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4. Data Report: Boron Contents of Leg 192 Sediments[1]

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ABSTRACT

Boron, Ca, Na, and Gd concentrations and H intensity in sediments obtained during Ocean Drilling Program Leg 192 were determined by prompt gamma neutron activation analysis. The results show strong positive correlation between B content and H intensity in carbonate samples; chalk samples have higher B contents than limestone samples. Average B content is 9.1 ppm for the chalk and 5.2 ppm for the limestone. When chert blocks or clay minerals are present in the carbonate samples, B content increases (up to 91 ppm).

INTRODUCTION

The geochemical characteristics of boron, which include high solubility in aqueous fluids and high magmatic incompatibility, make B a useful tracer of deep earth fluids and the recycling of subducted materials (You et al., 1995b). In subduction zones, B is an important element for evaluating the origin of fluids that are derived from accretionary prisms and subducted rocks (e.g., Bebout et al., 1993; You et al., 1995a; Deyhle et al., 2001). High B contents in volcanic rocks from island arcs suggest that the fluids may be recycled to the arc crust (e.g., Morris et al., 1990; Ryan et al., 1995; Sano et al., 2001).

Because, compared to other Earth materials, B is strongly concentrated in oceanic sediments, it is important to know their B contents (e.g., Spivack et al., 1987; Vengosh et al., 1991; Ishikawa and Nakamura, 1993). However, little is known about depth profiles of B concentra-

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tions within sedimentary sections, and average B contents of oceanic sediments are still unknown (Plank and Langmuir, 1998).

During Ocean Drilling Program Leg 192, thick sedimentary sequences were cored at two sites, Site 1183 and Site 1186 (Mahoney, Fitton, Wallace, et al., 2001). We measured the B contents of sediment samples from these sites.

SAMPLES AND ANALYTICAL METHODS

We analyzed 38 carbonate samples collected from Sites 1183 and 1186 (Table T1). The sedimentary sequences of these two sites are divided into three lithologic units based mainly on the presence or absence of chert (Mahoney, Fitton, Wallace, et al., 2001). Unit I consists of ooze to chalk, and Units II and III mainly consist of chalk to limestone. Although the sedimentary units of these sites are dominated by carbonates, Unit II is characterized by intercalation of chert blocks and the lowermost part of Unit III includes dark calcareous volcaniclastic sandstone.

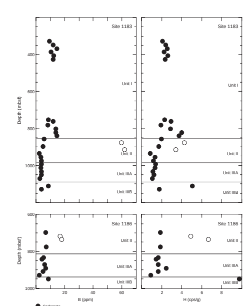
T1. Boron and other element contents, p. 6.

Boron, Ca, Na, and Gd concentrations and H intensity (measured in counts per second per gram) were determined by prompt gamma neutron activation analysis (PGNA) at the thermal and cold neutron beam guide of the JRR-3M reactor, Japan Atomic Energy Research Institute (Yonezawa et al., 1999). Samples were washed in an ultrasonic bath containing distilled water and then dried for >12 hr in an oven at 110°C. The cleaned samples were ground to a fine powder in a tungsten carbide mill. The sample powder (0.5–0.6 g) was cold-pressed into disks (12 mm in diameter and 2–3 mm in thickness). These disks were heat-sealed in 25-micron-thick fluorinated ethylenepropylene resin film smaller than 14 mm × 14 mm. A compton suppression prompt gamma activation spectrum was accumulated for 1,200–12,000 s. Geological Survey of Japan standards JLs-1 and JB-2 were used to calibrate the B, Ca, Na, and Gd contents. Details of the analytical procedures have been described in Sano et al. (1999). Replicate analyses of JB-2 indicate overall precision and accuracy on the order of 3% for B, Na, and Ca and 6% for Gd.

RESULTS AND DISCUSSION

Contents of B and other elements in Leg 192 sediments are given in Table T1. Boron content and H intensity of the sediments are plotted vs. depth in Figure F1.

F1. B contents and H intensity, p. 5.



Boron contents of the chert samples (17–62 ppm) are distinctly higher than those of the carbonates (2–15 ppm). Our B values are in the same range as reported values for marine sediments (Vengosh et al., 1991; Ishikawa and Nakamura, 1993). The high B contents in the chert samples are probably caused by the uptake of boron from seawater into tetrahedral silicon sites (Ishikawa and Nakamura, 1993).

Figure F1 shows that Unit I (ooze to chalk) has higher B contents than the lower units, Unit II and IIIA (limestone), at Site 1183. Positive correlation between B content and H intensity is also observed. The correlation could be explained by loss of B and H_2O during fluid expulsion from the sediments as a result of compaction and shortening (e.g., You et al., 1995a). Average B content is 9.1 ppm for the chalk and 5.2 ppm for the limestone.

Most carbonates in Subunit IIIB have high B contents (up to 91 ppm), probably derived from clay minerals (predominantly illite), because clay minerals are high in B (>100 ppm) (Ishikawa and Nakamura, 1993).

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REFERENCES

Bebout, G.E., Ryan, J.G., and Leeman, W.P., 1993. B-Be systematics in subduction-related metamorphic rocks: characterization of the subducted component. *Geochim. Cosmochim. Acta,* 57:2227–2237.

Deyhle, A., Kopf, A., and Eisenhauer, A., 2001. Boron systematics of authigenic carbonates: a new approach to identify fluid processes in accretionary prisms. *Earth Planet. Sci. Lett.,* 187:191–205.

Ishikawa, T., and Nakamura, E., 1993. Boron isotope systematics of marine sediments. *Earth Planet. Sci. Lett.,* 117:567–580.

Mahoney, J.J., Fitton, J.G., Wallace, P.J., et al., 2001. *Proc. ODP, Init. Repts.,* 192 [CD-ROM]. Available from: Ocean Drilling Program, Texas A&M University, College Station, TX 77845-9547 USA.

Morris, J.D., Leeman, W.P., and Tera, F., 1990. The subducted component in island arc lavas: constraints from Be isotopes and B-Be systematics. *Nature,* 344:31–36.

Plank, T., and Langmuir, C.H., 1998. The chemical composition of subducting sediment and its consequences for the crust and mantle. *Chem. Geol.,* 145:325–394.

Ryan, J.G., Morris, J., Tera, F., Leeman, W.P., and Tsvetkov, A., 1995. Cross-arc geochemical variations in the Kurile arc as a function of slab depth. *Science,* 270:625–627.

Sano, T., Fukuoka, T., Hasenaka, T., Yonezawa, C., and Matsue, H., 1999. Accurate and efficient determination of boron content in volcanic rocks by neutron induced prompt gamma-ray analysis. *J. Radioanal. Nucl. Chem.,* 239:613–617.

Sano, T., Hasenaka, T., Shimaoka, A., Yonezawa, C., and Fukuoka, T., 2001. Boron contents of Japan Trench sediments and Iwate basaltic lavas, northeast Japan arc: estimation of sediment-derived fluid contribution in mantle wedge. *Earth Planet. Sci. Lett.,* 186:187–198.

Spivack, A.J., Palmer, M.R., and Edmond, J.M., 1987. The sedimentary cycle of the boron isotopes. *Geochim. Cosmochim. Acta,* 51:1939–1949.

Vengosh, A., Kolodny, Y., Starinsky, A., Chivas, A.R., and McCulloch, M.T., 1991. Coprecipitation and isotopic fractionation of boron in modern biogenic carbonates. *Geochim. Cosmochim. Acta,* 55:2901–2910.

Yonezawa, C., Ruska, P.P., Matsue, H., Magara, M., and Adachi, T., 1999. Determination of boron in Japanese geochemical reference samples by neutron-induced prompt gamma-ray analysis. *J. Radioanal. Nucl. Chem.,* 239:571–576.

You, C.-F., Chan, L.H., Spivack, A.J., and Gieskes, J.M., 1995a. Lithium, boron, and their isotopes in sediments and pore waters of Ocean Drilling Program Site 808, Nankai Trough: implications for fluid expulsion in accretionary prisms. *Geology,* 23:37–40.

You, C-F., Spivack, A.J., Gieskes, J.M., Rosenbauer, R., and Bischoff, J.L., 1995b. Experimental study of boron geochemistry: implications for fluid processes in subduction zones. *Geochim. Cosmochim. Acta,* 59:2435–2442.

Figure F1. Depth profile of B contents and H intensity for Site 1183 and Site 1186 sediments.

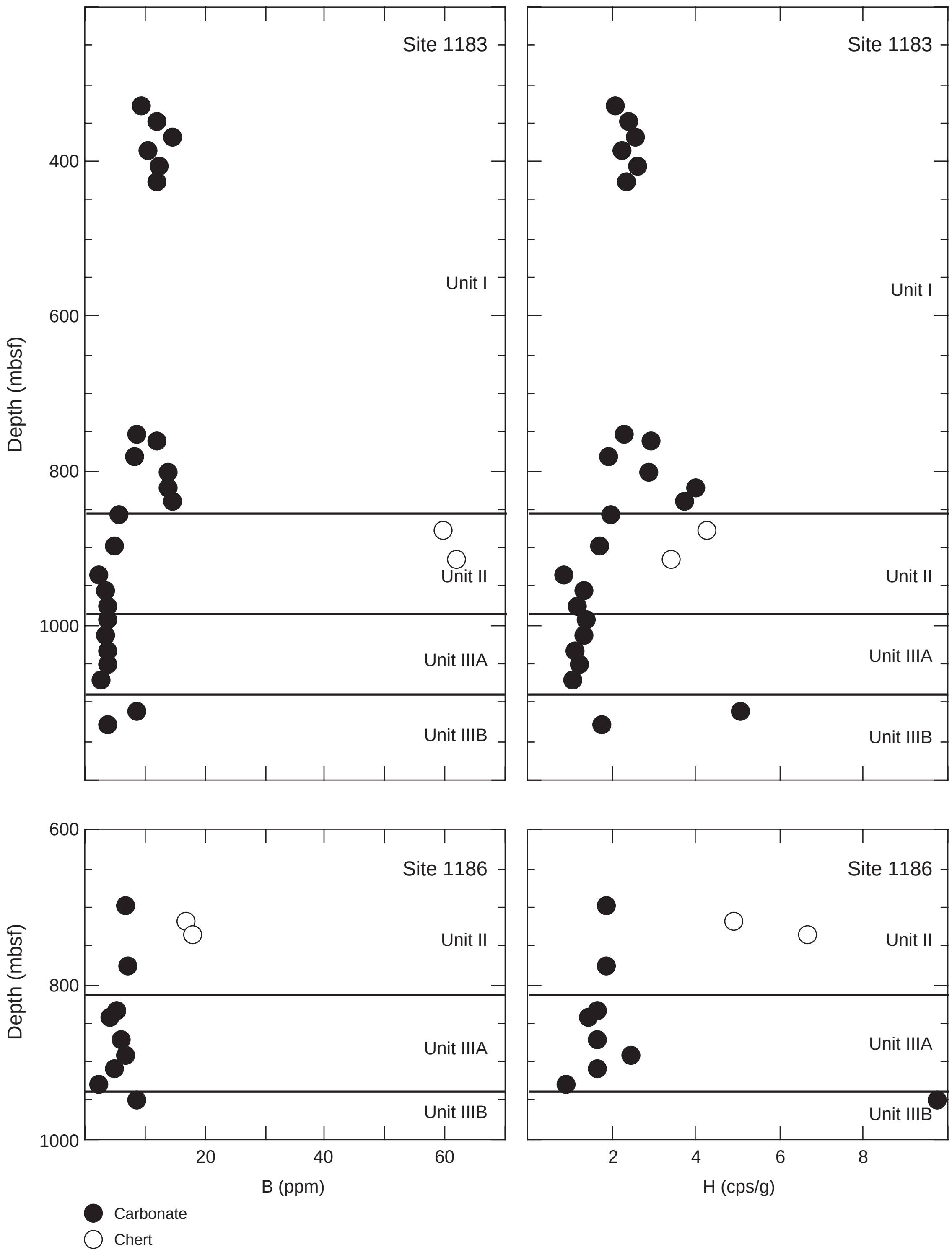

Table T1. Boron and other element contents for Ontong Java Plateau sediments.

Core, section, interval (cm)	Depth (mbsf)	Unit	Sediment type	Mineral	$CaCO_3$ (wt%)	Na_2O (wt%)	B (ppm)	Gd (ppm)
192-1183A-								
2R-1, 21–22	328.2	IA	Ooze	CC	99.8 (3.0)	0.29 (4)	9.2 (3)	0.42 (7)
4R-1, 70–71	347.9	IB	Chalk	CC	95.7 (2.9)	0.64 (6)	12.0 (4)	0.61 (13)
6R-1, 121–123	367.5	IB	Chalk	CC	93.2 (2.9)	0.71 (6)	14.5 (4)	0.47 (18)
8R-1, 20–21	385.7	IB	Chalk	CC	93.5 (1.6)	0.37 (2)	10.6 (2)	0.32 (4)
10R-1, 65–66	405.4	IB	Chalk	CC	92.3 (1.6)	0.61 (3)	12.1 (3)	0.59 (5)
12R-1, 125–126	425.2	IB	Chalk	CC	92.8 (2.9)	0.51 (5)	11.8 (4)	0.74 (11)
15R-1, 59–61	752.6	IB	Chalk	CC	93.5 (2.9)	0.39 (5)	8.5 (3)	0.46 (16)
16R-1, 79–81	761.9	IB	Chalk	CC	97.4 (2.9)	0.30 (4)	11.9 (3)	0.61 (10)
18R-1, 70–71	781.2	IB	Chalk	CC	94.8 (1.6)	0.37 (2)	8.3 (2)	0.40 (4)
20R-1, 49–50	800.2	IB	Chalk	CC	92.3 (2.7)	0.42 (5)	13.8 (4)	0.62 (11)
22R-1, 146–148	820.5	IB	Chalk	CC	90.3 (1.6)	0.55 (3)	13.6 (3)	0.79 (5)
24R-1, 66–67	838.9	II	Limestone	CC	93.3 (1.8)	0.60 (3)	14.6 (3)	1.88 (6)
26R-CC, 17–18	857.2	II	Limestone	CC	99.2 (3.0)	0.32 (5)	5.6 (3)	0.72 (11)
28R-CC, 4–5	876.2	IIA	Chert	CC, Q	14.3 (0.4)	0.24 (2)	59.7 (9)	1.43 (5)
30R-1, 3–4	895.5	II	Limestone	CC	43.5 (0.9)	0.30 (2)	4.7 (2)	0.96 (5)
32R-1, 36–37	915.1	IIA	Chert	Q			61.7 (1.0)	0.74 (6)
34R-1, 63–65	934.5	II	Limestone	CC	91.2 (2.7)		2.2 (1)	0.86 (6)
36R-1, 39–40	953.5	II	Limestone	CC	100.5 (2.9)	0.17 (3)	3.3 (2)	1.08 (6)
38R-1, 100–102	974.9	II	Limestone	CC	95.1 (2.9)	0.13 (3)	3.8 (2)	0.66 (8)
40R-1, 26–27	993.4	IIIA	Limestone	CC	101.0 (1.8)	0.25 (2)	3.8 (1)	1.43 (4)
42R-1, 54–55	1013.1	IIIA	Limestone	CC	102.3 (3.0)	0.95 (4)	3.6 (2)	1.88 (5)
44R-1, 27–28	1031.6	IIIA	Limestone	CC	98.2 (2.9)	0.27 (4)	3.6 (2)	2.23 (4)
46R-1, 30–31	1049.9	IIIA	Limestone	CC	96.9 (2.9)	0.44 (5)	3.9 (2)	3.28 (4)
48R-1, 46–48	1069.3	IIIA	Limestone	CC	97.4 (1.8)	0.36 (3)	2.5 (1)	3.38 (2)
50R-1, 113–114	1089.3	IIIB	claystone	CC, Q, ill	21.1 (0.9)	9.06 (27)	90.6 (1.8)	67.1 (2)
52R-2, 29–30	1109.3	IIIB	Limestone	CC	89.1 (2.7)	0.74 (5)	8.5 (3)	5.67 (3)
54R-1, 13–14	1126.9	IIIB	Limestone	CC	98.5 (2.9)	0.28 (4)	3.8 (2)	3.47 (3)
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2R-1, 13–15	697.5	II	Limestone	CC	98.3 (1.2)	0.61 (3)	6.6 (2)	1.27 (7)
4R-1, 55–57	717.1	IIA	Chert	CC, Q	67.6 (0.9)	0.54 (3)	16.7 (3)	4.39 (9)
6R-CC, 5–6	735.8	IIA	Chert	CC, Q	38.7 (0.7)	0.30 (2)	17.9 (3)	2.11 (7)
10R-1, 29–30	774.5	II	Limestone	CC	97.8 (1.2)	0.64 (3)	7.0 (2)	1.28 (7)
16R-1, 21–23	832.2	IIIA	Chalk	CC	98.5 (1.2)	0.64 (3)	5.2 (2)	2.03 (4)
17R-1, 112–113	842.1	IIIA	Chalk	CC	99.0 (1.2)	0.51 (3)	4.0 (1)	2.09 (4)
20R-1, 26–27	870.5	IIIA	Chalk	CC	99.2 (1.2)	0.68 (3)	6.1 (2)	3.53 (3)
22R-1, 24–25	889.7	IIIA	Chalk	CC	95.8 (1.2)	0.69 (3)	6.7 (2)	4.90 (2)
24R-1, 12–13	908.8	IIIA	Chalk	CC	98.3 (1.2)	0.73 (3)	4.7 (2)	4.71 (2)
26R-1, 24–25	928.2	IIIA	Chalk	CC	100.5 (1.2)	0.44 (3)	2.1 (1)	3.46 (2)
28R-2, 123–124	949.9	IIIB	Limestone	CC	84.1 (1.1)	1.05 (4)	8.5 (2)	5.21 (2)

Notes: Unit names are from Mahoney, Fitton, Wallace, et al., 2001: IA = ooze, IB = chalk, II = limestone, IIA = chert, IIIA = white limestone, IIIB = mottled gray and pinkish white limestone. CC = calcite, Q = quartz and/or opal, ill = illite. Mineral determinations are from Mahoney, Fitton, Wallace, et al., 2001. Numbers in parentheses adjacent to the analyses are one standard deviation; for example, 99.8 (3.0) = 99.8 ± 3.0 wt% and 0.29 (4) = 0.29 ± 0.04 wt%.