29. BASAL IRON-TITANIUM-RICH SEDIMENTS FROM HOLE 315A (LINE ISLANDS, CENTRAL PACIFIC)

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ABSTRACT

Basal red, blue, and green radiolarian claystones and sandstones (chiefly montmorillonite and illite) of probable Santonian age (Hole 315A, Line Islands) have a chemistry that differs both from modern and ancient spreading-ridge sediments and from Pacific pelagic clays. Relative to deep-sea Pacific clays, the 315A basal sediments are enriched in Fe and Ti; however, their trace element levels generally are lower. This chemistry roughly matches that of the underlying volcanics. The iron may thus derive from submarine weathering of basalt; the titanium is probably specifically related to the presence of detrital clinopyroxene and authigenic anatase.

The chemistry of these Line Islands sediments is comparable with that of the red claystones lying on the altered volcanics of Meiji Guyot (Emperor Seamounts); the implication is, therefore, that oceanic islands are characterized by a specific type of basal deposit in the genesis of which geothermal systems and "hydrothermal solutions" play a negligible role.

INTRODUCTION

The basal radiolarian-bearing claystones and sandstones (?Santonian) of Hole 315A (Line Islands) aroused considerable interest aboard ship as they were vividly colored in shades of blue, green, and red, and differently colored zones alternated. As these sediments lie just above basaltic basement it was suspected that they might be enriched in Fe, Mn, and certain trace metals, much as in the deposits described by Boström and Peterson (1966, 1969) and Piper (1973) from the East Pacific Rise and many other authors from Deep Sea Drilling cores sampled immediately above oceanic basalt (e.g., von der Borch and Rex, 1970; Drever, 1971; von der Borch et al., 1971; Cook, 1972; Cronan, 1973). Accordingly, major- and minor-element analyses and X-ray mineralogical studies were carried out on nine samples of these multicolored deposits.

METHODS

X-Ray Diffraction

The qualitative and quantitative mineralogy of the samples was determined by X-ray diffraction techniques. The method used was a modification of that described by Griffin (1954) and Gibbs (1967), in which synthetic boehmite was added as an internal standard.

The X-ray equipment employed was a Philips PW1130 3-kw diffractometer, with a sealed proportional counter, using iron-filtered cobalt radiation at 60 kv 30 mA. All smear-oriented specimens were run at a scanning speed of 1° of 2θ per min over the required angular range. Several samples were subjected to specialized X-ray investigation as well as quantitative mineralogical analyses.

X-Ray Fluorescence

Major elements (determined as the oxides with the exception of sulphur) and certain minor elements were analyzed by X-ray fluorescence analysis, using equipment at Durham University. The samples were crushed, washed with distilled water, and dried. The X-ray equipment used was a Philips PW1212 automatic spectrometer in conjunction with a Torrens Industries TE 108 automatic sample loader. Elemental line intensities were measured with respect to igneous and sedimentary rocks of established composition, including several well-known international standards. A computerized mass-absorption correction procedure was applied to the line-intensity data for the major elements (see Holland and Brindle, 1966), but only a simple peak-to-background ratio method was used for the trace-element intensity data. Calibration curves for the elements were then obtained and from these the composition of the unknown samples was determined.

RESULTS

The X-ray diffraction data are shown in Table 1. Clearly the claystones and sandstones comprise variable but dominant (except Sample 315A-29-1, 31-33 cm) amounts of montmorillonite-group clays, plus illite, and locally quartz, anatase, clinopyroxene, and clinoptilolite. Quartz-filled radiolarian molds and clinopyroxene are optically recognizable in some smear slides. The montmorillonites fall into three groups: one is very crystalline, giving a strong peak at 15Å (in acetone) which expands to 17Å on glycolation; another is very poorly crystalline and very difficult to glycolate; the last is intermediate in crystallinity and is associated with a mixed-layer clay. Illite varies slightly in its crystallinity

TABLE 1
X-Ray Diffraction Data From Basal Sediments at Hole 315A

Sample (Interval in cm)	Color	Smectite	Quartz	Calcite	Goethite	Hematite	Chlorite	Kaolinite	Pyroxene	Feldspar	Illite	Magnetite	Anatase	Clinop-tilolite
28-3, 40-41	Moderate red-brown claystone with small (2-3mm) brown concretions	Poorly crystalline montmorillonite plus mixed-layer clay	30%	Absent	Absent	Absent	Absent	Absent	Absent	Absent	20%	Absent	Absent	Present
28-3, 104-106	Blue-green claystone	Montmorillonite dominant plus mixed-layer clay	10%	Absent	Absent	Absent	Absent	Absent	Absent	Plagioclase	30%	Absent	Absent	Absent
29-1, 31-33	Grayish-blue-green to dusky blue-green claystone	Montmorillonite plus mized-layer clay	30%	Absent	Absent	Absent	Absent	Absent	Absent	Labradorite	50%	Absent	Absent	Absent
29-1, 105-108	Grayish-blue-green to dusky blue-green claystone	Montmorillonite dominant plus mixed-layer clay	Absent	Absent	Absent	Absent	Absent	Absent	Trace amount	Plagioclase	Present	Absent	Absent	Absent
29-1, 120-122	Grayish-green volcanogenic sandstone	Very crystalline montmorillonite dominant	Absent	Absent	Absent	Absent	Absent	Absent	Present	Absent	30%	Absent	Trace amount	Absent
30-1, 58-60	Grayish-green volcanogenic sandstone	Very crystalline montmorillonite dominant	Absent	Absent	Present	Absent	Absent	Absent	Present	Labradorite	20%	Absent	Present	Absent
30-1, 65-66	Grayish-red to very dusky red claystone	Poorly crystalline montmorillonite plus mixed-layer clay	Absent	Absent	Present	Absent	Absent	Absent	Present	Labradorite	30%	Absent	Trace amount	Absent
30-1, 103-104	Grayish-red to very dusky red claystone	Poorly crystalline montmorillonite plus large amounts of mixed-layer clay	Absent	Absent	Present	Absent	Absent	Absent	Present	Labradorite	20%	Absent	Trace amount	Absent
30-2, 132-134	Moderate reddish-brown to dark reddish-brown claystone	Very crystalline montmorillonite dominant plus mixed-layer clay	20%	Absent	Absent	Absent	Absent	Absent	Absent	Absent	20%	Absent	Absent	Absent

from sample to sample and is most crystalline in 315A-29-1, 31-33 cm where it is dominant over montmorillonite. In this sample and in 315A-28-3, 40-41 cm free crystalline quartz is present up to 30% by weight; this is reflected in the chemical analyses and is presumably related to the local abundance of quartz-filled radiolarian spheres. Opaline silica occurs in some samples. Despite the red color of certain of these sediments hematite was not detected; goethite was, however, identified in three samples including a grayish-green sandstone. The high level of X-ray fluorescence in 315A-28-3, 40-41 cm and 315A-30-2, 132-134 cm suggests that most of the iron in these samples is held as X-ray-amorphous oxide-hydroxides.

The major- and minor-element analyses are presented in Tables 2 and 3. When compared with the analyses of modern and ancient spreading-ridge sediments and with average Pacific deep-sea clays, the 315A claystones and sandstones show features in common with both, but match neither. Spreading-ridge sediments are characterized by Fe contents of about 15%-20% and accompanying Mn values of 2%-6%; their Al values (ca 0.5%), and Ti values (ca 0.02%) are abnormally low (Boström and Peterson, 1969). Clearly the 315A sediments with average Fe contents of ca 8.5%, Mn contents of ca 0.4%, Al contents of ca 5.6%, and Ti contents of ca 1% are chemically very different. Furthermore, the trace-metal contents of the 315A samples are low compared with Pacific spreading-ridge sediments (Boström and Peterson, 1969; Drever, 1971; Cronan, 1973). Even when compared with Pacific deep-sea clays (Goldberg and Arrhenius, 1958; Cronan, 1969), the 315A sediments are but humbly endowed with most trace elements; the Si values are, however, roughly comparable and the Al values are only slightly lower. The Mn contents are also roughly the same, but the Na values are notably lower in the multicolored claystones and volcanogenic sandstones. However, with respect to the iron and titanium contents, the claystones and sandstones are certainly the richer (cf. Cronan, 1969), with average Fe values of 8.5% (cf. ~5% in pelagic clays) and Ti values of around 1% (cf. 0.45% in pelagic clays). Thus, the description of the basal claystones and sandstones as "iron-titanium-rich" is considered appropriate.

CONCLUSIONS AND IMPLICATIONS

Clearly the basal blue, green, and red sediments from the Line Islands Hole 315A are not akin to Pacific pelagic clays derived from the usual intra-oceanic and aeolian sources. Neither are they comparable with spreading-ridge sediments. Their chemistry is presumably governed by the composition of component clay minerals, silica-filled radiolarian spheres, and of more or less degraded igneous material. Analyses of the underlying basalts (Jackson et al., this volume) support this contention. The high titanium values, for example, are related to the presence of detrital pyroxenes and authigenic anatase (Goldberg and Arrhenius, 1958); the iron presumably owes its origin to pyroxene and other altered ferromagnesian minerals.

TABLE 2
Major-Element Analyses of Basal Sediments at Hole 315A

Sample (Interval in cm)	Color	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	S	P_2O_5	Total
28-3, 40-41	Moderate red-brown claystone with small (2-3mm) brown concretions	74.41	4.74	14.83	0.70	2.55	0.92	0.78	1.02	0.71	0	0.01	100.67
28-3, 104-106	Blue-green claystone	66.69	9.00	10.87	0.53	5.51	1.04	0.82	3.09	1.43	0	0.08	99.06
29-1, 31-33	Grayish-blue-green to dusky blue-green claystone	71.89	7.84	9.15	0.38	5.34	0.56	0.77	3.08	0.53	0	0.05	99.59
29-1, 105-108	Grayish blue-green to dusky blue-green claystone	57.70	11.07	12.47	0.44	6.14	2.50	1.34	2.75	2.30	0	0.38	97.09
29-1, 120-122	Grayish-green volcanogenic sandstone	51.60	13.74	11.26	0.61	11.02	2.66	1.68	1.57	2.86	0	0.28	97.28
30-1, 58-60	Grayish-green volcanogenic sandstone	54.34	15.36	7.64	0.40	6.59	2.24	1.05	4.11	3.82	0	0.23	95.78
30-1, 65-66	Grayish-red to very dusky red claystone	55.88	13.30	12.11	0.36	5.86	1.40	0.98	4.33	1.50	0	0.28	96.00
30-1, 103-104	Grayish red to very dusky red claystone	55.23	13.45	12.68	0.40	4.64	1.09	0.89	5.42	2.57	0	0.29	96.66
30-2, 132-134	Moderate reddish-brown to dark reddish-brown claystone	54.32	8.03	19.56	0.66	3.84	1.54	1.12	1.49	1.41	0	0.30	92.27

TABLE 3
Minor-Element Analyses of Basal Sediments at Hole 315A

Sample (Interval in cm)	Ba	Nb	Zr	Y	Sr	Rb	Zn	Pb	Cu	Ni	Cr	Co
28-3, 40-41	476	13	73	35	143	36	146	30	355	27	31	93
28-3, 104-106	64	15	136	18	179	102	60	10	78	38	54	27
29-1, 31-33	94	8	68	18	108	103	72	5	170	32	44	27
29-1, 105-108	63	21	191	44	220	71	114	19	64	43	63	25
29-1, 120-122	0	23	198	28	232	21	126	14	3	109	183	60
30-1, 58-60	0	4	125	13	130	31	83	0	89	24	318	28
30-1, 65-66	294	36	280	49	154	76	110	0	127	35	66	0
30-1, 103-104	363	26	232	36	133	83	83	11	221	15	73	0
30-2, 132-134	267	20	214	75	176	50	302	74	143	129	24	35

The chemistry of these basal 315A sediments indicates they were not formed from rocks of the oceanic-ridge type (Winterer, this volume; Jackson and Schlanger, this volume). The formation of metal-rich spreading-ridge sediments is assumed to depend on the action of geothermal systems involving circulating sea water and nascent oceanic crust (e.g., Corliss, 1971; Hart, 1973; Spooner and Fyfe, 1973). Thus, if the Line Islands represent a simple relict oceanic ridge, its geothermal system never became operative. Furthermore, the Line Islands volcanic rocks are not typical ocean-ridge tholeiites, but match more alkalic oceanic-island basalts (Jackson et al., this volume).

The only Pacific basal sediments known to us that resemble those from the Line Islands are red claystones reported by Natland (1973) from above the altered volcanics of Meiji Guyot in the northwest Pacific. It is significant that this guyot is part of a linear volcanic chain: that is, the Emperor Seamounts. The sediments here, although not analyzed for Ti, are comparable in their Fe and Mn contents with the 315A material and are equally scanty in their trace-element levels. The implication is, therefore, that the deposits directly overlying volcanic seamounts constitute a distinct type of basal sediment essentially derived only from submarine weathering of basalt, and where geothermal systems and "hydrothermal solutions" play a negligible role.

ACKNOWLEDGMENTS

We are grateful to Harry Cook, Dale Jackson, Kerry Kelts, and Jerry Winterer for profitable discussions, and to Mrs. C.L. Mines for typing the manuscript. H. Jenkyns gratefully acknowledges financial support from the Astor Foundation.

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