULE, WHOLE NODULE, HALF NODULE, HALF NOD & PICCFACC X-SECTION NODULE, WHOLE NODULE, WHOLE NODULE, WHOLE NODULE, WHOLE NODULE, HALF NODULE, HALF NODULE, HALF	10X9X9 12X10X9 8X7X7 20X14X10 22X12X11 75X56X30 7X7X6 7X7X7 10X9X9 12X12X10 14X13X9 15X13X12 24X17X11	27.9 26.2 27.0 25.7 25.8 13.9 28.7 26.6 26.2 29.8 27.5 28.3 30.4	6.1 5.9 5.9 6.4 6.3 6.4 6.9 7.5 7.9 6.5 7.4 6.3 6.8	0.32 0.32 0.34 0.31 0.28 0.23 0.46 0.49 0.40 0.30 0.37 0.31 0.34	1.51 1.42 1.36 1.17 1.31 0.99 1.45 1.45 1.42 1.58 1.52 1.42 1.64	0.98 1.12 1.10 0.92 0.95 0.74 1.15 1.13 1.01 1.15 0.95 1.05 1.17	0.13 0.14 0.13 0.11 0.13 0.10 0.13 0.12 0.12 0.16 0.13 0.12 0.17	0.05 0.04 0.05 0.06 0.05 0.04 0.06 0.06 0.07 0.05 0.06 0.05 0.06
3750477	K79-05 66 BC	11.010N	140.095W	C	4910	NODULE, HALF NODULE, HALF	16X13X12 19X19X11	22.6 27.0	6.8 4.3	0.33 0.18	1.36 1.50	1.24 1.31	0.15 0.19	0.04 0.03
3750476	K79-05 62 BC	11.013N	140.095W	C	4910	NODULE, HALF	28X22X16	21.7	6.5	0.48	1.20	1.62	0.10	0.05
3750462	K79-05 91 BC	11.008N	140.095W	C	4910	NODULE, HALF NODULE, HALF	28X12X9 40X31X14	27.8 28.8	5.2 5.4	0.24 0.25	1.34 1.53	1.22 1.27	0.17 0.16	0.04 0.04
3750120	MN7503-01G06	10.970N	140.097W	G	4905	NODULE, HALF NODULE, HALF NODULE, HALF NODULE, WHOLE NODULE, HALF NODULE, HALF	28X20X18 17X15X15 12X12X11 12X11X11 21X16X9 19X16X12	27.6 29.2 30.8 29.8 27.9 30.7	4.4 3.1 3.1 6.5 6.0 4.2	0.17 0.13 0.14 0.30 0.28 0.18	1.41 1.29 1.25 1.58 1.44 1.44	1.42 1.27 1.29 1.15 1.20 1.41	0.19 0.26 0.02 0.16 0.21 0.26	0.03 0.02 0.02 0.05 0.03 0.03
3750119	MN7503-01G05	10.967N	140.098W	G	4905	NODULE, HALF NODULE, WHOLE NODULE, HALF NODULE, QUARTER NODULE, HALF NODULE W/C NUCLEUS NODULE W/C NUCLEUS NODULE, WHOLE NODULE, HALF	25X25X17 10X8X8 17X13X13 22X21X15 9X9X8 15X14X14 9 11X5X5 13X13X13	25.9 31.2 30.4 27.1 30.0 27.2 27.4 28.8 30.8	4.8 3.2 4.1 4.3 2.9 4.1 4.2 3.1 3.8	0.15 0.16 0.23 0.16 0.27 0.20 0.24 0.17 0.14	1.58 1.59 1.71 1.64 1.54 1.73 1.70 1.59 1.58	1.34 1.47 1.36 1.44 1.35 1.39 1.44 1.44 1.53	0.18 0.23 0.20 0.16 0.25 0.17 0.18 0.22 0.21	0.03 0.03 0.04 0.03 0.03 0.03 0.04 0.03 0.03
3750186	MN7601-20G04	11.025N	140.102W	G	4930	NODULE, HALF	19X17X13	30.8	4.3	0.21	1.49	1.50	0.19	0.03
3750487	K79-05 106BC	11.013N	140.105W	C	4900	NODULE, HALF NODULE, HALF NODULE, HALF NODULE, HALF	27X26X9 28X25X10 19X17X13 20X15X10	26.7 29.5 27.9 25.8	6.5 5.2 4.8 5.2	0.32 0.24 0.22 0.24	1.59 1.60 1.56 1.48	1.09 1.20 1.24 1.14	0.15 0.17 0.18 0.14	0.05 0.04 0.04 0.04
3750117	MN7503-01G02	11.017N	140.115W	G	4872	NODULE W/C NUCLEUS NODULE W/C NUCLEUS	9X9X8 20X19X11	26.5 27.9	5.2 5.0	0.29 0.22	1.55 1.65	1.15 1.21	0.15 0.17	0.04 0.04

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZPN	ZFE	ZCC	ZNI	ZCU	ZZN	ZPB
						NODULE, HALF NODULE, OUTER LAYER	16X15X9	25.7 27.9	7.0 6.6	0.34 0.35	1.37 1.39	1.05 1.06	0.15 0.16	0.05 0.04
3750118	MN7503-01G03	11.015N	140.112W	G	4867	NODULE, HALF NODULE, HALF NODULE, HALF NODULE W/C NUCLEUS NODULE W/C NUCLEUS NODULE W/C NUCLEUS	18X16X14 20X16X15 12X11X10 23X18X16 21X14X13 33X27X13	29.2 25.4 28.6 28.2 28.4 26.5	4.3 4.7 4.9 4.7 4.6 5.1	0.21 0.20 0.25 0.21 0.22 0.19	1.52 1.53 1.65 1.77 1.51 1.59	1.25 1.32 1.33 1.33 1.27 1.26	0.18 0.17 0.18 0.16 0.17 0.15	0.03 0.03 0.04 0.03 0.03 0.04
3750135	MN7503-01G01	11.015N	140.118W	G	4867	NODULE W/C NUCLEUS NODULE W/C NUCLEUS NODULE FRAGMENTS NODULE, HALF NODULE, HALF NODULE, HALF NODULE, QUARTER NODULE, QUARTER NODULE, HALF NODULE W/C NUCLEUS NODULE W/C NUCLEUS NODULE, HALF	17X16X15 16X13X10 34X28X18 10X9X9 14X13X11 15X13X12 26X22X13 26X21X16 17 11X10X10 10 11X11X10	28.3 27.4 26.3 28.2 29.0 31.7 28.2 30.6 27.9 25.2 28.8 27.0	5.1 5.5 4.6 6.3 5.8 5.3 5.9 4.8 6.0 4.5 5.4 4.9	0.25 0.31 0.16 0.35 0.30 0.31 0.25 0.22 0.37 0.31 0.38 0.29	1.67 1.41 1.41 1.41 1.67 1.60 1.48 1.54 1.64 1.53 1.64 1.55	1.22 1.28 1.14 1.31 1.31 1.31 1.09 1.31 1.19 1.25 1.24 1.12	0.17 0.15 0.17 0.13 0.15 0.16 0.17 0.18 0.15 0.18 0.17 0.16	0.04 0.04 0.03 0.05 0.05 0.04 0.04 0.04 0.04 0.04 0.04 0.04
3750123	MN7503-01G09	10.927N	140.135W	G	4767	NODULE, HALF NODULE, HALF NODULE, WHOLE	14X13X9 19X14X11 10X10X8	28.2 28.9 25.3	4.0 6.4 4.2	0.20 0.22 0.25	1.45 1.67 1.80	1.24 1.35 1.27	0.21 0.22 0.20	0.03 0.03 0.03
3750124	MN7503-01G10	10.927N	140.135W	G	4767	NODULE, WHOLE NODULE, HALF	10X9X7 14X13X9	30.7 28.5	4.9 5.9	0.28 0.26	1.72 1.78	1.31 1.35	0.22 0.18	0.04 0.04
3750132	MN7503-01G20	10.965N	140.148W	G	4619	NODULE, HALF NODULE, HALF NODULE W/C NUCLEUS NODULE W/C NUCLEUS NODULE W/C NUCLEUS NODULE, HALF NODULE, HALF	16X13X13 14X14X11 18X9X6 25X18X14 12X10X10 12X11X11 15X12X12	30.2 28.6 26.8 28.4 30.0 28.4 28.9	4.1 4.0 5.2 4.6 4.6 4.6 4.6	0.23 0.23 0.32 0.22 0.27 0.25 0.23	1.52 1.57 1.65 1.62 1.72 1.65 1.66	1.29 1.26 1.22 1.23 1.25 1.32 1.28	0.20 0.17 0.17 0.18 0.17 0.19 0.18	0.03 0.03 0.05 0.04 0.04 0.04 0.04
3750131	MN7503-01G19	10.950N	140.156W	C	4223	MN COATED ROCK, OUTER LAYER MN COATED ROCK, OUTER LAYER		25.0 21.7	10.2 10.7	0.41 0.59	1.08 0.98	0.59 0.66	0.11 0.09	0.07 0.09
3750190	MN7601-20G08	10.990N	140.182W	G	4892	NODULE, HALF NODULE, HALF	11X11X11 17X15X11	32.7 28.5	4.9 6.6	0.34 0.38	1.93 1.81	1.35 1.08	0.22 0.17	0.04 0.04
3750189	MN7601-20G07	10.988N	140.182W	G	4892	NODULE, WHOLE NODULE, HALF NODULE, HALF	9X9X8 18X15X12 21X12X10	26.3 31.1 26.0	7.2 5.6 8.2	0.43 0.32 0.41	1.62 1.72 1.50	0.99 1.14 0.86	0.15 0.15 0.14	0.06 0.04 0.06
3750188	MN7601-20G06	10.990N	140.193W	G	4555	NODULE, WHOLE NODULE, WHOLE NODULE, WHOLE NODULE	9X7X6 11X10X10 13X13X11 19X15X14	26.3 29.3 26.4 29.0	7.6 7.2 7.9 8.1	0.45 0.38 0.36 0.32	1.52 1.80 1.57 1.63	0.99 1.05 0.85 0.97	0.13 0.16 0.14 0.16	0.06 0.06 0.06 0.06
3750187	MN7601-20G05	10.990N	140.193W	G	4555	NODULE W/C NUCLEUS NODULE, WHOLE	9X7X6 11X10X10	22.2 26.2	8.3 7.7	0.55 0.36	1.46 1.47	0.95 0.88	0.13 0.14	0.06 0.06

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEF (P)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZPN	ZFE	ZCC	ZNI	ZCU	ZZN	ZPB
						NODULE W/C NUCLEUS	13X12X12	25.6	7.2	0.39	1.70	0.97	0.17	0.05
						NODULE W/C NUCLEUS	16X13X12	28.2	7.5	0.30	1.62	0.98	0.16	0.06
						NODULE, HALF	16X14X13	26.4	7.5	0.29	1.48	0.79	0.14	0.06
3750350	SS72-840B	11.933N	146.448W	C	5311	NODULE, HALF	35X25X18	29.4	6.4	0.22	1.44	1.14	0.16	0.04
3750353	SS72-790B	11.132N	146.072W	D	5125	NODULE, QUARTER	46X45X30	29.8	5.8	0.23	1.46	1.25	0.13	0.04
						NODULE, HALF	27X25X22	30.8	5.7	0.21	1.55	1.18	0.14	0.04
3750354	SS72-800B	10.978N	146.325W	C	5121	NODULE, HALF	25X21X18	27.4	5.8	0.21	1.54	1.33	0.14	0.04
						NODULE, HALF	29X22X20	25.4	6.7	0.20	1.36	1.17	0.13	0.04
						NODULE, WHOLE	16X12X11	21.9	6.9	0.21	1.20	1.07	0.13	0.04
						NODULE, HALF	24X22X16	24.1	8.4	0.28	1.34	1.01	0.12	0.05
						NODULE FRAGMENTS	59X50X33	25.0	5.6	0.14	1.13	0.90	0.13	0.04
						NODULE, HALF	29X21X16	23.0	6.7	0.21	1.21	1.13	0.13	0.04
3750356	SS72-830B	11.018N	146.498W	C	5341	NODULE X-SECTION	31X28X26	28.4	6.2	0.21	1.36	1.22	0.14	0.04
3750358	SS72-900B	11.513N	146.578W	C	5125	NODULE, HALF	33X32X30	19.1	11.6	0.28	0.75	0.54	0.07	0.10
						MN ENCRUSTED SED, WHOLE	24X23X13	11.5	11.1	0.09	0.35	0.32	0.10	0.10
						NODULE X-SECTION	51X27X26	18.4	11.7	0.22	0.78	0.54	0.07	0.11
						NODULE, HALF	38X33X28	30.6	5.3	0.16	1.40	1.26	0.15	0.03
						NODULE, WHOLE	26X16X15	13.0	7.8	0.08	0.66	0.43	0.07	0.03
						MICRONOC IN SED	27X25X22	21.1	4.3	0.09	0.94	0.84	0.11	0.03
3750359	SS72-850B	11.803N	146.662W	D	5400	NODULE, QUARTER	48X41X34	28.7	6.5	0.25	1.29	1.26	0.12	0.03
						NODULE, QUARTER	46X40X30	29.4	6.1	0.19	1.40	1.23	0.13	0.03
3750360	SS72-890B	11.487N	149.183W	D	5300	NODULE, HALF	28X22X16	23.5	8.4	0.25	1.24	0.86	0.10	0.05
						NODULE, HALF	34X24X20	26.5	7.1	0.24	1.41	1.04	0.13	0.04
						NODULE, HALF	43X34X18	20.0	8.4	0.24	1.11	0.69	0.10	0.04
						NODULE, WHOLE	18X14X10	21.3	6.7	0.21	1.15	0.89	0.09	0.06
3750361	SS72-860B	12.023N	149.300W	C	5308	NODULE, HALF	32X22X19	23.4	7.5	0.19	1.23	1.16	0.11	0.04
						NODULE, HALF	15X15X13	27.3	5.9	0.25	1.59	1.29	0.13	0.04
						NODULE, HALF	27X20X12	24.2	6.1	0.23	1.34	1.12	0.12	0.04
						NODULE, HALF	23X23X10	25.7	7.0	0.25	1.45	1.12	0.12	0.04
3760226	SS72-870B	11.970N	150.308W	D	5000	NODULE, HALF	28X16X11	26.5	5.1	0.16	1.38	1.33	0.16	0.00
						NODULE, HALF	24X18X18	29.0	5.2	0.17	1.39	1.34	0.16	0.03
3760073	STYX-15G	14.500N	154.800W	C	5233	NODULE, WHOLE	13X10X9	19.8	6.8	0.19	1.21	0.95	0.12	0.04
3760075	STYX-13G	14.317N	154.800W	C	5272	NODULE FRAGMENTS	23X17X10	22.5	10.1	0.28	0.95	0.65	0.10	0.06
3760083	SCAN-64-G	11.000N	154.967W	C	5312	NODULE, HALF	43X18X13	23.7	8.8	0.27	1.14	0.77	0.20	0.05
3760118	STYX-24G	15.817N	157.067W	C	5118	CRUST, HALF	20X12X10	20.3	15.3	0.30	0.54	0.38	0.08	0.08
3770046	SCAN-16-P	16.417N	164.390W	C	5600	NODULE FRAGMENTS		21.1	13.3	0.43	0.71	0.44	0.08	0.08
3770073	PROA-168G	14.933N	167.567W	C	4315	NODULE, QUARTER	50X40X34	21.3	16.1	0.59	0.40	0.27	0.05	0.10
3770149	SS72-470B	10.283N	169.325W	C	4792	FRAGMENTS		11.1	19.8	0.09	0.15	0.14	0.07	0.09
3790111	GH771-G39C	10.993N	174.958W	C	4580	NODULE FRAGMENTS		22.2	14.0	0.42	0.68	0.45	0.08	0.09

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUD E	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	2MN	2FE	2CO	2NI	2CU	2ZN	2PB
						NODULE FRAGMENTS		21.2	14.1	0.42	0.68	0.42	0.07	0.10
3780052	SCAN-59-P	11.013N	175.117W	C	4813	NODULE, QUARTER	58X50X40	19.7	13.6	0.22	0.42	0.39	0.06	0.08
3780053	SCAN-59-PG	11.013N	175.117W	C	4813	NODULE FRAGMENTS		21.5	13.6	0.38	0.72	0.53	0.09	0.09
3780116	GH771-G385	10.987N	175.983W	C	5536	NODULE, HALF NODULE, W/GLE NODULE, W/GLE	20X16X11 14X13X11 13X13X12	23.9 22.4 24.2	8.9 8.2 8.6	0.28 0.27 0.29	1.09 1.13 1.13	0.95 0.97 1.06	0.12 0.11 0.11	0.05 0.05 0.05
3830014	ANTIPD-212P	16.908N	138.975E	C	3924	NODULE, HALF	19X16X9	11.4	18.4	0.04	0.13	0.15	0.06	0.03
3830121	ANTIPD-201PG	17.067N	133.260E	C	5721	NODULE, HALF	26X23X22	17.8	19.9	0.12	0.43	0.30	0.06	0.11
4070216	TURTLE-281	21.450N	108.300W		1540	SEV. CRUSTS FRAGMENTS SEV. CRUSTS FRAGMENTS		15.1 12.3	22.2 13.3	0.35 0.19	0.15 0.18	0.06 0.08	0.05 0.03	0.14 0.09
4070217	TURTLE-280	23.050N	108.750W			SEV. CRUSTS FRAGMENTS		29.2	10.8	0.14	0.50	0.09	0.11	0.03
4070218	TURTLE-279	20.150N	109.000W		1900	SEV. CRUSTS FRAGMENTS		23.8	13.0	0.16	0.39	0.09	0.10	0.04
4070225	TURTLE-278	20.850N	109.217W		1825	SEV. CRUSTS FRAGMENTS		10.2	23.7	0.24	0.08	0.07	0.05	0.11
4080473	SS72-23DB	20.943N	113.932W	D	3567	NODULE, QUARTER	60X48X32	27.2	9.0	0.06	1.15	0.74	0.20	0.04
4080472	SS72-32DB	20.917N	113.932W	D	3655	NODULE, HALF NODULE, HALF NODULE, HALF	61X41X38 52X40X34 44X28X23	20.9 26.0 27.4	12.7 11.2 10.0	0.01 0.05 0.08	0.83 1.09 1.16	0.48 0.63 0.74	0.10 0.15 0.17	0.06 0.05 0.04
4080474	SS72-31DB	20.963N	113.933W	D	3859	NODULE, QUARTER		26.2	10.2	0.12	1.11	0.72	0.16	0.04
4080477	SS72-20DB	20.930N	113.953W	D	3567	NODULE, HALF NODULE, HALF	65X40X35 47X41X30	26.5 27.2	10.3 10.6	0.11 0.11	1.13 1.11	0.68 0.70	0.17 0.18	0.05 0.05
4080478	SS72-21DB	20.903N	113.958W	D	3612	NODULE, HALF NODULE, HALF	44X24X20 36X26X12	26.6 15.4	10.5 8.1	0.11 0.01	1.23 0.91	0.69 0.51	0.16 0.13	0.05 0.03
4080479	SS72-22DB	20.955N	113.958W	D	3658	NODULE, HALF NODULE, HALF	65X42X19 45X35X15	24.3 26.5	9.4 8.2	0.04 0.06	1.18 1.27	0.73 0.76	0.17 0.17	0.04 0.04
4080476	SS72-33DB	20.950N	113.960W	D	3685	NODULE, QUARTER	54X34X33	27.0	9.8	0.08	1.25	0.79	0.16	0.04
4080484	SS72-24DB	20.882N	113.968W	D	3568	NODULE, HALF	53X32X28	25.5	9.3	0.04	1.15	0.82	0.15	0.04
4080483	SS72-30DB	20.913N	113.970W	D	3621	NODULE, QUARTER	59X45X32	26.0	10.3	0.13	1.08	0.72	0.16	0.04
4080482	SS72-28DB	20.958N	113.972W	D	1981	NODULE X-SECTION NODULE, QUARTER	60X50X30 43X29X27	27.6 26.4	9.8 10.3	0.06 0.08	1.19 1.20	0.75 0.72	0.19 0.16	0.04 0.04
4080480	SS72-26DB	20.935N	113.972W	D	3658	NODULE FRAGMENTS NODULE, HALF	71X55X36 51X34X22	24.6 25.4	10.5 10.4	0.06 0.09	1.17 1.14	0.79 0.76	0.12 0.14	0.05 0.05
4080481	SS72-27DB	20.932N	113.972W	D	3658	NODULE FRAGMENTS NODULE, HALF	38X28X17 46X38X17	26.6 30.0	11.1 10.7	0.01 0.11	1.20 1.14	0.68 0.66	0.34 0.15	0.05 0.04
4080485	SS72-25DB	20.952N	113.988W	D	3658	NODULE, QUARTER	65X40X35	27.2	10.6	0.09	1.01	0.64	0.18	0.05

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYFF	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZMN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB
4080486	SS72-29DB	20.972N	113.992W	C	3640	NODULE, HALF	55X44X20	26.8	11.0	0.09	1.21	0.65	0.16	0.05
4120469	SS72-149DB	27.572N	150.572W	D	5123	NODULE, HALF NODULE, WHOLE NODULE, HALF NODULE, HALF	34X30X14 26X16X14 43X33X27 41X30X14	15.4 16.1 12.9 12.3	8.0 8.5 8.4 6.9	0.18 0.19 0.15 0.12	1.00 1.03 0.76 0.80	0.62 1.64 0.52 0.47	0.08 0.08 0.07 0.07	0.06 0.06 0.06 0.06
4120470	SS72-148DB	25.000N	153.065W	C	5160	NODULE, HALF NODULE, HALF NODULE, HALF NODULE, HALF	31X21X11 40X35X24 30X24X14 33X20X18	20.8 18.0 18.9 17.4	13.1 12.3 13.8 12.5	0.33 0.22 0.29 0.24	0.91 0.69 0.70 0.66	0.57 0.48 0.45 0.46	0.09 0.08 0.07 0.08	0.07 0.07 0.08 0.08
4130239	SS72-135DB	25.256N	160.303W	D	4790	NODULE, HALF NODULE, HALF	43X27X17 41X37X23	16.7 16.1	13.0 12.7	0.21 0.19	0.71 0.65	0.47 0.43	0.06 0.06	0.11 0.11
4130240	SS72-91DE	23.495N	161.008W	D	4576	NODULE, HALF NODULE FRAGMENTS	32X26X19 41X40X22	29.2 30.0	4.3 5.6	0.16 0.20	1.23 1.36	1.49 1.21	0.18 0.17	0.03 0.04
4130241	SS72-134DE	27.533N	161.157W	D	4938	NODULE, HALF NODULE, HALF	30X20X18 30X23X18	22.3 21.8	11.1 10.1	0.24 0.18	1.05 1.07	0.73 0.65	0.08 0.08	0.10 0.10
4130242	SS72-92DB	25.062N	163.647W	C	4847	NODULE, HALF	39X25X20	18.1	14.9	0.20	0.54	0.33	0.06	0.13
4130243	SS72-93DB	26.503N	165.962W	C	4393	NCC & MICRODOC, HALF	32X18X17	15.5	12.6	0.33	0.82	0.48	0.07	0.13
4130244	SS72-94DB	28.397N	169.050W	D	4393	NODULE, WHOLE NODULE FRAGMENTS NODULE, HALF NODULE, WHOLE	24X17X15 32X20X18 28X20X17 22X16X12	18.1 21.7 21.6 21.0	10.5 12.2 11.8 10.8	0.30 0.37 0.32 0.22	0.96 0.98 1.00 1.05	0.54 0.57 0.59 0.61	0.08 0.08 0.08 0.09	0.10 0.11 0.12 0.12
4150059	NOVA-A 5C	25.750N	175.883E	C	5894	NODULE FRAGMENTS	18X16X12	22.4	12.5	0.32	1.08	0.52	0.08	0.10
4160015	SCAN-21-F	28.978N	168.920E	C	5710	NODULE, HALF	18X15X14	15.9	12.9	0.26	0.33	0.21	0.06	0.09
4450385	SS72-157DB	33.122N	126.615W	C	4298	NODULE, QUARTER	32X30X24	18.3	10.4	0.07	0.92	0.62	0.10	0.08
4460092	SS72-156DB	32.985N	130.105W	D	4495	NODULE, HALF NODULE, HALF	33X23X15 33X25X20	15.0 20.1	10.9 11.9	0.06 0.09	0.69 1.00	0.47 0.65	0.08 0.09	0.10 0.09
4460093	SS72-155DB	36.023N	132.907W	C	5046	NODULE, QUARTER NODULE, QUARTER	34X30X17 40X21X19	16.7 18.0	13.6 14.4	0.09 0.15	0.63 0.67	0.42 0.45	0.07 0.07	0.11 0.12
4460094	SS72-154DB	39.002N	136.020W	C	4755	NODULE, HALF NODULE, HALF	30X21X15 49X32X19	17.0 15.5	8.5 9.5	0.11 0.07	1.00 0.78	0.63 0.46	0.10 0.07	0.07 0.09
4470027	SS72-151DB	33.045N	144.520W	C	5377	NODULE, HALF NODULE, HALF	30X17X15 21X16X12	14.3 19.4	10.8 13.1	0.11 0.19	0.66 0.80	0.45 0.53	0.06 0.06	0.10 0.00
4480039	V74-3-62	33.150N	151.267W	C	5329	NODULE W/C NUCLEUS	39X25X25	12.3	11.2	0.09	0.40	0.31	0.05	0.09
4490031	SS72-126DB	30.667N	164.315W	C	5359	NODULE, HALF NODULE, HALF	35X21X12 37X27X24	19.3 23.3	10.8 11.3	0.26 0.29	0.97 1.05	0.58 0.68	0.07 0.08	0.10 0.08
4490033	SS72-132DB	30.660N	164.348W	D	3045	NODULE, HALF	42X35X25	22.5	11.7	0.27	1.03	0.59	0.09	0.09

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZMN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB
						NODULE, QUARTER		20.7	13.0	0.33	0.90	0.50	0.07	0.11
4490037	SS72-131CB	30.633N	164.407W	D	5487	NODULE W/C NUCLEUS NODULE W/C NUCLEUS	39X32X30 28X22X20	15.8 15.3	12.5 12.0	0.17 0.12	0.56 0.52	0.41 0.40	0.05 0.05	0.11 0.11
4490038	SS72-127DB	30.687N	164.440W	C	5560	NODULE, QUARTER	45X35X18	20.7	12.0	0.28	0.57	0.61	0.07	0.10
4490039	SS72-125DB	31.730N	165.717W	D	5597	NODULE, QUARTER NODULE FRAGMENTS MN ENCRUSTED SED, WHOLE NODULE FRAGMENTS	52X30X25 28X19X13 22X21X17	16.8 26.2 6.7 23.2	10.2 6.1 7.5 10.1	0.06 0.17 0.01 0.29	0.84 1.61 0.12 1.03	0.52 1.13 0.16 0.76	0.08 0.13 0.04 0.11	0.08 0.05 0.05 0.07
4490040	SS72-124CB	33.738N	166.843W	D	5624	NODULE, QUARTER NODULE FRAGMENTS	54X40X25 76X60X50	17.2 18.5	13.0 14.7	0.18 0.31	0.70 0.57	0.41 0.33	0.06 0.06	0.11 0.12
4500029	SS72-96DB	31.330N	174.022W	C	5401	NODULE, QUARTER NODULE, HALF NODULE, HALF	39X36X31 32X19X19 35X21X20	17.3 12.7 14.2	10.8 10.8 10.6	0.12 0.03 0.04	0.67 0.44 0.63	0.55 0.34 0.50	0.07 0.05 0.07	0.10 0.10 0.09
4500042	SS72-115DB	38.940N	178.622W	C	5396	MN ENCRUSTED SED W/C NUC NODULE, HALF	33X20X19 43X40X29	10.9 15.9	9.6 10.7	0.02 0.01	0.35 0.71	0.31 0.48	0.05 0.07	0.08 0.08
4510011	ARIES-45PG	36.577N	174.950E	C	5155	NODULE, QUARTER	42X28X28	15.4	9.5	0.00	0.55	0.41	0.12	0.07
4530032	SCAN-26-G	31.858N	157.353E	C	3622	NODULE, QUARTER	45X35X34	17.8	17.5	0.21	0.44	0.22	0.07	0.14
4530038	SCAN-25-G	31.895N	157.247E	C	3416	NODULE, HALF	32X26X18	9.6	13.0	0.13	0.18	0.16	0.06	0.12
4530039	SCAN-24-P	31.905N	157.137E	C	3582	NODULE, HALF	53X39X38	18.4	15.3	0.31	0.48	0.30	0.08	0.13
4830005	SCAN-6-P	41.062N	140.582W	C	4539	NODULE, HALF	50X32X25	19.9	10.3	0.36	0.83	0.62	0.09	0.10
4970025	SS72-112DB	40.340N	175.830E	D	5304	MN ENCRUSTED SED W/C NUC NODULE, HALF	28X19X12 37X28X20	10.4 16.5	8.3 20.1	0.02 0.14	0.38 0.31	0.30 0.12	0.06 0.05	0.05 0.05

APPENDIX B

STATION LOCATIONS AND CHEMICAL COMPOSITION OF SAMPLES COMPILED FROM THE LITERATURE, 1979-80

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGIT- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZPN	ZFE	ZCC	ZNI	ZCU	ZZN	ZPB	REF
2420007	VITYAZ 5186	26.792S	108.318E	C	5263	NODULE W/C OUTER LAYER NODULE, OUTER LAYER		19.4 14.5	13.2 13.4	0.05 0.12	0.50 0.42	0.04 0.05	0.01 0.01	0.03 0.06	A435 A435
2430025	VITYAZ 5201	22.363S	91.633E	C	5290	NODULE W/C OUTER LAYER NODULE, OUTER LAYER		13.2 14.4	11.8 15.8	0.04 0.09	0.31 0.33	0.04 0.05	0.01 0.01	0.02 0.06	A435 A435
2460027	VEMA16-SET19	29.867S	62.600E	D	4520	NODULE W/C OUTER LAYER NODULE, OUTER LAYER NODULE		11.2 13.2 11.8	17.3 16.3 16.8	0.06 0.09 0.08	0.22 0.27 0.28	0.04 0.04 0.03	0.01 0.01 0.01	0.04 0.03 0.04	A435 A435 A435
2670224	CM-II-14	13.567S	149.300W		4520	NODULE W/C NUCLEUS		13.2	14.2	0.48	0.41	0.17			A389
2680079	CM-9	13.833S	150.550W	C		NODULE W/O NUCLEUS		14.8	12.3	0.54	0.42	0.27			A389
2680076	CM-II-10	13.917S	150.550W		3755	NODULE W/C NUCLEUS		18.1	11.3	0.57	0.42	0.20			A389
2680077	CM-II-11	14.050S	150.633W		3760	NODULE W/C NUCLEUS		16.9	13.8	0.50	0.54	0.23			A389
2680124	CM-15	13.333S	150.650W			NODULE W/C NUCLEUS		16.8	9.5	0.32	0.86	0.47			A389
2780096	VIT.-6731-6	10.833S	104.633E	D	4940	NODULE		20.9	7.1	0.09	0.59	0.35			A451
2780095	VIT.-6731-5	10.833S	104.633E	D	3850	CRUST		10.6	14.3	0.27	0.19	0.12			A451
2780097	VIT.-6732-1	11.133S	104.533E	D	1585	NODULE W/C NUCLEUS NODULE NUCLEUS		19.1 10.9	13.1 7.5	0.37 0.26	0.33 0.18	0.06 0.04			A451 A451
2780048	ODOL-620	16.300S	104.267E	D	5660	NODULE		20.8	8.1	0.07	0.96	0.31	0.02	0.06	A435
2790098	VIT.-6734	11.817S	102.900E	C	5076	MN COATED ROCK, OUTER LAYER NODULE		15.8 21.8	12.8 0.1	0.11 0.10	0.51 0.92	0.27 0.85			A451 A451
2790099	VIT.-6755	15.550S	102.850E	D	5800	NODULE NODULE	50-30	20.6 21.3	9.1 6.5	0.13 0.12	0.61 0.77	0.52 0.70			A451 A451
2790001	ODOL-660(A)	19.933S	100.000E	D	5860	NODULE		17.0	10.2	0.05	0.77	0.07	0.01	0.04	A435
2790128	VIT.-7411-1	15.467S	99.983E	C	5000	NODULE NODULE	10-5	12.6 15.1	12.8 12.2	0.16 0.17	0.24 0.32	0.16 0.20			A451 A451
2790129	VIT.-7411-2	15.567S	99.933E	D	3308	NODULE, OUTER LAYER		13.7	13.5	0.35	0.28	0.09			A451
2790120	VIT.-6754-5	15.767S	99.900E	C	4850	NODULE		16.6	11.4	0.24	0.54	0.33			A451
2790127	VIT.-6754-16	15.767S	99.900E	D	3420	NODULE		17.1	14.5	0.53	0.28	0.06			A451
2790118	VIT.-6754-1	15.767S	99.900E	C	4780	NODULE		18.5	7.8	0.14	0.86	0.53			A451
2790122	VIT.-6754-7	15.767S	99.900E	D	4800	NODULE		16.8	12.5	0.24	0.46	0.20			A451
2790121	VIT.-6754-6	15.767S	99.900E	D	4840	NODULE		16.9	9.8	0.23	0.50	0.38			A451
2790126	VIT.-6754-15	15.767S	99.900E	C	3760	NODULE		16.7	13.5	0.68	0.65	0.13			A451

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZPN	ZFE	ZCC	ZNI	ZCU	ZZN	ZPB	REF
2790125	VIT.-6754-12	15.767S	99.900E	D	4970	MODULE, TOPSIDE MODULE, UNDERSIDE		14.5 21.4	11.4 10.5	0.28 0.16	0.44 0.78	0.18 0.55			A451 A451
2790119	VIT.-6754-4	15.767S	99.900E	D	5000	CRUST		18.6	12.5	0.26	0.36	0.13			A451
2790124	VIT.-6754-11	15.767S	99.900E	D	5720	MODULE		18.5	10.3	0.16	0.70	0.47			A451
2790123	VIT.-6754-10	15.767S	99.900E	D	5600	MODULE SEV. CRUSTS	784	13.5 5.9	11.8 14.7	0.14 0.10	0.52 0.53	0.36 0.22			A451 A451
2790103	VIT.-6736-1	11.583S	99.817E	D	5220	MODULE		17.8	12.6	0.12	0.56	0.28			A451
2790117	VIT.-6753-1	14.367S	98.517E	D	4430	MODULE MODULE, OUTER LAYER		15.3 14.4	10.3 14.4	0.28 0.30	0.34 0.34	0.22 0.19			A451 A451
2790116	VIT.-6751-1	14.300S	98.500E	D	4660	MODULE MODULE	50-40 10-5	15.2 24.0	10.6 10.2	0.30 0.27	0.32 0.37	0.18 0.23			A451 A451
2790104	VIT.-6737	11.417S	97.900E	D	4860	MODULE, OUTER LAYER		15.9	10.6	0.10	0.64	0.37			A451
2790115	VIT.-6749-1	12.563S	95.400E	D	1500	CRUST		21.8	10.9	0.56	0.56	0.10			A451
2790130	VIT.-7413	17.333S	94.517E	D	5360	MODULE		17.3	11.0	0.20	0.39	0.18			A451
2790105	VIT.-6742-2	13.017S	91.250E	D	4400	CRUST		13.8	12.5	0.24	0.34	0.18			A451
2790109	VIT.-6742-3	13.017S	91.250E	D	4700	MODULE		22.7	9.9	0.15	0.62	0.50			A451
2790106	VIT.-6742-4	13.017S	91.250E	D	4260	CRUST		19.1	12.6	0.24	0.47	0.17			A451
2790112	VIT.-6742-15	13.017S	91.250E	D	5225	MODULE, OUTER LAYER		19.5	10.6	0.18	0.78	0.44			A451
2790110	VIT.-6742-11	13.017S	91.250E	D	5700	MODULE		22.5	8.5	0.18	0.52	0.64			A451
2790114	VIT.-6742-22	13.017S	91.250E	D	4500	MODULE, TOPSIDE		19.5	13.2	0.25	0.48	0.16			A451
2790113	VIT.-6742-21	13.017S	91.250E		4760	CRUST		18.9	15.2	0.27	0.50	0.09			A451
2790107	VIT.-6742-6	13.017S	91.250E	D	4800	MODULE, OUTER LAYER		20.0	11.9	0.11	0.52	0.35			A451
2790108	VIT.-6742-8	13.017S	91.250E	D	5660	MODULE		20.4	6.6	0.14	0.72	0.88			A451
2790111	VIT.-6742-13	13.017S	91.250E	D	5560	MODULE, OUTER LAYER		26.3	5.0	0.17	1.01	1.01			A451
2790131	VIT.-7414	16.633S	90.283E	D	5670	MODULE		17.3	12.2	0.23	0.35	0.19			A451
2800085	VIT.-6746-1	11.117S	89.367E	D	5000	MODULE		24.8	7.9	0.15	0.64	0.75			A451
2800080	VIT.-6744-1	12.767S	88.900E	D	5090	MODULE		16.0	7.1	0.16	0.46	0.36			A451
2800083	VIT.-6744-37	12.767S	88.900E	D	4750	CRUST		15.2	10.6	0.20	0.58	0.23			A451
2800082	VIT.-6744-4	12.767S	88.900E	D	4480	CRUST		14.3	10.6	0.17	0.35	0.19			A451
2800081	VIT.-6744-2	12.767S	88.900E	D	5180	CRUST, OUTER LAYER		5.6	6.2	0.05	0.18	0.12			A451

Site A map

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUD	LONGI- TUD	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZMN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB	REF
						NODULE NODULE NODULE NODULE NODULE		31.7 31.3 32.3 31.1 32.1 22.9	4.0 5.2 4.3 4.3 4.5	0.14 0.19 0.15 0.15 0.15	1.65 1.62 1.66 1.84 1.53	1.42 1.27 1.43 1.40 1.29			A386 A386 A386 A386 A386
3390223	VA13/2-147GB	9.457N	145.825W	G	5200	NODULE	15 30.6	6.0	0.17	1.50	1.30				A446
3390224	VA13/2-219GB	9.498N	145.828W	G	5200	NODULE		6.0		1.40	1.10				A446
3390227	VA13/2-222GB	9.508N	145.828W	G	5200	NODULE		6.0		1.40	1.10				A446
3390222	VA13/2-146Gb	9.457N	145.828W	G	5200	NODULE	Red	5.3		1.50	1.30				A446
3390225	VA13/2-220GB	9.502N	145.828W	G	5200	NODULE	green	6.0		1.40	1.10				A446
3390229	VA13/2-226GB	9.523N	145.828W	G	5200	NODULE	Blue	5.0		1.60	1.30				A446
3390226	VA13/2-223GB	9.512N	145.828W	G	5200	NODULE		5.3		1.50	1.30				A446
3390228	VA13/2-224Gb	9.517N	145.828W	G	5200	NODULE		6.0		1.50	1.10				A446
3390237	VA13/2-145GB	9.457N	145.833W	G	5200	NODULE		5.0		1.50	1.20				A446
3390236	VA13/2-144GB	9.457N	145.838W	G	5200	NODULE		5.4		1.50	1.30				A446
3390235	VA13/2-143GB	9.457N	145.842W	G	5200	NODULE		5.0		1.30	1.20				A446
3390238	VA13/2-215KA	9.453N	145.842W	G	5200	NODULE		5.0		1.40	1.20				A446
3390234	VA13/2-142GB	9.457N	145.845W	G	5200	NODULE		5.6		1.30	1.30				A446
3390242	VA13/2-202GJ	9.505N	145.850W	G	5200	NODULE		6.0		1.50	1.10				A446
3390244	VA13/2-208GB	9.518N	145.850W	G	5200	NODULE		4.5		1.70	1.40				A446
3390243	VA13/2-206GB	9.515N	145.850W	G	5200	NODULE		5.5		1.50	1.30				A446
3390245	VA13/2-210GB	9.522N	145.850W	G	5200	NODULE		5.0		1.60	1.30				A446
3390246	VA13/2-212-J	9.520N	145.855W	G	5200	NODULE		5.5		1.50	1.20				A446
3390257	VA13/2-141GB	9.458N	145.867W	G	5200	NODULE		5.6		1.50	1.30				A446
3390256	VA13/2-140GB	9.458N	145.870W	G	5200	NODULE		5.8		1.50	1.30				A446
3390255	VA13/2-138GB	9.458N	145.877W	G	5200	NODULE		6.0		1.50	1.20				A446
3390254	VA13/2-137GB	9.458N	145.880W	G	5200	NODULE		5.8		1.50	1.20				A446
3390253	VA13/2-200-1	9.375N	145.882W	G	5200	NODULE		6.0		1.40	1.20				A446
3390262	VA13/2-179GB	9.373N	145.885W	G	5200	NODULE		6.2		1.30	0.90				A446
3390263	VA13/2-136GB	9.458N	145.885W	G	5200	NODULE		5.7		1.60	1.30				A446

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZMN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB	REF
3390261	VA13/2-178GB	9.372N	145.890W	G	5200	NODULE		31.0	6.0		1.4C	1.20			A446
3390260	VA13/2-177GB	9.372N	145.893W	G	5200	NODULE		30.6	5.5		1.50	1.20			A446
3390267	VA13/2-175GB	9.370N	145.902W	G	5200	NODULE		30.0	6.0		1.4C	1.10			A446
3390268	VA13/2-153GB	9.340N	145.905W	G	5200	NODULE		31.0	6.2		1.4C	1.10			A446
3390416	VA13/2-197GB	9.370N	145.905W	G	5200	NODULE		29.6	5.4		1.40	1.00			A446
3390269	VA13/2-152GB	9.340N	145.910W	G	5200	NODULE		30.0	6.2		1.40	1.10			A446
3390270	VA13/2-151GB	9.340N	145.913W	G	5200	NODULE		28.4	9.0		1.2C	0.80			A446
3390274	VA13/2-228-9	9.278N	145.917W	C	5200	NODULE		31.6	6.4		1.4C	1.10			A446
3390275	VA13/2-150GB	9.340N	145.918W	C	5000	NODULE		23.0	14.0		0.8C	0.60			A446
3390279	VA13/2-195GB	9.362N	145.922W	G	5200	NODULE		30.0	7.5		1.2C	0.90			A446
3390278	VA13/2-193GB	9.362N	145.925W	G	5200	NODULE		26.0	11.0		1.00	0.80			A446
3390277	VA13/2-191GB	9.362N	145.922W	G	5200	NODULE		31.4	6.0		1.4C	1.00			A446
3390276	VA13/2-148KA	9.335N	145.932W	C	4900	NODULE		23.0	10.0		1.1C	0.70			A446
3390286	VA13/2-189GB	9.362N	145.933W	G	5200	NODULE		26.0	6.0		1.3C	1.00			A446
3390284	VA13/2-155KA	9.333N	145.940W	G	4800	NODULE		25.0	10.0		1.0C	0.60			A446
3390285	VA13/2-187GB	9.362N	145.940W	C	5200	NODULE		27.0	6.0		1.4C	1.00			A446
3390293	VA13/2-85GBH	9.347N	145.950W	C	5000	NODULE		24.0	12.0		0.9C	0.50			A446
3390295	VA13/2-90GBH	9.358N	145.950W	G	5200	NODULE		27.0	9.0		1.20	0.80			A446
3390294	VA13/2-87GBH	9.352N	145.950W	G	5200	NODULE		26.0	10.3		0.9C	0.70			A446
3390297	VA13/2-93GBH	9.365N	145.950W	G	5200	NODULE		22.0	8.0		1.2C	0.90			A446
3390296	VA13/2-91GBH	9.362N	145.950W	G	5200	NODULE		21.0	7.0		1.20	0.80			A446
3390289	VA13/2-83KA	9.318N	145.955W	C	4800	NODULE		24.0	10.0		1.0C	0.80			A446
3390290	VA13/2-95GBH	9.280N	145.952W	G	5200	NODULE		28.5	7.0		1.50	1.10			A446
3390292	VA13/2-103GB	9.297N	145.958W	G	5200	NODULE		23.0	8.0		1.20	0.90			A446
3390291	VA13/2-99GBH	9.289N	145.952W	G	5200	NODULE		28.6	7.0		1.50	1.10			A446
3390311	VA13/2-106GB	9.315N	145.972W	G	5000	NODULE		25.0	13.0		0.90	0.60			A446
3390312	VA13/2-107GB	9.315N	145.977W	C	5000	NODULE		28.0	10.3		1.1C	0.70			A446
3390313	VA13/2-126KA	9.320N	145.978W	G	5000	NODULE		26.0	11.0		1.00	0.70			A446

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZMN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB	REF
3390314	VA13/2-108GB	9.315N	145.982W	G	5000	NODULE		27.0	11.0		1.10	0.70			A446
3390323	VA13/2-167-B	9.337N	145.983W	G	5100	NODULE		28.0	8.0		1.30	0.90			A446
3390320	VA13/2-109GB	9.315N	145.985W	G	5100	NODULE		26.0	10.5		1.10	0.70			A446
3390319	VA13/2-117KA	9.308N	145.987W	G	5200	NODULE		25.0	6.0		1.30	1.10			A446
3390321	VA13/2-110GB	9.315N	145.990W	G	5100	NODULE		26.0	10.0		1.20	0.70			A446
3390322	VA13/2-132GB	9.315N	145.998W	G	5200	NODULE		24.7	11.4		1.00	0.60			A446
3390328	VA13/2-131GB	9.315N	146.000W	G	5200	NODULE		25.8	12.0		0.90	0.50			A446
3390329	VA13/2-130GB	9.315N	146.005W	G	5200	NODULE		26.4	12.0		0.80	0.50			A446
3390330	VA13/2-129GB	9.315N	146.008W	G	5200	NODULE		30.3	5.7		1.40	1.20			A446
3390331	VA13/2-125KA	9.357N	146.015W	G	5200	NODULE		28.0	5.5		1.50	1.30			A446
3390205	VA13/2-28GBH	9.265N	146.017W	G	5200	NODULE		30.0	5.5		1.50	1.20			A446
3390204	VA13/2-164-5	9.322N	146.018W		5200	NODULE		31.5	5.5		1.45	1.20			A446
3390200	VA13/2-127GB	9.315N	146.020W	G	5200	NODULE		27.5	5.0		1.50	1.30			A446
3390206	VA13/2-29GBH	9.267N	146.022W	G	5200	NODULE		30.8	5.4		1.40	1.10			A446
3390201	VA13/2-116GB	9.313N	146.023W	G	5200	NODULE		24.8	9.7		1.00	0.70			A446
3390207	VA13/2-30GBH	9.272N	146.027W	G	5200	NODULE		31.0	5.6		1.40	1.10			A446
3390202	VA13/2-115GB	9.313N	146.028W	G	5200	NODULE		29.4	8.0		1.40	1.00			A446
3390203	VA13/2-114GB	9.313N	146.032W	G	5200	NODULE		27.0	6.2		1.30	1.00			A446
3390209	VA13/2-31GBH	9.275N	146.032W	G	5200	NODULE		30.8	5.0		1.50	1.30			A446
3390214	VA13/2-32GBH	9.278N	146.035W	G	5200	NODULE		30.5	0.0		1.50	1.10			A446
3390338	VA13/2-216BH	9.520N	146.035W	G	5200	NODULE		25.3	4.3		1.10	1.00			A446
3390215	VA13/2-33GBH	9.280N	146.040W	G	5200	NODULE		29.5	6.0		1.40	1.00			A446
3390333	VA13/2-60GBH	9.268N	146.042W	G	5000	NODULE		27.0	5.8		1.40	1.10			A446
3390336	VA13/2-181-2	9.452N	146.043W	G	5200	NODULE		30.5	6.0		1.30	1.10			A446
3390213	VA13/2-111GB	9.313N	146.043W	G	5200	NODULE		23.5	13.0		0.90	0.50			A446
3390334	VA13/2-61GBH	9.270N	146.043W	G	5000	NODULE		29.7	5.4		1.40	1.10			A446
3390335	VA13/2-62GBH	9.273N	146.047W	G	5000	NODULE		28.0	5.5		1.40	1.20			A446
3390337	VA13/2-19GBH	9.523N	146.048W	G	5200	NODULE		28.0	2.8		1.00	1.00			A446

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (CM)	ZMN	ZFE	ZCO	ZNT	ZCU	ZZN	ZPB	REF
3390339	VA13/2-24KA	9.505N	146.048W	C	5200	NODULE		29.0	5.7		1.5C	1.10			A446
3390348	VA13/2-44KA	9.293N	146.050W	C	5000	CRUST		24.0	6.5		1.1C	0.80			A446
3390345	VA13/2-63GBH	9.275N	146.050W	G	5000	NODULE		29.0	7.0		1.70	1.00			A446
3390355	VA13/2-15GBH	9.515N	146.050W	G	5200	NODULE		25.0	4.0		1.30	1.10			A446
3390352	VA13/2-18GBH	9.523N	146.053W	G	5200	NODULE		28.0	4.2		1.10	1.00			A446
3390346	VA13/2-64GBH	9.278N	146.055W	G	5000	NODULE		27.8	0.0		1.30	1.00			A446
3390347	VA13/2-65GBH	9.282N	146.060W	G	5000	NODULE		27.8	0.0		1.30	0.90			A446
3390354	VA13/2-13GBH	9.515N	146.060W	G	5200	NODULE		27.8	4.2		1.30	1.20			A446
3390351	VA13/2-17GBH	9.523N	146.060W	G	5200	NODULE		26.4	3.5		1.10	1.00			A446
3390350	VA13/2-16GBH	9.523N	146.062W	G	5200	NODULE		27.3	5.0		1.10	0.90			A446
3390357	VA13/2-9GBH	9.503N	146.062W	C	5200	NODULE		26.4	4.2		1.30	1.00			A446
3390349	VA13/2-34GBH	9.297N	146.063W	G	5000	NODULE		23.8	11.4		1.00	0.80			A446
3390353	VA13/2-12GBH	9.515N	146.063W	G	5200	NODULE		26.4	4.7		1.30	1.20			A446
3390356	VA13/2-8GBH	9.503N	146.065W	G	5200	NODULE		26.3	7.0		1.00	0.90			A446
3390385	VA13/2-11GBH	9.515N	146.067W	G	5200	NODULE		25.0	7.6		1.00	0.70			A446
3390383	VA13/2-81GBH	9.358N	146.067W	C	5200	NODULE		31.0	6.0		1.40	1.10			A446
3390384	VA13/2-10GBH	9.515N	146.070W	G	5200	NODULE		25.6	8.2		1.00	0.70			A446
3390387	VA13/2-7GBH	9.503N	146.070W	G	5200	NODULE		26.7	7.0		1.00	0.90			A446
3390368	VA13/2-36GBH	9.305N	146.073W	G	5000	NODULE		23.2	10.3		0.90	0.60			A446
3390371	VA13/2-74KA	9.290N	146.073W	G	5200	NODULE		26.0	7.0		1.00	0.90			A446
3390382	VA13/2-124GB	9.342N	146.075W	G	5200	NODULE		28.0	8.4		1.30	0.90			A446
3390378	VA13/2-115GB	9.322N	146.075W	G	5200	NODULE		27.0	12.0		0.80	0.50			A446
3390373	VA13/2-68GBH	9.270N	146.075W	G	5200	NODULE		26.0	7.0		1.00	1.00			A446
3390372	VA13/2-67GBH	9.273N	146.075W	G	5200	NODULE		27.2	6.5		1.40	1.00			A446
3390381	VA13/2-122GB	9.333N	146.075W	G	5200	NODULE		27.3	11.7		0.80	0.50			A446
3390380	VA13/2-121GB	9.332N	146.075W	G	5200	NODULE		26.3	12.7		0.90	0.60			A446
3390379	VA13/2-120GB	9.327N	146.075W	G	5200	NODULE		26.2	13.0		0.90	0.50			A446
3390374	VA13/2-69GBH	9.265N	146.075W	G	5200	NODULE		23.0	7.4		1.20	0.90			A446

[illegible]

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZMN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB	REF
						NODULE X-SECTION		20.5	5.8	0.15	0.97	0.66	0.09	0.04	A445
						NODULE X-SECTION		22.0	4.5	0.14	1.02	0.82	0.11	0.04	A445
						NODULE X-SECTION		22.1	5.3	0.16	0.99	0.79	0.10	0.04	A445
						NODULE X-SECTION		21.6	6.9	0.21	1.07	0.73	0.12	0.05	A445
						NODULE X-SECTION		23.4	6.3	0.22	1.25	0.96	0.11	0.06	A445
						NODULE X-SECTION		17.6	10.0	0.27	0.83	0.57	0.08	0.08	A445
						NODULE X-SECTION		12.7	8.6	0.21	0.91	0.53	0.10	0.05	A445
						NODULE X-SECTION		20.8	6.1	0.23	1.03	0.68	0.09	0.05	A445
						NODULE X-SECTION		18.3	7.2	0.20	0.81	0.51	0.09	0.03	A445
						NODULE X-SECTION		15.6	5.7	0.17	0.71	0.51	0.08	0.03	A445
						NODULE X-SECTION		15.2	6.5	0.20	0.74	0.60	0.07	0.04	A445
						NODULE X-SECTION		20.7	6.8	0.19	0.76	0.62	0.08	0.04	A445
						NODULE X-SECTION		20.1	7.6	0.21	0.95	0.65	0.11	0.05	A445
						NODULE X-SECTION		19.6	6.8	0.22	1.06	0.73	0.09	0.05	A445
						NODULE X-SECTION		25.6	5.7	0.24	1.20	1.01	0.16	0.03	A445
						NODULE X-SECTION		24.0	5.7	0.19	1.37	1.12	0.12	0.06	A445
						NODULE X-SECTION		23.5	6.5	0.23	1.15	0.88	0.12	0.04	A445
						NODULE X-SECTION		22.3	7.0	0.21	1.12	0.80	0.11	0.04	A445
						NODULE X-SECTION		20.7	7.9	0.23	0.87	0.60	0.11	0.05	A445
						NODULE X-SECTION		20.0	6.4	0.20	1.14	0.72	0.10	0.06	A445
						NODULE X-SECTION		19.9	8.5	0.21	0.97	0.60	0.09	0.06	A445
						NODULE X-SECTION		22.5	7.5	0.26	1.16	0.72	0.10	0.07	A445
						NODULE X-SECTION		15.0	8.9	0.18	0.58	0.38	0.08	0.04	A445
						NODULE X-SECTION		17.0	7.6	0.21	0.76	0.55	0.08	0.04	A445
						NODULE X-SECTION		23.0	7.3	0.27	1.13	0.76	0.10	0.07	A445
						NODULE X-SECTION		27.2	5.5	0.20	1.33	1.06	0.16	0.05	A445
						NODULE X-SECTION		23.0	4.7	0.22	1.42	1.11	0.11	0.06	A445
						NODULE X-SECTION		18.5	7.4	0.23	0.94	0.60	0.09	0.07	A445
						NODULE X-SECTION		23.0	9.0	0.27	1.06	0.67	0.10	0.07	A445
						NODULE X-SECTION		21.5	5.5	0.23	1.24	1.05	0.10	0.07	A445
						NODULE X-SECTION		26.9	5.3	0.22	1.29	1.05	0.14	0.03	A445
						NODULE X-SECTION		26.0	7.1	0.26	1.16	0.88	0.12	0.05	A445
						NODULE X-SECTION		22.8	8.1	0.23	1.08	0.70	0.11	0.06	A445
						NODULE X-SECTION		22.8	8.0	0.26	0.98	0.62	0.11	0.05	A445
						NODULE X-SECTION		22.0	7.3	0.28	1.15	0.76	0.10	0.08	A445
						NODULE X-SECTION		22.0	8.5	0.27	0.92	0.71	0.10	0.05	A445
						NODULE X-SECTION		24.2	8.5	0.26	1.26	0.72	0.11	0.08	A445
						NODULE X-SECTION		19.8	9.1	0.26	0.86	0.61	0.08	0.07	A445
						NODULE X-SECTION		21.5	9.3	0.24	0.87	0.60	0.10	0.04	A445
						NODULE X-SECTION		24.5	7.8	0.23	1.21	0.80	0.11	0.06	A445
						NODULE X-SECTION		24.1	6.3	0.24	1.36	0.94	0.12	0.07	A445
						NODULE X-SECTION		22.8	6.5	0.21	0.85	0.71	0.10	0.04	A445
						NODULE X-SECTION		22.5	8.1	0.21	0.87	0.67	0.10	0.03	A445
						NODULE X-SECTION		21.8	7.4	0.24	1.00	0.71	0.10	0.05	A445
						NODULE X-SECTION		22.5	7.2	0.23	1.35	0.79	0.10	0.06	A445
						NODULE X-SECTION		15.7	5.8	0.19	0.69	0.46	0.09	0.04	A445
						NODULE X-SECTION		22.1	7.5	0.22	1.10	0.74	0.10	0.05	A445
						NODULE X-SECTION		24.2	5.6	0.23	1.38	1.01	0.12	0.06	A445
							(11) Aug	21.6	6.8	0.21	1.04	0.75			
3400233	80C75-50-32	R.71°N	150.235°W	C	4978	NODULE, HALF		25.0	13.0	0.27	1.01	0.64	0.04		A448
						NODULE, HALF		24.5	13.0	0.27	0.99	0.33	0.05		A448
						NODULE, HALF		25.2	10.3	0.29	1.04	0.64	0.05		A448
						NODULE, HALF		21.6	14.3	0.31	0.84	0.77	0.05		A448
						NODULE, HALF		24.7	10.2	0.28	1.19	0.59	0.07		A448
						NODULE, HALF		26.0	12.2	0.28	1.06	0.72	0.07		A448

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT	SAMPLED (MP)	DIMENSIONS							XPB	REF
								2MN	2FE	2CO	2NI	2CU	2ZN			
						NODULE, HALF		23.2	12.9	0.30	0.97	0.57	0.09			A448
						NODULE, HALF		20.9	14.4	0.36	1.06	0.76	0.07			A448
						NODULE, HALF		22.8	12.5	0.26	0.82	1.19	0.07			A448
						NODULE, HALF		26.1	12.0	0.27	1.12	0.67	0.07			A448
						NODULE, HALF		23.6	10.2	0.00	0.90	0.61	0.00			A448
						NODULE, HALF		22.8	11.4	0.00	0.88	0.59	0.00			A448
						NODULE, HALF		23.5	10.6	0.00	1.01	0.65	0.00			A448
						NODULE, HALF		19.1	11.2	0.00	0.86	0.56	0.00			A448
						NODULE, HALF		18.3	6.3	0.00	1.03	1.60	0.00			A448
3400234	80C75-50-31	8.690N	150.250W	C	4969	NODULE, HALF		21.0	9.7	0.24	1.23	0.77	0.07			A448
						NODULE, HALF		18.8	11.3	0.26	0.84	0.50	0.05			A448
						NODULE, HALF		12.0	11.9	0.20	0.58	0.33	0.04			A448
						NODULE, HALF		19.3	10.9	0.24	0.94	0.54	0.08			A448
						NODULE, HALF		22.2	10.4	0.25	1.16	0.68	0.08			A448
						NODULE, HALF		25.5	13.2	0.24	1.11	0.55	0.07			A448
						NODULE, HALF		23.1	11.2	0.29	1.18	0.75	0.07			A448
						NODULE, HALF		18.9	10.1	0.24	1.06	0.60	0.06			A448
						NODULE, HALF		26.2	12.2	0.24	0.89	0.59	0.06			A448
						NODULE, HALF		22.0	13.9	0.22	0.88	0.47	0.06			A448
3400235	80C75-50-30	8.685N	150.252W	C	4928	NODULE, HALF		22.5	11.6		0.89	0.53				A448
						NODULE, HALF		23.1	11.6		0.84	0.55				A448
						NODULE, HALF		22.3	12.1		0.85	0.53				A448
						NODULE, HALF		22.5	12.0		0.85	0.53				A448
						NODULE, HALF		23.7	11.1		0.94	0.61				A448
3400236	80C75-50-28	8.695N	150.312W	C	5009	NODULE, HALF		25.3	11.7	0.22	0.94	0.57	0.04			A448
						NODULE, HALF		22.5	12.3	0.21	0.89	0.64	0.07			A448
						NODULE, HALF		25.6	10.4	0.25	1.10	0.81	0.07			A448
						NODULE, HALF		22.7	14.0	0.27	0.78	0.63	0.07			A448
						NODULE, HALF		25.5	11.3	0.28	0.97	0.64	0.07			A448
						NODULE, HALF		21.5	12.1	0.26	1.44	0.54	0.08			A448
						NODULE, HALF		20.8	11.8	0.25	0.86	0.64	0.07			A448
						NODULE, HALF		23.5	10.4	0.39	0.95	0.71	0.04			A448
						NODULE, HALF		23.4	11.9	0.26	0.76	0.65	0.07			A448
						NODULE, HALF		20.6	14.4	0.40	0.88	0.72	0.06			A448
						NODULE, HALF		22.1	10.8		0.92	0.58				A448
						NODULE, HALF		22.9	11.2		0.92	0.59				A448
						NODULE, HALF		22.6	11.0		0.90	0.58				A448
						NODULE, HALF		22.4	11.7		0.84	0.55				A448
3400237	80C75-50-29	8.730N	150.312W	C	5033	NODULE, HALF		19.3	10.3	0.27	0.74	0.74	0.07			A448
						NODULE, HALF		18.0	8.3	0.23	0.86	0.61	0.08			A448
						NODULE, HALF		23.1	11.9	0.23	0.89	0.67	0.08			A448
						NODULE, HALF		24.4	12.4	0.28	0.87	0.57	0.06			A448
						NODULE, HALF		20.9	12.0	0.22	1.03	0.47	0.06			A448
						NODULE, HALF		22.2	11.7	0.21	0.88	0.29	0.05			A448
						NODULE, HALF		23.9	13.1	0.27	0.74	0.51	0.05			A448
						NODULE, HALF		27.3	8.7	0.25	1.44	1.03	0.08			A448
						NODULE, HALF		23.5	7.8	0.31	0.99	0.57	0.09			A448
						NODULE, HALF		23.9	12.3	0.26	0.76	0.59	0.06			A448
						NODULE, HALF		18.9	10.9		0.72	0.69				A448
						NODULE, HALF		17.8	12.3		0.65	0.75				A448
						NODULE, HALF		18.8	12.4		0.73	0.72				A448

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAPP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZPN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB	REF
						NODULE, HALF		19.7	11.7		0.74	0.79			A448
						NODULE, HALF		18.8	11.4		0.78	0.92			A448
3400110	FW74-2-BC11	8.453N	150.478W	C	4850	NODULE, HALF	65X57X35	29.8	6.1	0.19	1.43	1.40	0.14		A441
3400238	80C75-49-25	8.475N	150.742W	C	5005	NODULE, HALF		22.1	10.9	0.19	0.62	0.71	0.08		A448
						NODULE, HALF		21.7	11.3	0.20	0.95	0.62	0.06		A448
						NODULE, HALF		26.0	10.9	0.22	1.25	0.83	0.08		A448
						NODULE, HALF		27.8	10.6	0.31	1.04	0.70	0.11		A448
						NODULE, HALF		25.0	10.8	0.23	1.15	0.85	0.09		A448
						NODULE, HALF		24.4	10.4	0.22	1.09	0.87	0.08		A448
						NODULE, HALF		26.8	7.5	0.29	1.23	0.88	0.12		A448
						NODULE, HALF		26.0	11.0	0.25	1.17	0.85	0.11		A448
						NODULE, HALF		25.4	11.3	0.23	1.14	0.77	0.07		A448
						NODULE, HALF		25.3	10.9	0.24	1.20	0.85	0.09		A448
3400239	80C75-49-24	8.458N	150.778W	C	5027	NODULE, HALF		11.1	4.9	0.20	1.10	0.83	0.08		A448
3400240	80C75-49-27	8.503N	150.797W	C	5039	NODULE, HALF		28.4	5.8	0.23	1.62	1.32	0.11		A448
						NODULE, HALF		29.7	5.3	0.21	1.58	1.03	0.12		A448
						NODULE, HALF		26.8	4.3	0.19	1.42	1.34	0.11		A448
						NODULE, HALF		29.9	3.7	0.19	1.48	1.37	0.12		A448
						NODULE, HALF		27.7	5.6	0.21	1.42	1.33	0.14		A448
						NODULE, HALF		26.3	5.5	0.21	1.42	1.27	0.12		A448
						NODULE, HALF		28.6	5.7	0.20	1.35	1.10	0.13		A448
						NODULE, HALF		25.7	8.4	0.26	1.23	1.02	0.09		A448
						NODULE, HALF		27.2	5.7	0.20	1.46	1.16	0.11		A448
						NODULE, HALF		28.9	5.0	0.20	1.56	1.36	0.15		A448
						NODULE, HALF		24.2	6.3		1.42	1.31			A448
						NODULE, HALF		25.2	6.8		1.41	1.24			A448
3400241	80C75-46-5	9.333N	150.807W	C	4839	NODULE, HALF		25.6	13.0	0.38	0.93	0.65	0.07		A448
						NODULE, HALF		25.2	10.8	0.41	1.04	0.73	0.07		A448
						NODULE, HALF		21.6	10.8	0.54	0.79	0.63	0.06		A448
						NODULE, HALF		16.7	14.6	0.56	0.67	0.70	0.07		A448
						NODULE, HALF		22.8	14.6	0.32	0.60	0.59	0.08		A448
						NODULE, HALF		24.8	12.7	0.41	1.02	0.68	0.09		A448
						NODULE, HALF		24.9	13.4	0.39	1.00	0.64	0.07		A448
						NODULE, HALF		13.8	9.3	0.35	0.83	0.51	0.04		A448
						NODULE, HALF		25.1	13.4	0.39	1.02	0.64	0.07		A448
						NODULE, HALF		16.2	18.6		0.42	0.36			A448
						NODULE, HALF		14.6	13.9		0.31	0.32			A448
						NODULE, HALF		18.5	13.7		0.74	0.67			A448
3400243	80C75-46-6	9.400N	150.832W	C	5229	NODULE, HALF		21.9	10.2	0.22	1.34	0.93	0.07		A448
						NODULE, HALF		26.5	9.5	0.23	1.45	1.02	0.14		A448
						NODULE, HALF		23.5	9.6	0.25	1.18	0.97	0.11		A448
						NODULE, HALF		22.5	10.9	0.22	1.35	0.79	0.10		A448
						NODULE, HALF		15.7	9.0	0.25	1.06	0.69	0.07		A448
						NODULE, HALF		20.0	11.5	0.23	1.20	0.75	0.08		A448
						NODULE, HALF		21.2	11.4	0.26	1.58	0.94	0.10		A448
						NODULE, HALF		15.1	10.3	0.23	1.05	0.69	0.08		A448
						NODULE, HALF		26.3	9.7	0.28	1.45	0.94	0.11		A448
3400244	80C75-49-26	8.457N	150.837W	C	4971	NODULE, HALF		28.4	7.4	0.24	1.43	1.10	0.10		A448

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	TMN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB	REF
						NODULE, HALF		25.9	8.2	0.24	1.32	1.01	0.12		A448
						NODULE, HALF		27.7	7.5	0.24	1.37	1.11	0.12		A448
						NODULE, HALF		26.5	7.7	0.26	1.35	1.05	0.11		A448
						NODULE, HALF		27.4	7.8	0.24	1.25	1.07	0.10		A448
						NODULE, HALF		27.5	7.6	0.25	1.49	1.09	0.12		A448
						NODULE, HALF		27.3	7.9	0.23	1.37	1.02	0.10		A448
						NODULE, HALF		28.4	6.9	0.23	1.47	0.86	0.12		A448
						NODULE, HALF		27.2	7.7	0.24	1.41	1.10	0.13		A448
						NODULE, HALF		25.9	7.9	0.21	1.28	1.00	0.10		A448
3400245	80C75-46-8	9.318N	150.840W	C	5108	NODULE, HALF		23.7	8.7	0.20	1.36	0.92	0.09		A448
						NODULE, HALF		25.6	9.7	0.20	1.37	0.96	0.14		A448
						NODULE, HALF		20.7	9.8	0.21	1.25	0.85	0.12		A448
						NODULE, HALF		26.5	9.3	0.21	1.52	0.96	0.12		A448
						NODULE, HALF		26.4	7.1	0.21	1.46	0.79	0.13		A448
						NODULE, HALF		25.0	6.5	0.22	1.10	0.84	0.11		A448
						NODULE, HALF		25.7	9.2	0.27	1.74	1.17	0.14		A448
						NODULE, HALF		28.6	8.5	0.20	1.11	0.77	0.12		A448
						NODULE, HALF		22.0	10.6		1.06	1.74	0.00		A448
3400246	80C75-46-1	9.345N	150.845W	C	5160	NODULE, HALF		25.7	7.6	0.18	1.44	1.15	0.11		A448
						NODULE, HALF		24.7	7.8	0.23	1.98	1.14	0.08		A448
						NODULE, HALF		24.4	8.1	0.23	0.00	1.09	0.12		A448
						NODULE, HALF		19.3	8.0	0.22	1.41	1.09	0.12		A448
						NODULE, HALF		23.9	8.1	0.21	1.50	1.09	0.13		A448
						NODULE, HALF		24.1	8.9	0.22	1.51	1.10	0.10		A448
						NODULE, HALF		25.7	8.7	0.23	1.54	1.09	0.13		A448
						NODULE, HALF		22.4	8.0	0.21	1.40	1.01	0.10		A448
3400247	80C75-46-7	9.327N	150.845W	C	5116	NODULE, HALF		19.3	6.3		1.35	0.96			A448
						NODULE, HALF		14.2	7.5		1.02	0.72			A448
						NODULE, HALF		23.2	8.7		1.21	0.79			A448
						NODULE, HALF		23.1	6.9		1.41	1.03			A448
						NODULE, HALF		25.5	6.8		1.42	1.05			A448
3400249	80C75-46-3	9.317N	150.875W	C	4900	NODULE, HALF		24.4	11.8	0.26	0.94	0.52	0.07		A448
						NODULE, HALF		22.4	12.6	0.27	0.71	0.50	0.09		A448
						NODULE, HALF		16.9	13.0	0.30	0.62	0.60	0.08		A448
						NODULE, HALF		19.7	12.0	0.19	0.71	0.52	0.06		A448
						NODULE, HALF		23.7	11.3	0.28	0.52	0.60	0.07		A448
						NODULE, HALF		24.7	9.0	0.33	0.96	0.57	0.08		A448
						NODULE, HALF		22.5	12.3	0.25	0.83	0.52	0.07		A448
						NODULE, HALF		23.6	11.8	0.26	0.84	0.54	0.07		A448
						NODULE, HALF		24.6	11.4	0.27	0.93	0.65	0.10		A448
						NODULE, HALF		23.0	12.5	0.28	0.88	0.55	0.07		A448
						NODULE, HALF		17.2	11.2		0.73	0.47			A448
						NODULE, HALF		23.9	10.5		1.01	0.66			A448
3400250	80C75-46-4	9.397N	150.880W	C	5155	NODULE, HALF		21.5	11.7	0.27	0.89	0.51	0.06		A448
						NODULE, HALF		21.1	9.9	0.33	0.68	0.70	0.05		A448
						NODULE, HALF		23.6	12.7	0.27	0.90	0.51	0.08		A448
						NODULE, HALF		23.3	12.9	0.24	0.90	0.57	0.08		A448
						NODULE, HALF		18.8	9.3	0.22	0.83	0.52	0.08		A448
						NODULE, HALF		20.2	13.4	0.27	0.68	0.54	0.08		A448
						NODULE, HALF		19.3	7.9	0.28	0.89	0.55	0.07		A448

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLD	DIMENSIONS (MM)	ZMN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB	REF
						NODULE, HALF		19.1	11.3	0.27	0.90	0.55	0.07		A448
						NODULE, HALF		22.4	11.4	0.28	0.85	0.54	0.08		A448
						NODULE, HALF		20.2	10.9	0.21	0.65	0.50	0.07		A448
3400199	MN-74-2-SET4	8.417N	150.900W	D	5020	NODULE, HALF	64X40X38	29.1	5.2	0.16	1.52	1.58	0.13		A441
						NODULE, HALF	65X50X38	30.3	4.7	0.16	1.47	1.54	0.14		A441
						NODULE, HALF	62X50X35	25.7	5.2	0.17	1.26	1.50	0.13		A441
						NODULE, HALF	75X50X50	27.5	5.4	0.20	1.35	1.54	0.14		A441
						NODULE, HALF	89X53X43	28.4	5.5	0.19	1.32	1.46	0.14		A441
3400165	MN7401-05G15	2.938N	151.010W	G	5025	NODULE, HALF	34X24X23	30.5	9.6	0.14	1.28	1.34	0.15		A441
						NOD & MICRODOC		31.2	9.5	0.15	1.26	1.40	0.15		A441
3400251	80C75-48-19	8.275N	151.122W	C	5043	NODULE, HALF		25.6	7.9	0.34	1.10	1.04	0.10		A448
						NODULE, HALF		27.6	7.7	0.36	1.42	0.97	0.10		A448
						NODULE, HALF		27.8	7.5	0.19	1.37	1.06	0.11		A448
						NODULE, HALF		26.5	8.6	0.22	1.33	0.97	0.10		A448
						NODULE, HALF		26.5	9.0	0.22	1.28	1.00	0.09		A448
						NODULE, HALF		29.4	6.8	0.22	1.29	1.17	0.11		A448
						NODULE, HALF		26.2	8.3	0.24	1.17	1.01	0.10		A448
						NODULE, HALF		25.9	8.2	0.24	1.38	1.05	0.10		A448
						NODULE, HALF		26.3	7.8	0.23	1.26	1.05	0.11		A448
						NODULE, HALF		28.3	5.5	0.17	1.46	1.59	0.12		A448
3400254	80C75-47-11	9.042N	151.177W	C	5053	NODULE, HALF		31.8	3.8	0.28	1.67	1.49	0.14		A448
						NODULE, HALF		31.4	3.5	0.23	1.24	1.60	0.18		A448
						NODULE, HALF		31.6	2.8	0.28	1.67	1.67	0.13		A448
						NODULE, HALF		31.2	3.6	0.24	1.76	1.66	0.14		A448
						NODULE, HALF		26.0	5.2	0.00	1.76	1.36	0.00		A448
3400257	80C75-47-12	9.058N	151.185W	C	5005	NODULE, HALF		27.8	4.5		1.62	1.51			A448
						NODULE, HALF		20.1	6.9		1.37	1.30			A448
						NODULE, HALF		16.9	6.6		1.18	0.98			A448
						NODULE, HALF		22.7	5.5		1.50	1.24			A448
						NODULE, HALF		14.7	8.5		1.10	0.99			A448
3400258	80C75-47-15	9.080N	151.185W	C	5115	NODULE, HALF		31.2	4.5	0.28	1.72	1.48	0.14		A448
						NODULE, HALF		30.7	3.8	0.25	1.86	1.58	0.15		A448
						NODULE, HALF		31.3	3.9	0.26	1.74	1.50	0.10		A448
						NODULE, HALF		29.9	4.0	0.26	1.78	1.59	0.14		A448
						NODULE, HALF		30.4	4.3	0.28	1.32	1.44	0.14		A448
						NODULE, HALF		28.7	5.1	0.31	1.75	1.65	0.14		A448
						NODULE, HALF		29.6	4.6	0.28	1.86	1.62	0.14		A448
3400259	80C75-47-13	9.038N	151.187W	C	5039	NODULE, HALF		27.7	4.3		1.70	1.66			A448
						NODULE, HALF		28.0	4.8		1.56	1.59			A448
						NODULE, HALF		27.7	4.9		1.63	1.54			A448
						NODULE, HALF		26.6	5.3		1.52	1.51			A448
						NODULE, HALF		22.0	5.3		1.58	1.23			A448
3400260	80C75-48-22	8.267N	151.188W	C	5117	NODULE, HALF		29.7	5.6	0.18	1.52	1.64	0.12		A448
						NODULE, HALF		26.9	5.2	0.18	1.61	1.52	0.12		A448
						NODULE, HALF		31.7	2.9	0.16	1.76	1.71	0.13		A448
						NODULE, HALF		30.0	5.3	0.18	1.45	1.64	0.14		A448
						NODULE, HALF		29.9	5.3	0.18	1.65	1.66	0.12		A448

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	CIMENSIONS (MM)	ZMM	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB	REF
						NODULE, HALF		31.0	4.0	0.18	1.53	1.70	0.16		A448
						NODULE, HALF		29.7	4.5	0.18	1.59	1.65	0.14		A448
						NODULE, HALF		30.9	4.9	0.18	1.73	1.63	0.14		A448
						NODULE, HALF		30.3	4.5	0.16	1.61	1.62	0.12		A448
3400262	80C75-4d-21	8.293N	151.22CW	C	5097	NODULE, HALF		26.3	5.2		1.48	1.54			A448
						NODULE, HALF		28.6	4.9		1.56	1.66			A448
						NODULE, HALF		26.9	5.7		1.43	1.53			A448
						NODULE, HALF		28.4	5.1		1.54	1.56			A448
						NODULE, HALF		25.3	6.0		1.40	1.42			A448
3400263	80C75-4f-14	9.067N	151.237W	C	5110	NODULE, HALF		30.0	3.5	0.27	1.52	1.46	0.12		A448
						NODULE, HALF		28.6	5.5	0.33	1.62	1.53	0.13		A448
						NODULE, HALF		29.1	5.1	0.27	1.44	1.42	0.13		A448
						NODULE, HALF		29.0	4.4	0.29	1.60	1.55	0.14		A448
						NODULE, HALF		30.9	4.2	0.28	1.71	1.50	0.16		A448
3400264	80C75-4d-20	8.238N	151.238W	C	5043	NODULE, HALF		28.4	9.1	0.23	1.46	1.10	0.10		A448
						NODULE, HALF		28.2	8.2	0.22	1.19	1.09	0.11		A448
						NODULE, HALF		27.2	9.3	0.22	1.35	1.02	0.10		A448
						NODULE, HALF		28.3	9.2	0.21	1.30	1.07	0.10		A448
						NODULE, HALF		27.7	8.4	0.23	1.32	1.08	0.10		A448
						NODULE, HALF		27.3	6.3	0.26	1.35	1.02	0.11		A448
						NODULE, HALF		27.0	9.1	0.23	1.45	1.07	0.12		A448
						NODULE, HALF		27.9	9.2	0.21	1.41	1.08	0.10		A448
						NODULE, HALF		23.9	9.5	0.20	1.28	0.97	0.09		A448
						NODULE, HALF		27.2	9.7	0.21	1.28	1.09	0.10		A448
3400273	SS72-010R	7.945N	152.805W	D	5033	NODULE		30.5	5.6	0.18	1.68	1.52			A386
						NODULE		27.8	5.5	0.17	1.49	1.42			A386
						NODULE		29.7	5.5	0.16	1.53	1.50			A386
						NODULE		23.9	6.4	0.15	1.23	1.19			A386
						NODULE		30.5	5.6	0.18	1.62	1.55			A386
						NODULE		14.2	2.9	0.09	0.55	0.75			A386
3400274	SS72-590R	8.095N	153.915W	C	5000	NODULE		28.6	6.1	0.14	1.82	1.50			A386
						NODULE		19.8	5.4	0.07	1.04	0.88			A386
						NODULE		28.8	4.1	0.12	1.72	1.55			A386
						NODULE		25.9	6.3	0.15	1.55	1.47			A386
						NODULE		27.8	5.9	0.15	1.68	1.50			A386
						NODULE		28.6	5.0	0.13	1.64	1.65			A386
						NODULE		27.8	5.9	0.14	1.62	1.68			A386
						NODULE		28.4	5.5	0.14	1.58	1.64			A386
						NODULE		27.4	6.2	0.16	1.55	1.44			A386
						NODULE		26.5	6.0	0.13	1.59	1.50			A386
3420070	CM-11-16	8.067N	170.350W		5425	NODULE W/C NUCLEUS		18.0	9.4	0.31	0.73	0.59			A389
3420171	GH761-FG30-2	9.005N	173.507W	G	5960	NODULE		31.7	5.4	0.21	1.75	1.27			A386
						NODULE		31.5	4.6	0.16	1.69	1.40			A386
						NODULE		30.9	5.4	0.21	1.66	1.30			A386
						NODULE		30.9	5.7	0.19	1.80	1.29			A386
3540089	SH-1301A	6.072N	62.293E	D	3640	CRUST		17.2	21.7	0.37	0.25	0.09	0.05	0.13	A433
						CRUST		18.1	18.3	0.21	0.27	0.10	0.06	0.10	A433

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZMN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB	REF
						CRUST		16.3	20.2	0.18	0.21	0.05	0.05	0.10	A433
						CRUST		15.7	19.8	0.17	0.17	0.04	0.05	0.10	A433
						CRUST		17.1	20.0	0.17	0.20	0.05	0.05	0.09	A433
						CRUST		13.4	19.4	0.17	0.17	0.06	0.05	0.11	A433
						CRUST		24.3	9.4	0.18	0.38	0.22	0.06	0.05	A433
						CRUST		18.9	17.0	0.21	0.44	0.19	0.07	0.08	A433
						CRUST		0.0	23.0	0.18	0.20	0.10	0.07	0.13	A433
						CRUST		11.0	23.2	0.21	0.21	0.11	0.07	0.12	A433
						CRUST		21.2	13.1	0.21	0.42	0.22	0.06	0.07	A433
						CRUST		16.4	19.2	0.32	0.54	0.21	0.08	0.11	A433
						CRUST		9.8	23.4	0.20	0.17	0.10	0.06	0.11	A433
						CRUST		10.8	22.5	0.24	0.20	0.11	0.06	0.12	A433
						CRUST		21.0	17.3	0.21	0.43	0.16	0.07	0.09	A433
						CRUST		11.8	24.1	0.20	0.22	0.09	0.07	0.12	A433
						CRUST		11.6	23.3	0.18	0.20	0.11	0.07	0.12	A433
						CRUST		15.8	19.5	0.26	0.23	0.04	0.05	0.10	A433
						CRUST		13.7	21.0	0.23	0.17	0.07	0.05	0.07	A433
						CRUST		15.7	20.4	0.22	0.28	0.10	0.05	0.10	A433
						CRUST		16.6	20.2	0.20	0.20	0.04	0.05	0.11	A433
						CRUST		15.2	20.3	0.17	0.16	0.04	0.05	0.10	A433
						CRUST		17.0	19.3	0.15	0.19	0.06	0.04	0.09	A433
						CRUST		15.3	20.4	0.19	0.18	0.07	0.05	0.12	A433
						CRUST		14.9	21.6	0.18	0.18	0.08	0.03	0.11	A433
						CRUST		12.3	19.7	0.17	0.13	0.07	0.05	0.11	A433
						CRUST		12.2	18.6	0.17	0.21	0.11	0.05	0.08	A433
						CRUST		13.2	20.3	0.19	0.16	0.10	0.05	0.10	A433
						CRUST		14.7	22.1	0.27	0.17	0.07	0.05	0.11	A433
						CRUST		22.4	8.6	0.14	0.36	0.23	0.05	0.05	A433
						CRUST		20.2	15.4	0.21	0.50	0.23	0.07	0.08	A433
						CRUST		13.0	22.1	0.19	0.24	0.11	0.07	0.11	A433
						CRUST		11.0	22.8	0.18	0.12	0.19	0.10	0.12	A433
						CRUST		9.5	20.3	0.16	0.16	0.11	0.06	0.12	A433
						CRUST		20.5	10.6	0.19	0.50	0.26	0.06	0.06	A433
						CRUST		21.9	13.5	0.22	0.49	0.24	0.06	0.07	A433
						CRUST		10.7	20.9	0.18	0.22	0.12	0.07	0.11	A433
						CRUST		10.0	23.0	0.16	0.20	0.13	0.07	0.12	A433
						CRUST		14.6	18.6	0.16	0.17	0.04	0.05	0.09	A433
						CRUST		15.4	18.7	0.16	0.22	0.07	0.05	0.09	A433
						CRUST		12.5	22.2	0.16	0.14	0.07	0.05	0.11	A433
						CRUST		12.8	18.9	0.17	0.20	0.10	0.05	0.09	A433
						CRUST		9.1	17.1	0.08	0.17	0.11	0.04	0.05	A433
3540090	SH-1303A	5.01CN	61.548E	D	3000	CRUST		18.1	22.3	0.18	0.23	0.03	0.05	0.12	A433
						CRUST		13.6	20.4	0.16	0.19	0.05	0.06	0.10	A433
3540066	DISC-6273	2.942N	60.057E	E	4042	CRUST		17.3	16.8	0.17	0.35	0.14	0.07	0.10	A433
						CRUST		15.5	18.1	0.18	0.27	0.12	0.06	0.11	A433
						CRUST		21.4	12.6	0.10	0.83	0.31	0.09	0.08	A433
						CRUST		17.1	15.8	0.14	0.42	0.22	0.07	0.11	A433
						CRUST		17.7	14.9	0.11	0.48	0.17	0.07	0.09	A433
						CRUST		16.7	16.9	0.16	0.34	0.20	0.07	0.12	A433
3540072	DISC-6263	2.79CN	60.042E	E	3816	CRUST		16.2	18.8	0.14	0.29	0.15	0.05	0.09	A433
						CRUST		15.4	18.8	0.18	0.21	0.11	0.05	0.11	A433
						CRUST		15.9	16.6	0.31	0.27	0.10	0.05	0.11	A433

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	1PN	1FE	1CC	1NI	1CU	1ZN	1PB	REF
						CRUST		15.8	14.7	0.27	0.35	0.13	0.06	0.12	A433
						CRUST		17.7	14.8	0.22	0.55	0.21	0.07	0.10	A433
						CRUST		14.4	15.3	0.20	0.27	0.11	0.05	0.10	A433
3550069	SH-1323C	1.365N	56.612E	C	2940	CRUST		6.2		0.22	0.12	0.04	0.06	0.17	A433
						CRUST		0.0	15.8	0.18	0.18	0.12	0.04	0.07	A433
						CRUST		8.1	25.5	0.30	0.13	0.04	0.06	0.14	A433
						CRUST		6.5	26.7	0.22	0.13	0.05	0.05	0.14	A433
3550071	SH-1321A	1.320N	56.593E	D	2180	CRUST				0.41	0.26	0.05	0.06	0.21	A433
						CRUST		16.8	19.6	0.54	0.26	0.03	0.06	0.18	A433
						CRUST		12.6	22.2	0.35	0.23	0.05	0.06	0.16	A433
						CRUST		10.8	20.5	0.44	0.24	0.06	0.06	0.16	A433
						CRUST		20.8	14.3	0.44	1.03	0.16	0.10	0.13	A433
						CRUST		17.3	19.0	0.42	0.28	0.04	0.06	0.17	A433
						CRUST		20.7	16.4	0.37	0.66	0.10	0.07	0.17	A433
						CRUST		19.7	19.1	0.39	0.38	0.06	0.06	0.16	A433
						CRUST		16.2	17.8	0.39	0.42	0.06	0.06	0.13	A433
						CRUST		17.0	19.7	0.51	0.25	0.03	0.06	0.17	A433
						CRUST		18.4	17.4	0.39	0.41	0.08	0.06	0.15	A433
3550075	SH-1318B	0.177N	55.605E	C	1358	CRUST		17.6	16.7	0.89	0.32	0.02	0.05	0.23	A433
						CRUST		17.6	15.5	0.98	0.30	0.02	0.05	0.19	A433
						CRUST		19.3	16.5	0.93	0.31	0.02	0.05	0.22	A433
3550076	SH-1317B	0.187N	55.588E	C	1600	CRUST		18.9	19.3	0.30	0.34	0.04	0.06	0.18	A433
						CRUST		18.7	19.9	0.35	0.27	0.04	0.06	0.16	A433
						CRUST		9.8	18.5	0.32	0.15	0.07	0.05	0.14	A433
						CRUST		18.7	19.5	0.36	0.27	0.05	0.06	0.16	A433
						CRUST		18.8	19.4	0.34	0.23	0.02	0.06	0.17	A433
						CRUST		7.8	18.9	0.30	0.12	0.07	0.05	0.15	A433
						CRUST		13.5	22.8	0.44	0.13	0.07	0.08	0.21	A433
						CRUST		18.3		0.30	0.28	0.03	0.06	0.16	A433
						CRUST		19.4	15.8	0.34	0.92	0.16	0.10	0.12	A433
						CRUST		7.7		0.23	0.14	0.06	0.06	0.18	A433
3550081	SH-1325A	0.145N	55.155E	C	1800	CRUST		16.5	18.3	0.53	0.36	0.04	0.06	0.19	A433
						CRUST		18.5	19.3	0.51	0.25	0.04	0.06	0.18	A433
						CRUST		5.5	15.3	0.23	0.18	0.03	0.05	0.06	A433
7720043	BNFC 54BX	11.860N	110.007W	C	3886	NODULE, HALF	45X37X23	25.0	10.5	0.15	1.07	0.67	0.15		A441
3730046	BNFC 85BX	14.603N	121.032W	C	4302	NODULE, HALF	47X38X29	27.3	6.5	0.22	1.32	1.03	0.18		A441
3730142	SS72-70B	14.247N	123.703W	C	4435	NODULE		28.0	6.3	0.20	1.31	1.06			A386
3730071	MN7402-13G05	15.067N	125.000W	C	4525	NODULE, HALF	44X41X30	30.9	5.0	0.21	1.28	1.14	0.24		A441
3730077	MN7402-13G11	15.000N	125.067W	G	4510	NODULE, HALF	71X44X16	28.6	6.6	0.24	1.40	1.04	0.17		A441
3730075	MN7402-13G09	14.933N	125.067W	G	4590	NODULE, HALF	38X32X20	29.6	6.3	0.26	1.21	0.97	0.17		A441
						NODULE, HALF	43X28X25	30.4	5.5	0.23	1.22	1.09	0.19		A441
3730130	BQC75-58-60	15.297N	125.473W	C	4375	NODULE, HALF		27.1	7.8	0.32	1.47	1.02	0.09		A448
						NODULE, HALF		27.6	8.3	0.29	1.55	1.01	0.12		A448

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	XMN	XFE	XCO	XNI	XCU	XZN	XPB	REF
						NODULE, HALF		29.5	6.2	0.25	1.51	1.22	0.15		A448
						NODULE, HALF		24.2	7.9	0.31	1.46	0.90	0.07		A448
						NODULE, HALF		26.8	8.6	0.27	1.35	0.94	0.10		A448
						NODULE, HALF		27.3	8.3	0.31	1.44	0.99	0.10		A448
						NODULE, HALF		28.1	8.7	0.29	1.42	0.98	0.11		A448
						NODULE, HALF		28.9	7.9	0.29	1.52	1.02	0.13		A448
						NODULE, HALF		28.7	8.1	0.18	1.55	1.05	0.11		A448
						NODULE, HALF		27.7	0.0	0.29	1.38	0.94	0.09		A448
3730133	80C75-57-57	15.297N	125.922W	C	4520	NODULE, HALF		28.6	7.3	0.30	1.28	1.06	0.12		A448
						NODULE, HALF		28.2	7.6	0.29	1.51	1.07	0.12		A448
						NODULE, HALF		28.3	9.1	0.32	1.45	0.90	0.12		A448
						NODULE, HALF		19.7	9.1	0.27	1.26	0.97	0.09		A448
						NODULE, HALF		27.9	9.1	0.31	1.48	1.02	0.12		A448
						NODULE, HALF		27.6	9.3	0.29	1.12	0.96	0.11		A448
						NODULE, HALF		28.9	8.2	0.31	1.60	1.07	0.11		A448
						NODULE, HALF		28.7	7.7	0.36	1.53	0.97	0.11		A448
						NODULE, HALF		29.3	7.9	0.29	1.53	1.03	0.12		A448
						NODULE, HALF		28.7	8.3	0.31	1.18	1.05	0.12		A448
3730134	80C76-3-2	15.257N	125.908W	C	4363	NODULE, HALF		31.0	3.8	0.20	1.69	1.23	0.15		A448
3730124	80C75 16F-49	15.773N	126.187W	C	4552	NODULE, HALF		28.9	5.9	0.28	1.52	1.28	0.12		A448
						NODULE, HALF		25.2	5.1	0.25	1.49	1.23	0.16		A448
						NODULE, HALF		30.2	5.7	0.25	1.57	1.28	0.15		A448
						NODULE, HALF		30.3	5.6	0.24	1.53	1.31	0.14		A448
						NODULE, HALF		28.1	6.0	0.26	1.46	1.25	0.14		A448
						NODULE, HALF		25.7	6.2	0.30	1.46	1.25	0.14		A448
						NODULE, HALF		29.1	6.4	0.28	1.53	1.24	0.14		A448
3730119	80C75 5-10	15.245N	126.535W	C	4493	NODULE, HALF		14.8	4.2	0.20	1.13	0.84	0.07		A448
						NODULE, HALF		28.5	6.9	0.28	1.52	1.18	0.13		A448
						NODULE, HALF		28.1	6.7	0.25	1.47	1.23	0.12		A448
						NODULE, HALF		25.6	7.7	0.29	1.46	0.97	0.10		A448
						NODULE, HALF		25.2	6.8	0.26	1.44	1.10	0.10		A448
						NODULE, HALF		23.6	6.3	0.22	1.33	1.08	0.10		A448
						NODULE, HALF		28.1	6.7	0.25	1.47	1.12	0.12		A448
						NODULE, HALF		28.3	6.6	0.26	1.42	1.15	0.15		A448
						NODULE, HALF		26.7	6.5	0.25	1.38	1.15	0.14		A448
						NODULE, HALF		28.1	6.3	0.25	1.46	1.13	0.14		A448
3730172	SS72-1708	13.142N	128.602W	D	4710	NODULE		25.3	6.1	0.22	1.51	1.11	0.00		A386
3740070	MN7401-10G38	19.698N	132.001W	C	5155	NODULE, HALF		22.8	10.2	0.34	1.04	0.88	0.08		A441
3740074	MN7401-10C42	19.600N	132.133W	G	5125	NODULE, HALF	27X18X12	25.6	9.8	0.31	1.18	0.88	0.09		A441
3740075	MN7401-10C43	19.600N	132.133W	G	5080	NODULE, HALF	35X24X20	23.4	9.5	0.26	1.09	0.96	0.09		A441
						NODULE, HALF	28X17X11	26.3	8.5	0.32	1.29	0.94	0.11		A441
3740204	WSU-NF18	10.000N	135.000W			NODULE, HALF	53X39X20	25.9	6.5	0.27	1.37	0.93	0.14		A441
3740134	80C75-55-56	11.810N	137.405W	C	4896	NODULE, HALF		25.4	4.9	0.23	1.57	1.11	0.14		A448
						NODULE, HALF		27.8	4.6	0.23	1.65	1.18	0.13		A448
						NODULE, HALF		29.8	5.3	0.25	1.67	1.34	0.12		A448

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUE	LONGI- TUE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (CM)	ZMN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPA	REF
						NODULE, HALF		30.5	4.2	0.21	1.78	1.28	0.14		A448
						NODULE, HALF		24.5	4.3	0.23	1.77	1.32	0.12		A448
						NODULE, HALF		31.1	3.9	0.21	1.72	1.27	0.14		A448
						NODULE, HALF		25.9	4.3	0.28	1.58	1.31	0.12		A448
						NODULE, HALF		28.6	4.4	0.23	1.66	1.23	0.12		A448
						NODULE, HALF		29.9	4.3	0.22	1.69	1.18	0.12		A448
3740135	80C75-55-55	11.803N	137.438W	C	4853	NODULE, HALF		30.7	4.3	0.31	1.73	1.42	0.12		A448
						NODULE, HALF		29.4	4.6	0.25	1.74	1.39	0.11		A448
						NODULE, HALF		29.6	4.6	0.23	1.72	1.21	0.07		A448
						NODULE, HALF		25.6	4.2	0.23	1.55	1.27	0.14		A448
						NODULE, HALF		30.2	4.3	0.22	1.69	1.26	0.14		A448
						NODULE, HALF		29.2	4.4	0.25	1.68	1.27	0.11		A448
						NODULE, HALF		31.0	4.4	0.21	1.68	1.25	0.14		A448
						NODULE, HALF		29.9	4.0	0.23	1.75	1.25	0.14		A448
						NODULE, HALF		22.4	6.6		1.40	1.35			A448
						NODULE, HALF		27.0	5.3		1.28	1.02			A448
3740136	80C75-55-54	11.847N	137.445W	C	4830	NODULE, HALF		23.1	7.0	0.20	1.62	0.81	0.13		A448
						NODULE, HALF		30.2	4.7	0.34	1.80	1.31	0.12		A448
						NODULE, HALF		29.3	4.5	0.22	1.72	1.28	0.14		A448
						NODULE, HALF		30.0	4.9	0.24	1.56	1.18	0.15		A448
						NODULE, HALF		29.5	4.0	0.21	1.60	1.28	0.12		A448
						NODULE, HALF		29.7	4.6	0.25	1.62	1.21	0.12		A448
						NODULE, HALF		31.0	4.4	0.24	1.74	1.29	0.16		A448
						NODULE, HALF		30.2	4.5	0.23	1.71	0.92	0.05		A448
						NODULE, HALF		31.8	4.0	0.25	1.58	1.41	0.12		A448
						NODULE, HALF		30.5	4.2	0.31	1.66	1.30	0.12		A448
3740137	80C75-55-53	11.810N	137.472W	C	4659	NODULE, HALF		27.5	7.0	0.28	1.14	0.96	0.07		A448
						NODULE, HALF		30.7	2.4	0.20	1.79	1.61	0.16		A448
						NODULE, HALF		25.0	4.3	0.19	1.59	1.42	0.14		A448
						NODULE, HALF		30.0	3.4	0.20	1.56	1.60	0.17		A448
						NODULE, HALF		32.1	2.8	0.19	1.72	1.61	0.15		A448
						NODULE, HALF		26.5	3.1	0.21	1.65	1.47	0.13		A448
						NODULE, HALF		30.0	3.3	0.17	1.67	1.55	0.16		A448
						NODULE, HALF		28.9	2.5	0.19	1.65	1.43	0.15		A448
						NODULE, HALF		30.0	3.5	0.19	1.72	1.47	0.15		A448
						NODULE, HALF		31.0	3.3	0.20	1.77	1.56	0.18		A448
3740138	80C75-54-48	12.193N	137.683W	C	4930	NODULE, HALF		30.2	4.4	0.23	1.78	1.47	0.15		A448
						NODULE, HALF		29.8	5.4	0.23	1.44	1.15	0.12		A448
						NODULE, HALF		28.7	5.5	0.23	1.44	1.03	0.12		A448
						NODULE, HALF		28.6	5.4	0.23	1.65	1.26	0.09		A448
						NODULE, HALF		30.4	4.1	0.23	1.78	1.54	0.14		A448
						NODULE, HALF		30.5	3.6	0.21	1.47	1.41	0.14		A448
						NODULE, HALF		29.1	5.0	0.22	1.72	1.32	0.13		A448
						NODULE, HALF		29.7	9.3	0.19	1.34	1.03	0.14		A448
						NODULE, HALF		28.6	4.3	0.20	1.46	1.12	0.12		A448
						NODULE, HALF		28.1	5.2	0.22	1.32	1.03	0.12		A448
3740139	80C75-54-52	12.160N	137.707W	C	4954	NODULE, HALF		22.8	4.8	0.21	1.47	1.15	0.12		A448
						NODULE, HALF		30.3	4.5	0.21	1.60	0.97	0.15		A448
						NODULE, HALF		25.1	5.0	0.21	1.53	1.10	0.12		A448
						NODULE, HALF		29.2	4.8	0.22	1.58	1.23	0.11		A448

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT	DIMENSIONS SAMPLED (MM)	1PN	1FE	1CG	1NI	1CU	1ZN	1PB	REF
						NODULE, HALF		20.2	4.8	0.23	1.18	1.23	0.12		A448
						NODULE, HALF		30.0	4.8	0.22	1.59	1.23	0.12		A448
						NODULE, HALF		29.7	4.3	0.20	1.70	1.29	0.12		A448
						NODULE, HALF		27.8	5.1	0.20	1.65	1.30	0.12		A448
						NODULE, HALF		25.6	4.7	0.20	1.68	1.24	0.12		A448
						NODULE, HALF		28.0	4.8	0.22	1.58	1.30	0.08		A448
3740140	80C75-54-47	12.173N	137.735W	C	4930	NODULE, HALF		28.2	4.4		1.70	1.56			A448
						NODULE, HALF		28.5	4.3		1.69	1.52			A448
						NODULE, HALF		24.4	5.5		1.51	1.24			A448
3740141	80C75-54-51	12.148N	137.743W	C	4934	NODULE, HALF		29.4	5.3	0.23	1.66	1.19	0.12		A448
						NODULE, HALF		28.9	5.1	0.21	1.59	1.18	0.14		A448
						NODULE, HALF		29.0	5.2	0.21	1.57	1.13	0.15		A448
						NODULE, HALF		30.1	5.2	0.24	1.75	1.28	0.11		A448
						NODULE, HALF		30.2	4.8	0.23	1.65	1.18	0.13		A448
						NODULE, HALF		29.6	4.8	0.23	1.66	1.16	0.14		A448
						NODULE, HALF		30.5	4.6	0.23	1.74	1.24	0.13		A448
						NODULE, HALF		28.4	5.1	0.19	1.81	1.28	0.12		A448
						NODULE, HALF		28.7	4.8	0.25	1.70	1.38	0.11		A448
						NODULE, HALF		28.7	5.0	0.21	1.64	1.23	0.12		A448
						NODULE, HALF		27.1	5.4		1.40	1.11			A448
3740142	80C75-54-49	12.200N	137.745W	C	4942	NODULE, HALF		27.3	3.7		1.66	1.57			A448
						NODULE, HALF		25.8	3.4		1.66	1.42			A448
						NODULE, HALF		25.8	4.2		1.52	1.37			A448
						NODULE, HALF		25.9	4.2		1.52	1.41			A448
						NODULE, HALF		26.3	4.2		1.58	1.55			A448
3740143	80C75-54-50	12.142N	137.767W	C	4978	NODULE, HALF		28.2	4.2		1.54	1.45			A448
						NODULE, HALF		25.8	5.4		1.37	1.31			A448
						NODULE, HALF		25.6	5.2		1.40	1.37			A448
						NODULE, HALF		25.7	4.7		1.49	1.33			A448
						NODULE, HALF		28.3	4.5		1.53	1.48			A448
3740144	80C75-53-46	11.733N	138.353W	C	4930	NODULE, HALF		28.5	3.8		1.51	1.45			A448
3740145	80C75-53-45	11.732N	138.370W	C	4985	NODULE, HALF		30.0	5.7	0.23	1.68	1.27	0.13		A448
						NODULE, HALF		27.8	3.7		1.54	1.55			A448
						NODULE, HALF		24.6	5.9		1.33	1.29			A448
						NODULE, HALF		27.1	4.9		1.45	1.88			A448
3740146	80C75-53-44	11.722N	138.373W	C	5001	NODULE, HALF		28.1	4.4		1.74	1.85			A448
						NODULE, HALF		26.8	4.7		1.66	1.77			A448
3740150	80C75-52-40	11.272N	139.070W	C	4859	NODULE, HALF		31.0	5.0	0.20	1.65	1.10	0.16		A448
						NODULE, HALF		30.6	4.3	0.20	1.66	1.21	0.14		A448
						NODULE, HALF		31.7	4.4	0.19	1.67	1.18	0.14		A448
						NODULE, HALF		30.6	4.3		1.66	1.21			A448
						NODULE, HALF		27.6	4.3		1.46	1.29			A448
3740151	80C75-52-38	11.243N	139.090W	C	4932	NODULE, HALF		28.8	3.9		1.24	1.57			A448
						NODULE, HALF		30.0	3.3		1.32	1.41			A448
3740152	80C75-52-41	11.608N	139.128W	C	4850	NODULE, HALF		21.6	4.8		0.91	1.53			A448

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZMN	ZFE	ZCU	ZNI	ZCU	ZZN	ZPB	REF
3740153	80C75-51-36	11.728N	139.137W	C	4914	NODULE, HALF		28.6	3.7		1.40	1.48			A448
3740154	80C75-51-35	11.718N	139.148W	C	4914	NODULE, HALF NODULE, HALF		25.4 27.8	3.3 3.4		1.31 1.32	1.39 1.52			A448 A448
3740155	80C75-52-37	11.228N	139.165W	C	4872	NODULE, HALF		28.6	3.7		1.27	1.45			A448
3740156	80C75-51-34	11.707N	139.180W	C	4925	NODULE, HALF NODULE, HALF NODULE, HALF NODULE, HALF NODULE, HALF NODULE, HALF		32.8 30.1 28.8 29.2 28.6 24.1	3.6 4.6 3.9 4.8 3.8 10.6	0.17 0.19 0.18 0.20	1.42 1.57 1.60 1.70 1.57 1.02	1.01 1.15 1.13 1.28 1.48 3.69	0.15 0.16 0.15 0.13		A448 A448 A448 A448 A448 A448
3740157	80C75-51-33	11.693N	139.183W	C	4881	NODULE, HALF NODULE, HALF		28.1 27.5	4.9 3.7	0.20 0.20	1.88 1.93	1.41 1.66	0.14 0.11		A448 A448
3750488	WSU-NP22	10.000N	140.000W		4500	NODULE, HALF NODULE, HALF NODULE, HALF	75X55X35 63X53X30 70X70X50	31.3 28.7 29.8	5.0 5.6 6.0	0.24 0.25 0.22	1.22 1.47 1.32	1.18 1.24 1.07	0.15 0.16 0.19		A441 A441 A441
3750100	MN7402-16G34	11.067N	140.017W	G	4780	NODULE, HALF	72X58X47	30.2	5.0	0.21	1.41	1.07	0.20		A441
3750089	MN7401-07G29	10.010N	143.317W	G	5075	NODULE, HALF	82X70X53	30.5	5.3	0.25	1.39	1.08	0.13		A441
3750090	MN7401-07G30	10.008N	143.320W	G	5075	NODULE, HALF	80X65X62	31.2	5.1	0.20	1.52	1.07	0.17		A441
3760437	WSU-NP17	10.000N	150.000W		5100	NODULE, HALF	40X40X26	19.0	9.6	0.25	0.92	0.66	0.08		A441
3760175	MN7401-01G01	13.002N	154.033W	G	5413	NODULE, HALF	55X40X27	31.2	5.0	0.19	1.20	1.38	0.21		A441
3780083	CH-II-17	10.300N	170.633W		4550	NODULE W/C NUCLEUS		14.3	10.4	0.34	0.59	0.28			A389
3780089	CH-II-18	12.000N	175.717W		5340	NODULE W/C NUCLEUS		15.2	10.4	0.43	0.37	0.20			A389
4080121	DH-9	21.800N	113.050W	C	3450	NODULE FRAGMENTS		28.7	6.2	0.06	0.76	0.50	0.27		A441
4090144	CH-8	21.667N	113.500W	C	3420	NODULE, HALF NODULE FRAGMENTS	68X52 59X35	24.4 28.1	8.7 7.9	0.11 0.09	0.95 0.91	0.70 0.61	0.23 0.25		A441 A441
4090161	DH-5	21.450N	114.117W	C	3800	NODULE, HALF		20.6	11.5	0.18	0.78	0.55	0.10		A441
4090162	DH-4	21.517N	114.133W	C	3800	NODULE FRAGMENTS		26.4	7.6	0.10	0.97	0.83	0.22		A441
4090463	USB1	22.000N	114.583W	C	3400	NODULE FRAGMENTS NODULE, HALF NODULE FRAGMENTS NODULE FRAGMENTS		14.8 21.4 18.9 25.7	16.9 13.2 14.9 9.2	0.15 0.15 0.16 0.12	0.49 0.80 0.76 1.05	0.33 0.45 0.44 0.70	0.09 0.12 0.10 0.22		A441 A441 A441 A441
4090524	WSU-NP9	20.000N	115.000W		3700	NODULE, HALF		25.8	9.3	0.16	1.04	0.58	0.19		A441
4090238	CH-1	22.000N	116.233W	C	3480	NODULE, HALF NODULE, HALF		23.8 17.7	9.7 14.9	0.12 0.14	1.00 0.66	0.63 0.37	0.22 0.10		A441 A441
4130250	WSU-NP14	25.000N	160.000W			NODULE, HALF NODULE, HALF	38X35X25 34X26X10	15.3 13.8	10.3 12.8	0.33 0.40	0.70 0.64	0.57 0.35	0.07 0.05		A441 A441

SEQ NUMBER	SHIP/CRUISE STATION NO.	LATI- TUDE	LONGI- TUDE	SAMP TYPE	DEP (M)	SAMP. TYPE & SECT SAMPLED	DIMENSIONS (MM)	ZPN	ZFE	ZCO	ZNI	ZCU	ZZN	ZPB	REF
4190169	GDP8-12	29.917N	133.367E		2270	NODULE	9X7X7	17.8	19.1	0.24	0.39	0.07			A425
						NODULE	8X7X6	17.8	18.8	0.21	0.41	0.07			A425
						NODULE	8X8X6	15.3	18.5	0.18	0.51	0.14			A425
						NODULE	7X5X4	17.5	19.3	0.22	0.36	0.06			A425
						NODULE	10X7X6	18.8	18.1	0.22	0.49	0.08			A425
						NODULE	6X6X4	17.8	17.9	0.21	0.37	0.07			A425

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