19. MANGANESE NODULES IN SEDIMENTS CORED DURING LEG 16, DEEP SEA DRILLING PROJECT

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ABSTRACT

Buried manganese nodules or encrustations were encountered at five drill sites of Leg 16. Surface nodules were also sampled at two sites. With few exceptions, nodules within any one drill hole are fairly uniform in composition and are similar in composition to samples obtained previously from the eastern equatorial Pacific. Geochemical and paleontological evidence suggests that at least one of the buried samples was in situ when found and that at least one other was not. The remaining nodules may have fallen from the sediment surface to the positions in which they were found during the drilling process.

INTRODUCTION

Manganese nodules or encrustations were found at DSDP 156, 159, 160, 161, and 162 of Leg 16. Two or more nodules were found at various depths at each site except DSDP 156, where drilling terminated just below the sediment surface in a black ferromanganese oxide crust. Sample descriptions are given below and are summarized in Table 1.

The occurrence of subsurface nodules in deep-sea sediments is by no means uncommon. Cronan and Tooms (1967a) estimated from the examination of 113 Pacific cores collected by the Scripps Institution of Oceanography that nodules in the upper 2.5 meters of Pacific sediments, excluding those at the surface, are approximately equal in number to those in the surface layer. However, it is only with the advent of the deep drilling techniques of the Deep Sea Drilling Project that nodules have been found more than a few meters below the sediment surface. Whether or not these nodules are in situ is not clear. According to McManus, Burns et al. (1970, p. 7), occurrences of manganese nodules at depth in Deep Sea Drilling Project cores could result from slumping, the nodules having fallen down the drill hole from the sediment surface. Obviously, this problem must be resolved before the economic or any other significance of these nodules can be estimated.

SAMPLE DESCRIPTIONS

DSDP 156

The only samples of ferromanganese oxides obtained from DSDP 156 consist of fragments of crust 1 to 2 cm thick which show internal laminations of yellow brown material separated by massive black manganese and iron oxide phases. The upper surface of the crust is slightly botryoidal, and the internal laminations tend to follow the undulations of the botryoids.

DSDP 159

Nodules were found only at depth at DSDP 159. Some show the development of internal layering consisting of alternations of black reflecting bands separated by duller material, and all have black, smooth to slightly vesicular surfaces.

DSDP 160

As at DSDP 159, nodules were only found at depth at DSDP 160. They are more or less spherical to slightly elongate in shape, with smooth to slightly botryoidal or vesicular surfaces. Some have well-developed nuclei, whereas others only exhibit an increase in detrital materials toward their centers. Most of the samples are unbanded and consist of uniform, moderately reflecting, massive ferromanganese oxide phases, although some show weakly developed bands of poorly reflecting material.

DSDP 161

Nodules were found both at the surface and at depth at DSDP 161. The surface sample consists of several small fragments containing detrital materials scattered throughout. By contrast, the subsurface sample has a well-developed nucleus of volcanic material and also shows the development of internal banding.

DSDP 162

A total of eleven samples were obtained at DSDP 162, one at the surface and the remainder at depth. Most of the samples consist of small, almost spherical nodules, either singly or joined together in twos and threes, and all but one tend to have smooth surfaces. Some show the development of internal banding. This banding follows the outlines of the individual nodules where two or more have grown together. A small nodule quite unlike the others in the section was found near the base of DSDP 162. It is approximately 3mm in diameter, irregular in shape, and completely enclosed in an undisturbed white mottle.

COMPOSITION

The nodules described in this work have been analyzed for the elements Fe, Mn, Cu, Pb, Zn, Ni, and Co by atomic

TABLE 1
Manganese Nodules in Cores from Leg 16, Deep Sea Drilling Project

Sample No.	Site, Core, Section, Interval (cm)	Depth Below Sea Floor (m)	Size (cm)	Surface Texture	Probable Age Associated Sediment	Remarks
156-1	156-1(CC)	0.49	Fragments of crust	Slightly botryoidal	Late Pleistocene	Black massive unlayered crust.
159-1	159-11(CC)	99.00	1.4 × 1.1 × 2.0	Smooth	Early Miocene or Late Oligocene	Internal banding weakly developed, no nucleus.
159-2	159-12-1(50)	99.50	2.5 × 3.0 × 3.5	Vesicular	Early Miocene or Late Oligocene	Well-developed internal banding, no nucleus.
159-3	159-12-2(100)	101.50	1.6 × 1.3 × 0.8	Smooth	Early Miocene or Late Oligocene	Internal banding and nucleus absent.
159-4	159-12-4(147)	104.97	2.4 × 1.1 × 1.5	Smooth	Early Miocene or Late Oligocene	Nucleus absent, bands of poorly reflecting material present.
160-1	160-1-1(114)	1.14	2.1 × 2.1 × 2.1	Vesicular	Pleistocene	Nucleus of altered volcanic material surrounded by 4-5 mm banded phases.
160-2	160-1-1(120)	1.20	3.3 × 3.3 × 3.3	Botryoidal and vesicular	Pleistocene	Internally massive, no nucleus.
160-3	160-1-1(120)	1.20	1.8 × 2.0 × 2.5	Vesicular	Pleistocene	Internal banding and nucleus absent.
160-4	160-2-1(Top)	9.00	2.0 × 2.5 × 3.5	Predominantly smooth	Pleistocene or Early Miocene	Nucleus of volcanic material, banding absent.
160-5	160-3-1(53)	18.53	2.0 × 2.0 × 2.0	Botryoidal and slightly vesicular	Early Miocene	Some fine banding with detrital material scattered throughout.
161-1	161-1-1(Top)	0.00	Several small fragments	Smooth	Early Miocene	Internally massive, no nucleus.
161-2	161A-14(CC)	244.00	2.0 × 2.0 × 0.8	Smooth to slightly vesicular	Middle Eocene	Volcanic nucleus, some banding.
162-1	162-1-1(Top)	0.00	Small fragments	Smooth	Early Oligocene	Massive internally, no nucleus or banding.
162-2	162-1-1(127)	1.27	0.8 × 0.8 × 0.8	Smooth	Early Oligocene	Three spherical nodules fused together, banding present around small nuclei.
162-3	162-1-3(65)	3.65	0.5 × 0.5 × 0.5	Smooth	Early Oligocene	Sample not sectioned.
162-4	162-1-5(8)	6.08	1.3 × 1.3 × 0.8	Smooth	Early Oligocene	Sample not sectioned.
162-5	162-1-6(73)	8.23	0.5 × 0.5 × 0.5 1.0 × 1.0 × 1.0	Smooth	Early Oligocene	Two nodules fused together, not sectioned.
162-6	162-1-6(117)	8.67	Approx. 0.5 cm in diameter	Smooth	Early Oligocene	Two equal sized nodules fused together, not sectioned.
162-7	162-2-5(78)	15.78	2.0 × 2.1 × 1.1	Smooth	Early Oligocene	Internally massive, no nucleus but detrital materials scattered throughout.
162-8	162-2-6(31)	16.81	1.5 × 0.8 × 0.8	Smooth	Early Oligocene	Not sectioned.
162-9	162-2-6(86)	17.36	1.3 × 1.3 × 1.3 0.8 × 0.8 × 0.8	Smooth	Early Oligocene	Two nodules fused together; each sample is concentrically banded around its own nucleus.
162-10	162-9-1(30)	72.30	1.0 × 1.0 × 1.0	Smooth	Middle Eocene	Not sectioned.
162-11	162-15-4(52)	131.02	Approx. 0.3 cm in diameter	Rough	Middle Eocene	Irregularly shaped small nodule completely enclosed in a white mottle.

absorption spectrophotometry. The results are presented in Table 2.

Prior to analysis, all but one of the samples were ground to a fine powder and dried in a desiccator at room temperature. The remaining sample, 162-11, was too small to crush without the likelihood of significant loss of material and thus was attacked whole. The samples were digested in hot 50 per cent HCl, heated on a hot plate until reaction ceased, and filtered through Whatman No. 41 filter paper. The HCl-soluble portions were made up to 25 ml in 1 *N* HCl and aspirated either directly or, after further dilution as necessary, on a Techtron Mk 4 Atomic Absorption Spectrophotometer. Standards were made up in 1 *N* HCl and were also run at periodic intervals.

Examination of the data in Table 2 shows, with few exceptions, that nodules within any one hole are more or less similar in composition. The main exceptions are Samples 160-4, 162-1, 162-10, and 162-11. The former has a higher Fe content than do the other nodules in DSDP 160, whereas the latter three differ in many respects, both from each other and from the remainder of the nodules at DSDP 162. Overall compositional variations between sites are more pronounced than within most individual sections, but are nevertheless small in comparison with variations in the composition of Pacific nodules as a whole (Mero, 1965; Cronan and Tooms, 1969). Excluding the sample from DSDP 156 and the anomalous samples from deep in DSDP 162, there is an overall decrease in Mn, Cu, and Zn and an increase in Fe, Co, and Pb from east to west across the survey area. However, in general, the magnitude of the minor element variations is small.

DISCUSSION

The data presented in this report are of interest in at least two respects. Firstly, they can be used in attempts to distinguish those nodules found at depth in the holes as a result of slumping from those which may be in situ; and, secondly, they provide some information on variations in the composition of nodules across the east Pacific.

Previous studies on variations in the composition of nodules over small areas or within short sediment cores have shown that such variations are minor except where different morphological populations of nodules are involved (Skornyakova et al., 1962; Mero, 1965; Lorber, 1966; Cronan and Tooms, 1967b; Cronan and Tooms, 1969; Tooms et al., 1969; Goodell et al., 1971). It is possible, therefore, that where there are significant compositional differences between nodules from different depths in the present holes, these differences may reflect the sampling of in situ nodules, or, at least, nodules which did not belong to a single surface population and which had fallen to the positions in which they were found during the drilling process. For example, the two deepest nodules in DSDP 162, Samples 162-10 and 162-11, are markedly

TABLE 2
Composition of Manganese Nodules in Cores from Leg 16, Deep Sea Drilling Project (in weight %)

Sample No.	Fe	Mn	Cu	Pb	Zn	Ni	Co
156-1	15.226	23.902	0.095	0.040	0.091	0.877	0.071
159-1	4.496	35.001	1.411	0.032	0.212	1.360	0.151
159-2	4.170	34.994	1.507	0.030	0.220	1.391	0.155
159-3	4.173	34.161	1.428	0.032	0.228	1.374	0.151
159-4	4.434	35.243	1.455	0.032	0.219	1.491	0.158
Average	4.318	34.849	1.450	0.032	0.219	1.404	0.154
160-1	3.473	35.116	1.597	0.028	0.224	1.718	0.138
160-2	3.755	33.861	1.482	0.033	0.190	1.760	0.146
160-3	3.226	33.689	1.589	0.027	0.198	1.787	0.121
160-4	4.576	33.147	1.564	0.039	0.150	1.482	0.281
160-5	3.046	35.226	1.617	0.027	0.213	1.739	0.139
Average	3.615	34.207	1.569	0.031	0.195	1.697	0.165
161-1	5.406	30.264	1.220	0.040	0.155	1.584	0.244
161-2	5.020	31.157	1.299	0.033	0.176	1.523	0.214
Average	5.213	30.710	1.259	0.036	0.165	1.553	0.229
162-1	7.188	19.042	0.745	0.033	0.098	1.012	0.205
162-2	5.498	27.129	1.176	0.045	0.135	1.517	0.270
162-3	6.074	27.613	1.221	0.044	0.130	1.557	0.302
162-4	6.054	25.107	1.049	0.038	0.122	1.379	0.236
162-5	5.203	29.016	1.277	0.043	0.141	1.588	0.297
162-6	6.455	26.125	1.104	0.046	0.120	1.465	0.297
162-7	5.984	25.839	1.109	0.038	0.126	1.403	0.238
162-8	5.806	26.851	1.152	0.036	0.130	1.432	0.240
162-9	5.513	27.006	1.155	0.035	0.131	1.512	0.254
162-10	11.206	13.605	0.465	0.019	0.062	0.387	0.105
162-11	46.696	0.326	n.d.	n.d.	0.112	n.d.	n.d.
Average[a]	5.975	25.969	1.109	0.039	0.125	1.429	0.259

[a]Excluding 162-10 and 162-11.

different in composition from those higher in the section. As mentioned previously, Sample 162-11 occurred at the center of an undisturbed white mottle, strongly suggesting that it was in situ when found. The nannofossils in the mottle and in the darker sediment surrounding it are of the same species and age (Bukry, David, personal communication), supporting an in situ location for this sample. Its enrichment in Fe and its occurrence completely enclosed in a mottle suggests that it could have formed at depth as a result of the leaching of iron from the surrounding sediments.

Similar evidence for the in situ location of other nodules is lacking. However, there is good evidence that at least one of the buried nodules in DSDP 159 is not in situ. All the nodules in DSDP 159 are compositionally and morphologically very similar, suggesting that they all belong to a single population. Micropalaentological examination of the sediment coating Sample 159-2 from 99.5 meters below the surface revealed the presence of the Quaternary radiolarian *Ommatartus tetrathalamus* (Dinkleman, Menno G., personal communication), yet the sample occurs in a horizon of early Miocene or late Oligocene age. Unfortunately, direct evidence for the slumping of other nodules is lacking. The sediment coating Sample 160-4 from 9 meters in DSDP 160 contains Quaternary radiolarians, but the age of the horizon in which the nodule occurs is not known. The overlying sediments are Quaternary and the underlying ones are early Miocene.

Although the present data relate only to the HC1-soluble fraction of the samples and thus are not directly comparable with previous analyses, the concentrations of the elements determined are in general agreement with those found by previous workers in nodules from the east Pacific (Skornyakova and Andrushchenko, 1964; Mero, 1965; Cronan and Tooms, 1969). The chief exception to this generalization seems to be in the encrustation from DSDP 156 which is low in all the minor elements sought, except Ni, and has an Mn/Fe ratio significantly different from that of most of the other nodules examined. However, this sample occurs in an area where few nodules have been found previously, and thus direct comparison with its neighbors is not possible.

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