Bulletin of the Geological Survey of Japan, vol. 64 (1/2), p. 51 - 57, 2013

Article

Distribution of some ore metals around the Mau Due stibnite deposits, northernmost Vietnam

Shunso Ishihara[1, *] and Pham Tich Xuan[2]

Shunso Ishihara and Pham Tich Xuan (2013) Distribution of some ore metals around the Mau Due stibnite deposits, northernmost Vietnam. *Bull. Geol. Surv. Japan*, vol. 64 (1/2), p. 51-57, 4 figures, 3 tables.

Abstract: Soil and stream sediments were studied geochemically around the Mau Due ore deposits of the northernmost Vietnam. The ore deposits are fracture-filling type occurring in Devonian sediments composed mainly of impure calcareous sediments. The chemical elements brought up by the mineralizations are mainly S and Sb, and small amount of As and base metal. The analyzed surface samples were collected in the wet season (May to September) and the dry season (October to April).

Sb contents of surface materials are sporadically high in the soil samples, and have smaller variation in the stream sediments than in the soil samples. Sb contents of the soil of the wet season, 932 ppm Sb in the average, are higher than the average of 342 ppm Sb of the dry season. The Sb contents are much higher in the stream sediments, averaged as 2,536 ppm in the wet season and 2,504 ppm in the dry season.

Generally speaking, As contents of the soil are positively correlated with Sb contents, but the amounts are much lower than the Sb contents, averaged as 29 and 26 ppm in soil of the wet and dry seasons, respectively, but higher as 68 and 67 ppm in the stream sediments. These abundance data of Sb and As are best explained by both elements are present finest grained sulfides in the soil and river sediments. The Devonian host rocks may be originally high in the Sb contents, as compared with the Japanese eugeosynclinal sediments.

Keywords: Mau Due mine, stibnite, heavy metals, pollution, Vietnam

1. Introduction

Antimony is concentrated in many hydrothermal ore deposits of simple stibnite type and complex sulfide-sulphosalts type, and its production is heavily dependent upon the stibnite type in sedimentary terrain in the Xikuangshan area, Hunan province of China, which produces 83-90 % of the world production in the past five years (Ishihara and Ohno, 2011). The element is considered as a good geochemical marker for antimony ore deposits, particularly of the sulfide-sulphosalt type (Boyle and Jonasson, 1984).

Soils and stream sediments around given antimony ore deposit have been polluted by the ore metals, especially of antimony and arsenic (Flynn *et al.*, 2003; Murciego *et al.*, 2007).

In one case of mesothermal antimony deposits, the stibnite can contain up to 5,000 ppm As. Together with common occurrence of arsenopyrite and arsenian pyrite, dissolution of these minerals causes strong contamination of antimony and arsenic into the soil, stream sediments and plants of the antimony mining area (Ashley *et al.*, 2003; Murciego *et al.*, 2007).

In the largest mineralized area of the Hunan province, Wang *et al.* (2010) examined 10 heavy metals (Sb, As, Cd, Cr, Cu, Hg, Mn, Ni, Pb and Zn) of the surrounding agriculture soils in the mining region, and found that the strongest contamination on Sb (236 times), Cd (52 times), Hg (14 times), and As (3.1 times), Zn (2.9 times) and Pb (2.5 times), in which cadmium concentration is rather unusual.

In this paper, reconnaissance geochemical work has been done around the Mau Due stibnite mine area. This mine is located at a part of mountainous region, 300 to 1,000 m above sea level, in the northernmost part of Vietnam (N23°04′24″, E105°15′10″, Fig. 1), and are very close to the In-bearing Sn-Pb-Zn deposits of Du Long mine, China (Ishihara *et al.*, 2011). The Mae Due mine area is composed of two distinct seasons; wet and hot summer, and dry and cool winter. Average rainfall is 1200 to 1800 mm in a year, in which majority (73-81%) falls in the rainy season of May to September.

[1]AIST, Geological Survey of Japan

[2]Institute of Geological Sciences, Vietnamese Academy of Science and Technology, Hanoi, Vietnam.

*Corresponding author: S. ISHIHARA, Central 7, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan. Email: s-ishihara@aist.go.jp

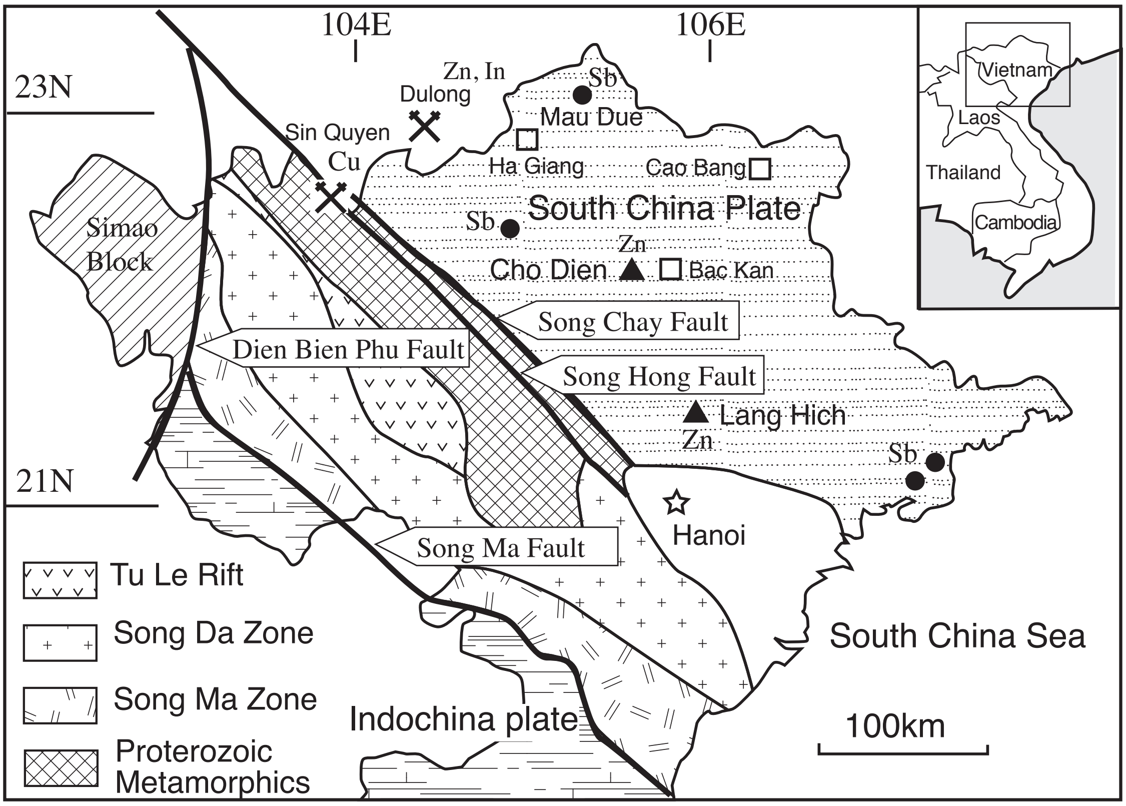

Fig. 1 Index map for the Mau Due mine occurring in the sedimentary terrain of the South China plate.

2. Geological background

Northeastern side of the Red River Fault in the northern Vietnam is essentially Paleozoic-Mesozoic sedimentary terrain intruded by Mesozoic granitoids. Small fracture filling-type antimony deposits are known at Lang Vai mine of the central part (500 tons Sb metal, 1986-1992), and Khe Chim, Duong Huy, and Dong Mo localities. In the northernmost part of Ha Giang province, an open pit mining was initiated in 1993 and is called Mau Due mine. A refinery was set up in 2002, and the mine produces annually 100 tons Sb metal since then.

This mine area is underlain by the Devonian Na Quan Formation (D1-2nq) of about 500 m thick, consisting of limestone alternated with carbonaceous shale and black shales (Tran Xuyen, 2001). The limestone is usually dolomitized. Other Devonian strata of the Toc Tat Formation (D3tt) comprise fine-layered silicic limestone alternated with silicic shale, shale, and carbonaceous shale. The thickness is about 300 m.

The Song Hien Formation (T1sh) is most widely distributed in the mine area. It is composed of sandstone, black shale and sericitic shale. The thickness is about 300 m. Quaternary sediments (Q) are distributed along the Nam Tam river, and are composed of pebbles, sand and clay.

3. Mineralization at Mae Due mine

Devonian sediments of the Na Quan Formation (D1-2nq) which have been folded with NNE-SSW axes and cut by the same NNE-SSW faults, host the stibnite deposits. The stibnite mineralizations are seen along the NNE-SSW structures, and are divided into three orebodies as I, II and III from the west to east.

The orebody I is 350 m long with the width of 3.7 m and dip of 70°W, and average grade of 10.3 % Sb. The orebody II is 410 m long, 10.1 m wide dipping 40-70° west. The average grade is 11.2 % Sb. The orebody III is 200 m long, 4.1 m wide, dipping 70° east. The average grade is 13.6 % Sb. These orebodies are mostly composed of quartz (20-70 %) and small amounts of calcite. The ore minerals are stibnite, and very small amounts of pyrite, arsenopyrite, sphalerite and berthierite. At the top of the orebodies, such secondary minerals as valetinite and lewisite may occur together with limonite.

Some ore components are analyzed for total carbon and sulfur by infrared method, and Fe, Sb, As, Se, Mo, Cu, Pb, Zn, Cd, Bi, Mn, Co, and Ni by ICP-MS methods on the ores and wastes of the Mau Due mine, and the results are listed in Table 1. The antimony ores only dominant in Sb, S, and Se, while other ore elements such As, Cu, Pb, Zn, Ni, Co, and Mo are rich in the wastes, implying that these elements are marginal

Table 1 Selected ore components of the ores and wastes of the Mau Due mine.

No.	Sample no. & samples	Al	Fe	Total S	Total C	Sb	As	Se	Mo	Cu	Pb	Zn	Cd	Bi	Co	Ni	Mn
	Detection limit	0.01%	0.01%	0.01%	0.01%	0.1	0.1	0.1	0.1	0.2	0.5	0.2	0.1	0.02	0.1	0.5	1
102	MD2-Q1, Sb ore, dry	0.44	0.02	28.00	0.65	176,000	17.5	153	1.5	3.9	< 0.5	4.2	0.7	0.09	< 0.1	0.8	3
103	MD2-Q2. Sb ore, dry	1.11	0.05	23,70	0.25	154,000	16.8	115	< 0.1	2.8	< 0.5	4.1	0.8	0.1	< 0.1	0.5	5
	Average(n=2)	0.78	0.04	25.85	0.45	165,000	17.2	134	0.8	3.4	<0.5	4.2	0.8	0.1	<0.1	0.7	4
104	MD2-BT1, waste, dry	>10	5.45	2.03	2.44	232	73.3	9.2	9.7	96.1	40.4	321	2.2	0.75	21.1	99.4	873
105	MD2-BT2, waste, dry	6.03	2.86	0.04	0.08	47.2	20.1	1.9	1.7	54.9	35.3	77.5	0.5	0.41	24.9	41.9	992
106	MD2-BT3, waste, dry	8.16	9.17	1.32	19.6	1200	18.8	4.7	24.4	118.0	7.3	33.4	< 0.1	0.07	45	123	421
107	MD2-BT4, waste, dry	6.09	10.6	1.37	12.9	13500	4.7	4.8	2.4	123.0	11.2	54.7	0.2	0.2	59.4	185	317
99	MD-BT6, waste, wet	7.44	3.68	0.04	2.58	43.7	22.1	2.5	4.0	60.1	28.6	125	0.2	0.52	9.4	35.4	299
101	MD-BT7, waste, wet	6.69	4.21	0.03	1.09	7.1	32.9	3.9	5.4	62.0	26.0	73.1	< 0.1	0.6	3.6	26.8	167
100	MD-BT8, waste, wet	6.19	3.19	0.37	1.39	148	46.5	6.3	6.2	45.6	21.5	80.5	0.3	0.41	4.3	37.7	303
	Average(n=7)	7.23	5.6	0.74	5.73	2,168	31.2	4.8	7.7	80.0	24.3	109	0.5	0.42	24	78.5	482

* Analytical unit is ppm, unless otherwise noted.

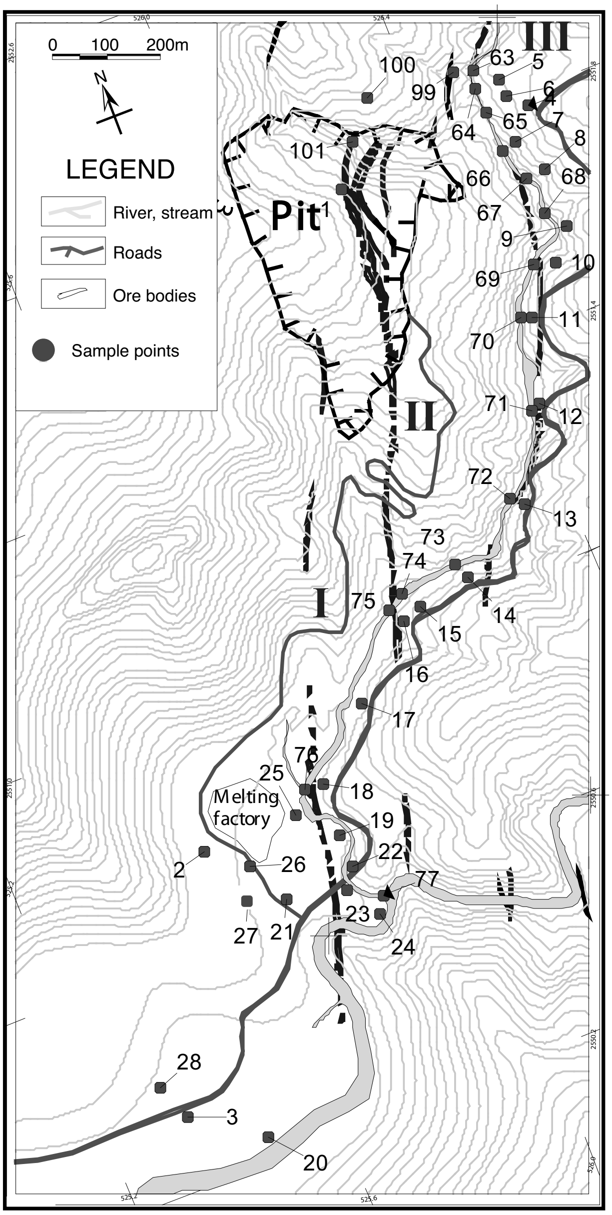

Fig. 2 Locality map of soils and stream sediments in the wet season.

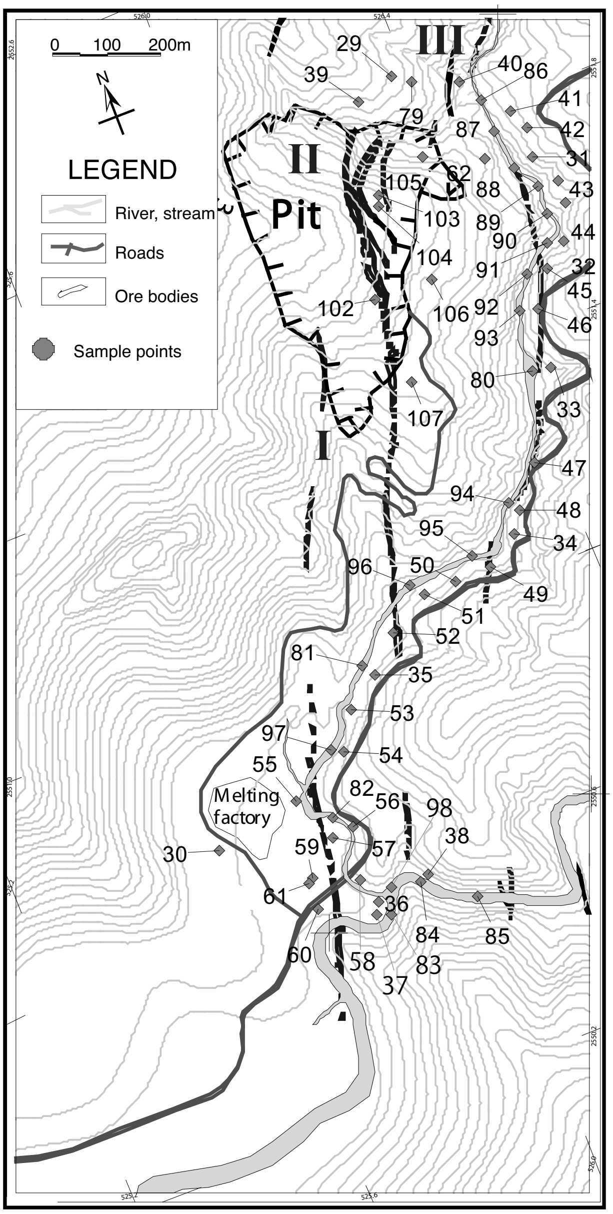

Fig. 3 Locality map of soils and stream sediments in the dry season.

Table 2 Selected ore components of the soil samples of the wet and dry seasons.

Sample no		Ai	Fe	Sb	As	Se	Mo	Cu	Pb	Zn	Cd	Bi	Co	Ni	Mn
1	MD-D1 wet	>10	3.69	2700	31.7	2.3	3.8	42.9	34.6	63.5	0.2	0.6	3.2	24.9	96
2	MD-D4	>10	6.44	49	61.7	2.9	4.1	71.8	94.9	224	0.5	1.0	30.8	77.5	3160
3	MD-D5	6.66	3.37	28	32.1	1.3	4.1	60.6	43.2	225	0.5	0.6	15.7	49.1	2000
4	MD-D6	8.29	3.73	19	24.3	2.6	3.4	53.4	25.4	136	0.1	0.5	3.3	27.5	266
5	MD-D7	2.91	2.60	393	21.5	2.1	3.6	34.2	27.5	67	0.2	0.4	4.0	21.8	188
6	MD-D8	4.59	3.55	10	17.2	1.9	3.5	48.9	27.1	84.8	0.1	0.4	12.0	30.7	488
7	MD-D9	9.40	4.71	13	17.8	2.9	5.2	75.2	35.0	123	0.2	0.6	20.9	38.1	936
8	MD-D10	>10	4.92	100	24.1	3.6	6.3	104	34.6	201	0.2	0.7	26.7	55.5	2560
9	MD-D11	8.23	4.22	7300	13.8	3.4	1.2	72.1	37.2	148	0.5	0.6	20.9	44.1	1590
10	MD-D12	7.50	3.79	1100	22.0	3.5	3.6	58.8	37.3	113	0.4	0.5	28.3	44.6	1340
11	MD-D13	7.18	3.47	5500	23.0	4.1	1.8	89.5	34.9	159	1.2	0.5	26.9	70.5	1350
12	MD-D14	0.07	4.57	90	21.0	2.9	6.0	101	33.1	147	0.2	0.6	23.3	48.6	2060
13	MD-D15	8.38	4.10	7600	11.7	2.2	1.0	71	33.2	105	0.3	0.5	24.2	44.7	1130
14	MD-D16	3.15	2.52	50	11.1	3.6	5.5	87.3	31.9	115	0.4	0.4	26.4	54.0	1360
15	MD-D17	6.90	4.48	261	30.5	9.0	9.1	103	31.2	114	0.3	0.5	33.2	44.3	1130
16	MD-D18	7.51	3.51	41	47.3	2.3	21.0	74.7	31.2	132	0.3	0.5	13.8	79.7	331
17	MD-D19	>10	3.74	3	9.3	2.8	3.2	74.7	28.6	64.7	0.2	0.6	22.9	55.1	457
18	MD-D20	8.12	3.97	80	29.8	2.8	2.2	54.9	54.6	335	3.0	0.6	45.2	106.0	2240
19	MD-D21	>10	4.26	45	34.7	2.0	2.5	50.9	44.5	123	0.3	0.6	20.0	37.9	921
20	MD-D22	6.54	3.03	1	6.8	1.5	< 0.1	46	28.8	121	0.4	0.4	15.7	43.8	677
21	MD-D23	>10	6.67	33	49.5	1.6	2.1	76.5	69.5	211	0.4	0.9	23.5	65.6	1240
22	MD-D24	>10	7.28	9	80.1	2.4	6.6	73.9	68.7	231	0.9	1.0	30.8	103.0	3670
23	MD-D25	7.70	4.06	6	24.6	2.1	3.2	58	35.2	148	0.3	0.5	22.8	56.2	908
24	MD-D26	2.87	2.76	19	10.2	1.6	2.3	41.3	23.0	105	0.4	0.3	14.1	44.3	790
25	MD-D27	6.67	3.52	26	23.5	2.0	1.7	43.6	47.3	183	1.3	0.6	22.9	67.7	1200
26	MD-D28	8.18	4.20	239	28.6	1.9	1.2	50.1	73.8	175	0.5	0.7	19.9	47.0	1550
27	MD-D29	>10	5.55	81	45.3	1.8	4.4	62.4	87.6	192	0.3	0.9	27.1	60.3	2350
28	MD-D30	> 10	5.26	46	59.9	1.5	6.7	58.5	52.1	216	0.2	0.8	21.2	46.0	2060
	Average	>7.53	4.21	923	29.0	2.7	4.3	65.7	43.1	152	0.5	2.5	21.4	53.3	1359
29	MD2-D1, dry	4.15	4.35	24	32.7	3.8	7.0	68.2	26.2	86.6	< 0.1	0.7	4.0	29.1	187
39	MD2-D2	8.01	3.59	113	47.1	3.4	7.1	52	30.2	60.5	0.1	0.8	2.2	21.8	127
30	MD2-D3	>10	6.02	22	31.9	1.6	1.8	73.9	82.0	201	0.2	0.9	27.3	61.0	2300
40	MD2-D4	7.35	3.17	44	21.8	2.6	4.7	56.1	32.1	99.9	0.3	0.5	3.9	27.3	128
41	MD2-D5	>10	4.07	12	25.1	3.9	7.6	53.7	38.3	86.1	< 0.1	0.6	16.0	34.3	439
42	MD2-D6	>10	5.24	10	23.3	3.0	6.3	76.2	34.0	109	0.3	0.6	39.1	49.4	1080
31	MD2-D7	>10	3.27	15	16.2	2.3	6.7	46.7	49.9	113	0.2	0.6	26.2	38.1	780
43	MD2-D8	2.46	3.58	147	15.5	2.0	4.2	89.9	34.4	166	0.4	0.5	29.1	44.9	2370
44	MD2-D9	6.84	4.49	469	15.3	3.5	3.5	82	37.6	125	0.2	0.6	38.7	37.7	2340
32	MD2-D10	8.18	5.04	3300	24.3	3.3	4.3	84.2	37.2	133	0.3	0.6	20.8	44.1	989
45	MD2-D11	7.79	3.68	4700	17.5	2.8	2.8	66.6	32.1	118	0.5	0.5	18.1	51.5	692
46	MD2-D12	>10	4.34	200	35.8	1.6	4.0	36.3	56.0	139	0.5	0.7	18.4	46.9	1720
33	MD2-D13	7.46	4.59	61	23.9	2.9	1.2	67.6	36.2	190	0.5	0.6	24.9	58.3	1610
47	MD2-D14	8.26	3.70	23	18.5	3.5	6.6	70	33.8	88.4	0.3	0.6	15.1	43.2	1050
48	MD2-D15	>10	4.94	187	18.4	4.4	9.1	136	50.2	269	1.7	0.7	67.9	169.0	4010
34	MD2-D16	8.09	3.29	85	16.4	5.8	5.1	84.4	32.6	140	0.6	0.8	26.2	60.6	1650
49	MD2-D17	9.78	5.61	19	18.7	2.2	3.9	62.6	25.6	86.7	< 0.1	0.6	4.9	36.0	185
50	MD2-D18	5.96	4.12	15	13.6	2.0	4.3	57.9	30.7	58.6	< 0.1	0.5	5.9	37.8	161
51	MD2-D19	4.11	2.78	33	47.8	2.1	7.2	78.1	32.3	145	0.5	0.5	21.3	68.0	1680
52	MD2-D20	6.89	3.19	89	42.8	2.1	15.1	69.5	31.2	141	0.3	0.5	19.3	68.2	867
35	MD2-D21	6.58	3.58	13	48.7	2.2	16.3	93.5	32.4	162	0.5	0.6	18.2	41.8	871
53	MD2-D22	8.19	3.77	96	32.3	3.8	1.7	87.2	41.4	213	2.2	0.8	24.7	76.7	1470
54	MD2-D23	6.36	3.06	29	19.9	1.2	4.7	38.6	33.4	82.8	0.4	0.3	18.4	48.0	1820
55	MD2-D24	>10	3.84	65	18.4	3.9	8.2	66.7	42.5	109	0.2	0.8	24.6	45.7	1580
56	MD2-D25	8.27	4.53	42	22.9	2.2	4.2	54	33.4	123	0.3	0.5	27.0	43.9	1020
57	MD2-D26	7.78	3.59	132	25.7	2.2	1.3	50.9	41.6	139	0.7	0.5	17.8	48.1	1130
58	MD2-D27	7.72	3.77	27	17.2	2.0	5.6	42.1	38.5	115	0.2	0.5	11.4	30.4	452
36	MD2-D28	6.00	2.94	17	13.3	1.7	1.1	40.1	34.6	106	0.5	0.4	15.5	41.7	1290
37	MD2-D29	2.78	3.21	27	13.6	1.3	2.8	51.1	25.7	105	0.4	0.4	18.2	45.8	1560
38	MD2-D30	6.78	3.45	35	23.3	2.1	3.2	54.8	37.6	158	0.5	0.5	19.6	45.6	1340
61	MD3-D8	6.03	20.20	1200	55.0	17.2	10.7	110	25.4	1360	3.0	0.2	30.1	121.0	873
59	MD3-D11	7.10	2.94	22	14.7	1.6	1.7	45.8	69.4	177	0.8	0.6	22.9	58.3	1080
62	MD3-D14	6.60	3.36	4	12.6	1.7	1.7	47.5	75.7	133	0.5	0.5	16.1	42.3	711
	Average	>7.44	4.40	342	25.0	3.1	5.3	66.5	39.2	168	0.5	0.6	21.0	52.0	1199

Table 3 Selected ore components of the stream sediment samples of the wet and dry seasons.

Sample Nos.	Al	Fe	Sb	As	Se	Mo	Cu	Pb	Zn	Cd	Bi	Co	Ni	Mn
63 MD-TT1, wet	9.27	4.52	13	33.9	2.4	4.1	81	28.8	146	0.2	0.5	20.9	55.3	690
64 MD-TT4	>10.0	4.37	344	69.2	7.0	4.9	133	61.3	466	3.2	0.6	33.7	154.0	1740
65 MD-TT5	8.29	4.22	336	77.1	6.3	5.5	102	54.6	340	2.3	0.5	22.0	117.0	1330
66 MD-TT6	9.03	4.53	4000	86.2	7.6	10.7	92.7	44.2	264	2.2	0.5	31.3	129.0	1860
67 MD-TT7	9.20	4.42	4200	88.0	9.9	16.6	101	45.8	252	2.1	0.5	19.8	108.0	1100
68 MD-TT8	6.24	3.87	3400	73.6	6.4	7.2	105	47.9	322	2.3	0.5	28.2	123.0	1500
69 MD-TT9	7.68	4.22	3700	76.3	7.7	11.7	100	38.4	331	2.3	0.4	27.4	126.0	1420
70 MD-TT10	9.86	4.25	3700	76.0	6.5	12.8	98	53.0	274	2.2	0.5	27.6	120.0	1810
71 MD-TT11	8.52	4.22	4100	70.2	6.8	9.5	101	43.1	282	2.3	0.5	27.7	121.0	1520
72 MD-TT12	9.20	4.22	3800	68.8	6.4	7.0	105	50.1	343	2.2	0.5	27.7	126.0	1640
73 MD-TT13	9.40	4.39	3300	76.3	6.2	12.4	114	51.7	411	2.0	0.6	30.9	129.0	1370
74 MD-TT14	9.21	4.39	3200	70.3	7.3	11.7	119	56.0	460	2.7	0.6	35.0	157.0	1640
75 MD-TT15	>10.0	4.53	3400	73.8	6.1	11.8	98.3	47.7	261	1.6	0.6	25.6	107.0	1520
76 MD-TT16	9.37	4.34	215	21.6	5.4	0.3	68.6	78.4	214	1.6	0.7	27.6	78.6	2360
77 MD-TT17	6.29	3.92	337	60.7	6.3	5.3	91.4	35.2	324	2.9	0.5	35.9	138.0	1300
Average	>8.58	4.29	2536	68.1	6.6	8.8	100.7	49.1	313	2.1	0.5	28.1	119.0	1520
78 MD2-TT1, dry	1.90	4.62	456	91.6	7.3	8.6	66.4	33.4	92.1	0.4	0.6	4.0	44.3	250
85 MD2-TT2	7.53	5.71	1800	74.3	4.2	22.4	155	63.2	537	2.2	0.6	38.3	153.0	1960
86 MD2-TT3	7.34	4.25	11900	90.6	10.6	7.6	95.1	48.4	221	2.4	0.7	18.8	97.7	1060
87 MD2-TT4	8.76	6.83	2000	70.0	6.9	19.9	86.5	48.4	232	1.0	0.5	18.3	93.6	1070
88 MD2-TT5	7.86	5.13	2500	71.8	5.5	19.6	91.1	54.7	219	1.4	0.5	22.2	91.9	1350
89 MD2-TT6	8.03	6.30	2600	76.8	6.3	16.8	65.4	46.4	200	1.0	0.6	14.8	74.1	854
90 MD2-TT7	7.78	4.59	3500	78.4	6.7	17.3	86	112.0	208	1.4	0.5	26.1	102.0	1500
91 MD2-TT8	8.41	6.44	2600	72.4	6.8	16.6	78.3	44.7	240	1.3	0.5	19.8	92.5	1180
92 MD2-TT9	6.89	4.15	3300	71.1	6.0	12.7	95.4	50.3	205	1.4	0.5	21.7	101.0	1220
79 MD2-TT10	9.95	4.93	2600	84.0	5.9	22.3	127	76.0	287	1.4	0.7	25.3	128.0	1890
93 MD2-TT11	2.61	3.41	3300	75.6	4.9	19.5	85.4	55.8	217	1.3	0.4	22.2	88.4	792
94 MD2-TT12	4.15	3.92	3500	76.1	5.8	13.0	81	39.2	234	1.9	0.5	28.0	104.0	1320
95 MD2-TT13	9.80	4.99	2800	81.9	5.7	25.6	112	70.1	271	1.1	0.7	22.0	112.0	1800
90 MD2-TT14	8.94	9.56	2300	72.8	7.2	17.5	103	48.8	536	1.5	0.6	41.7	138.0	1050
96 MD2-TT15	7.52	4.26	2600	74.7	5.7	19.8	109	53.2	308	1.8	0.5	33.2	125.0	1700
81 MD2-TT16	7.28	6.23	2300	64.4	5.3	10.7	93.2	47.6	738	3.2	0.5	52.7	142.0	1440
97 MD2-TT17	8.25	7.40	2200	65.3	6.6	12.7	95.2	48.7	979	4.4	0.5	95.6	214.0	2020
82 MD2-TT18	4.16	2.08	16.4	13.5	0.9	0.7	22.1	23.5	64.1	0.2	0.3	9.6	23.9	682
83 MD2-TT19	6.01	2.75	135	21.3	1.7	2.7	35.5	31.1	145	0.7	0.4	16.8	41.7	774
84 MD2-TT20	4.68	2.44	78.9	16.3	1.7	2.1	33.9	24.0	159	0.7	0.3	19.0	47.6	622
98 MD3-B6 (MD3-TT6	2.23	3.60	94.9	59.4	6.4	12.3	88.5	28.2	552	4.3	0.5	24.4	161.0	921
Average	6.67	4.93	2504	66.8	5.6	14.3	85.9	49.9	316	1.7	0.5	27.4	103.6	1212

* Analytical unit and detection limits are the same as those in Table 1.

to the main antimony mineralization. Another characteristic is very low Al contents and high stibnite components, implying all the feldspars of the original rocks were replaced by stibnite. The mineralized fluids must have been strongly enriched in sulfur and antimony.

4. Ore components in soil and stream sediments

Localities of the studied samples are shown in Figs. 2 (wet season) and 3 (dry season). Chemical analyses of the soil and stream sediments were listed in Tables 2 and 3. Stream sediments of Table 3 are listed from the upper stream side to the down stream side. Therefore, the contents increase to the orebody site, then decrease downward.

The stream sediments have smaller variation than the soils in the contents, which is largely due to homogenization in the water relative to the soil samples, as best shown by Sb contents. The samples were also grouped into those taken in the wet season of May to September and the dry season of October to April. Compared with the average values of the two seasons, antimony seems to be predominant in the wet-season soil samples (932 ppm vs. 342 ppm). On the other hand, molybdenum is definitely higher in the stream sediments of the dry season (14.3 ppm vs. 8.8 ppm Mo).

Antimony of the soil is sporadically high due to mixing of high-grade ores, but the high values are lowered in the stream sediments (Fig. 4A), which is considered resulted from mechanical mixing of other rocks during sedimentation. Arsenic has a positive correlation with antimony in general, implying both the elements were essentially derived from the mineralized rocks as sulfides. However, the amounts are higher as 67 ppm As (average) in the stream sediments, than the soil of 27 ppm As (average), thus arsenic is considered concentrated as finest grained arsenopyrite in the stream sediments.

Sporadic high values are found in the soils of the wet season and also the stream sediments of the wet season.

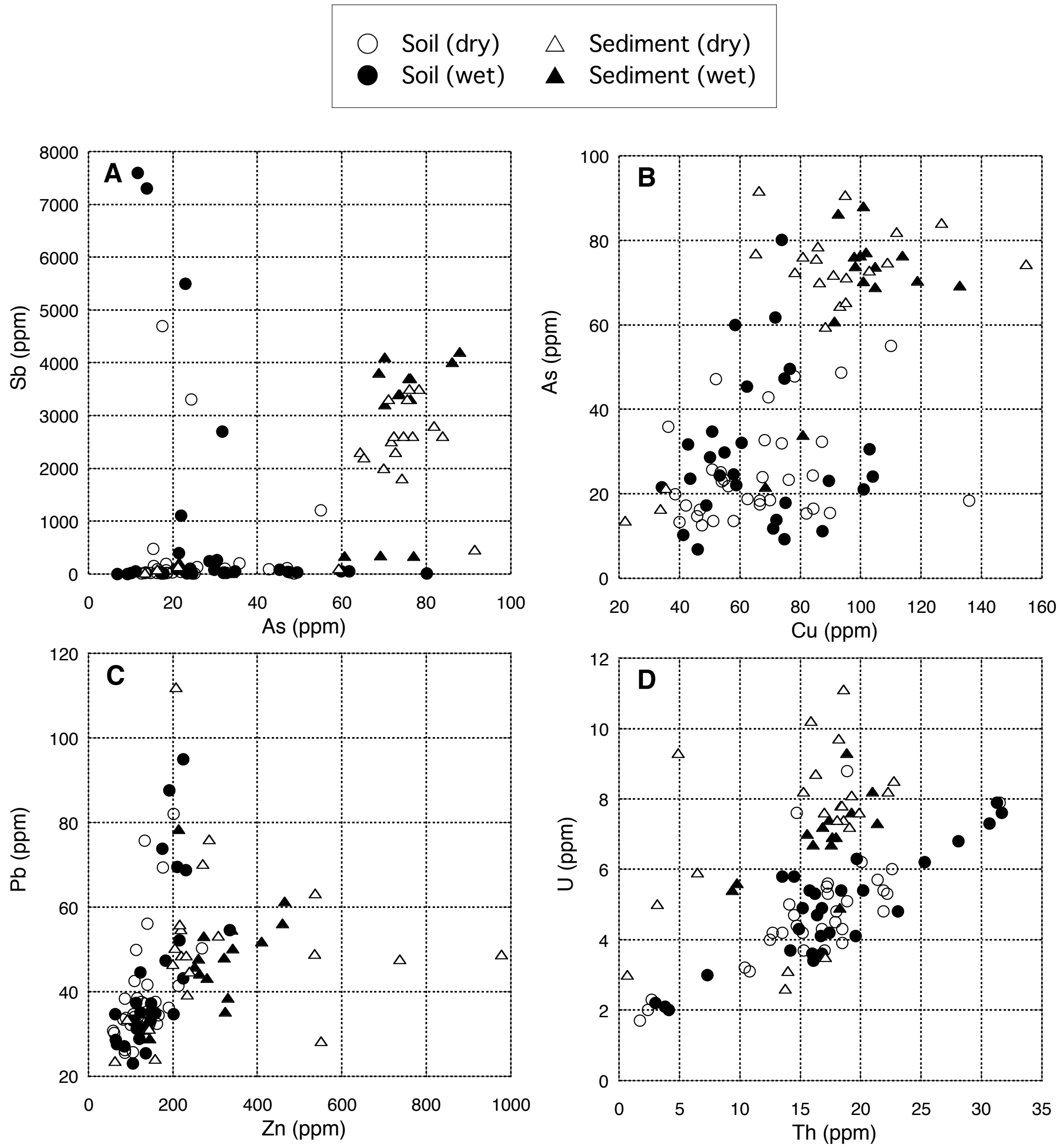

Fig. 4 Variation diagrams of the selected ore components.

A positive correlation of antimony and arsenic of the sediments is unclear on the soil samples (Fig. 4A). Arsenic and copper have broadly positive correlation (Fig. 4B), and stream sediments show higher values in both the elements relative to the soil samples. Lead of the soil samples have a narrow range between 20 and 100 ppm, but zinc contents are scattered especially on those of dry season (Fig. 4C). Thorium and uranium show unique variations. Thorium of wet and dry seasons soils have a good positive variations with uranium. Uranium of sediments is, however, enriched, especially on those of dry season (Fig. 4D), indicating secondary concentration in the element.

5. Geochemical setting of Sb-mineralized terrain in Japan

Antimony deposits in Japan are best concentrated in sedimentary terrains of the Outer Zone of Southwest Japan. They are quartz vein or fracture-filling types with simple ore mineralogy of stibnite with quartz. This kind of ore deposits are best concentrated in western Shikoku, where the famous Ichinokawa deposits are located (Ishihara, 2012). The antimony deposits occur in the Sanbagawa metamorphic belt and southward of the Shimanto sedimentary terrains. Antimony contents of these metamorphic and sedimentary rocks were examined by the same analytical method as of the Mae Due samples, and found to have the following range and average values of antimony:

Sanbagawa metamorphic rocks (n=3): 0.2~0.9 ppm. Average 0.5 ppm Sb.

Chichibu-Sanbosan, Sandstone (n=4): <0.1~2.9 ppm. Average 0.9 ppm Sb,
Shale (n=6): <0.1~5.4 ppm. Average 1.0 ppm Sb.

Shimanto Belt, North, Sandstone (n=2): <0.1~2.2 ppm. Average 1.1 ppm Sb,
Shale (n=7):<0.1~5.2 ppm. Average 1.2 ppm Sb.

Shimanto Belts, South, Sandstone (n=6): <0.1~1.6 ppm. Average 0.6 ppm Sb,
Shale (n=6): <0.1~2.6. Average 0.9 ppm Sb.

The same set of sedimentary rocks is not available in the Mau Due mine area. But the soils of nos. 4, 6, 7 and 8 are located in un-mineralized area at northeastern side of vein III, and they have the range of 10 to 100 ppm Sb and average of 36 ppm Sb (n=4). Thus, Devonian sediments of north Vietnam, which are supposed to be continental in origin, appear to be one or two order of magnitude higher in trace amounts of antimony than eugeosynclinal sediments of western Shikoku of the Japanese Islands.

6. Conclusions

Soils and stream sediments around the Mau Due stibnite deposits were geochemically studied together with some ores and mineralized wastes. The mineralization brought up largely stibnite components. The host sediments seem to have enriched Sb contents, as compared with eugeosynclinal sediments. Pollution due to As and base metals around the ore deposits is found to be weak.

References

Ashley, P. M., Craw, D., Graham, B. P. and Chappell D. A. (2003) Environmental mobility of antimony around mesothermal stibnite deposits, New South Wales, Australia and southern New Zealand. *Jour. Geochem. Expl.*, **77**, 1-14.

Boyle, R. W. and Jonassan, I. R. (1984) Geochemistry of antimony and its use as an indicator element in geochemical prospecting. *Jour. Geochem. Expl.*, **20**, 223-302.

Flynn, H. C., Meharg, A. A., Bowyer, P. K. and Paton, G. I. (2003) Antimony bioavailability in mine soils. *Environ. Pollution*, **124**, 93-100.

Ishihara, S. (2012) On the main antimony ore deposits in Japan and their genetic problems. *Shigen-Chishitsu*, **62**, 151-161 (in Japanese with English abstract).

Ishihara, S. and Ohno, T. (2011) Present status of antimony mineral resources of this world. *Shigen-Chishitsu*, **62**, 91-97 (in Japanese with English abstract).

Ishihara, S., Murakami, H. and Li, X. (2011) Indium concentration in zinc ores in plutonic and volcanic environments. Examples at the Dulong and Dachang mines, South China. *Bull. Geol. Surv. Japan*, **62**, 259-272.

Murciego, A. M., Sanchez, A. G., Gonzalez, M. A. R., Gil, E. P., Gordillo, C. T., Fernandez, J. C. and Triguero, T. B. (2007) Antimony distribution and mobility in top soils and plants from polluted Sb-mining areas in Extremadura (Spain). *Environ. Pollution*, **145**, 15-21.

Tran Xuyen compiled (2001) Geology and mineral resources of Ma Quan sheet. Scale 1:200,000, Text 42 p., Geol. Surv., Ministry of Industry, Vietnam.

Wang, X., He, M., Xi, J. and Lu, X. (2010) Heavy metal pollution of the world largest antimony mine-affected agricultural soils in Hunan province (China). *Jour. Soils Sediments*, **10**, 827-837.

Received January 11, 2013
Accepted March 22, 2013

ベトナム北部の Mau Due アンチモン鉱床周辺の重金属元素分布について

石原舜三・Pham Tich XUAN

要　旨

ベトナム最北部の Mau Due 鉱床はデボン紀の不純なドロマイト質頁岩中の裂罅充填性の輝安鉱鉱床である．その地化学的な研究によると，その鉱化成分は主として S 及び Sb からなり，若干の As・ベースメタル成分を伴う．土壌中の Sb 含有量は変化が激しく，これは鉱石成分の混在によるものと考えられる．雨季 (5−9 月) と乾季 (10−4 月) に分けられた採取試料の分析結果，土壌の Sb 平均含有量は雨季 932 ppm，乾季 342 ppm であって雨季で高く，一方河川堆積物では，雨季 2,563 ppm ，乾季 2,504 ppm であり，両者で著しく増加する．As は Sb と同様な挙動をとり，その含有量は雨季／乾季の土壌において 29/26 ppm と，絶対量が少ない．河川堆積物では 68-67 ppm に増加するが，この事実は Sb，As が微細な硫化物として存在することを示唆している．日本の地向斜帯の堆積岩と比べてベトナムの堆積岩類は，微量成分としての Sb に富んでいる可能性がある．