ON THE SULPHUR DEPOSITS OF THE AKAN SULPHUR MINE, HOKKAIDO, JAPAN

by

Jun SUZUKI, Toshio ISHIKAWA, Hokuichirô ÔMACHI and Yoshio SUZUKI

(With 9 Text-Figures and 2 Plates)

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Introduction

The Akan sulphur mine is situated at Moashoro in Ashoro-Mura (village), Tokachi Province in eastern Hokkaidô (Figure 1 and 2). Its office, dressing plant and smeltery stand near the public bus-road from Ashoro railway station on the Abashiri line to the famous lake of Akan; they are about 45 km distant from Ashoro station. The sulphur ores being now worked have had been deposited in the central crater of the main volcanic cone or "Nakamachineshiri" of the active volcano, Meakan. The working place is 1280 m above sea-level and about 6 km distant from the office.

The Akan sulphur mine has been worked since 1951, and crude ores containing 30 percents of sulphur in average are mined at present. The refined sulphur is produced at the rate of about 2000 tons a month. Some of it is exported to Australia and India. They are transported through the Ashoro or Kitami-aioi railway stations and the port of Kushiro. This mine is at present, next to the "Matsuo," the largest sulphur mine in Japan, in the amount of production.

The present writers investigated the sulphur deposits of this mine for several days in August, 1955. The present paper deals mainly with

the type and genesis of the sulphur deposit and the characters of the sulphur ores of this mine.

The authors wish to express their cordial gratitude to the staff of this mine, especially to Mr. MORIIZUMI (manager), Mr. KODA (chief engineer) and Mr. NISHIHARA (chief in charge of mining) who helped the authors very kindly during the time of their field observations.

History of the sulphur mining on Volcano Meaken

As the formation of sulphur is closely related with volcanic activity, it is natural that volcanoes are marked for the sulphur resource. In 1802, the Meakan volcano was explored by an officer of the Tokugawa-Bakufu (Shogunate) who was searching for sulphur ore, and then called Meakan Iwozan (sulphur mountain) [Tarao, 1889], though only the Ainos had visited there before. B. S. LYMAN, an American geologist, called it

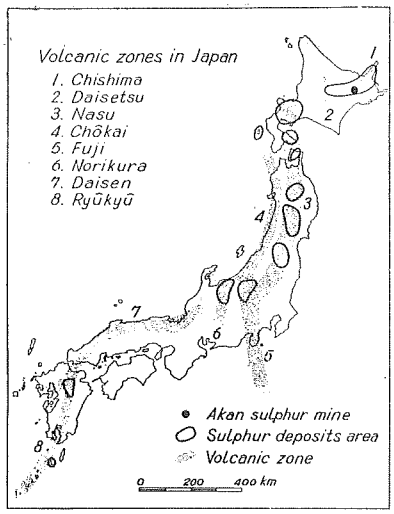

Fig. 1. Map showing volcanic zones and sulphur deposits areas [Watanabe and Kimura, 1951] in Japan, with a location of the Akan sulphur mine. Notice that sulphur deposits distribute abundantly only in some volcanic zones.

"Miakan sulphur mountain" in his report [LYMAN, 1874]. But the first man who actually prospected the sulphur deposit of this volcano, was Magoemon SANO from Kushiro in 1876 [NISHIYAMA, 1891]. In 1887, Zenkichi TAKETOMI from Hakodate built a smeltery there. Though the amount of production is not clear, the ore reserves had been imagined as 600,000 koku (about 110,000 kilo-litres) according to Kazusuke ÔHINATA, an engineer of the Hokkaidô Prefectural Office [TARAO, 1899]. In 1891, Shôgo NISHIYAMA, a geologist of the same office, estimated all the reserves

of sulphur ore on this volcano as 544,000 tons of ore containing 70 to 90 percents of sulphur. Then the central crater of Nakamachineshiri, where the sulphur ores are now being worked, was very deep, and the sound of boiling water was heard like a thunder's roar at its bottom [NISHIYAMA, 1891]. During the period 1906 to 1908, Tokitarô HOSOKAWA

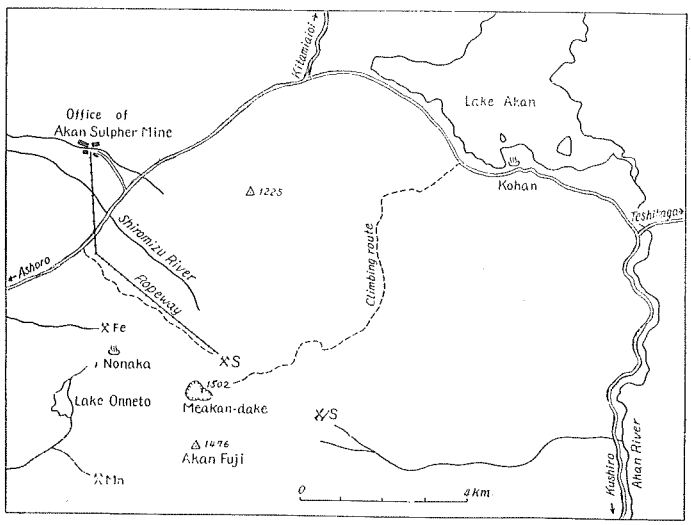

Fig. 2. Regional map around the "Akan" sulphur mine.

produced 6,000 tons of refined sulphur yearly. Yôzô OKAMURA of the Geological Survey stated in 1913 that sulphur fumes were rising at various points on the bottom of the central crater and sulphur ores had deposited in the ash bed covering the crater bottom, 2.5 m or more in thickness [OKAMURA, 1914].

In 1934, the volcanic district around the beautiful lakes of Kuccharo, Akan and Mashû, including this volcano, 87,498 hecto-are in area, was set aside as the Akan National Park, and since then the mining within this region has been restricted. But in 1951, "Nihon Tokushu" Mining Company began to work this mine, established a smeltery in the following year and a floatation plant capable of treating 200 tons of crude ore daily in 1954. In 1955 the "Akan" Sulphur Mining Company was newly organized and is now working this mine.

Volcanological and geological outline of the Akan sulphur mine and its neighbourhood

The Meakan volcano in which the ore deposits of the Akan sulphur mine originated, was early observed geologically by JIMBO [1891], YOKOYAMA [ISHIKAWA and YOKOYAMA, 1894], NISHIYAMA [1891], KATO [1913] and OKAMURA [1914]. Then TANAKADATE [1925, 1927, 1934] studied this volcano from the volcanological viewpoint. He described its structure and the then state of the central crater of Nakamachineshiri. In 1949, KATSUI [1951] made researches on this volcano from the viewpoints of geology and petrology, and completed the geological map covering its whole area.

According to these authorities, Meakandake is an active volcano located at the south-western extremity of the Chishima (Kurile) volcanic zone running south-westward from the volcanic island, Alaid, at the north end of the Kurile Islands (Figure 1). It stands on the south-west wall of a depression called "Akan" concha caldera by TANAKADATE [1934]. After this caldera was formed by the collapse in the Late Pleistocene age, volcanoes Fuppushi-dake and Furebetsu-dake, and then Oakan-dake and Meakan-dake were built in the caldera or on its wall in Holocene times, although some of them may have begun to erupt at the end of Pleistocene. The former three volcanoes early ceased their activity, though their lavas do not petrographically much differ from those of Meakandake.

The structure of this volcano is very complicated, and the history of its construction was divided by KATSUI [1951] as follows;

1. The earlier stage—The formation of Minamidake (augite hypersthene andesite), 1042 m. peak (quartz-bearing augite hypersthene andesite) and Higashiyama (augite hypersthene andesite).
2. The main stage—The formation of three peaks, Kobuyama (quartz-bearing augite hypersthene andesite), Kengamine (olivine augite andesite and quartz bearing augite hypersthene andesite) and Nakamachineshiri (augite hypersthene andesite with or without olivine and quartz).
3. The first parasitic cone stage—The eruption of Nishiyama (augite hypersthene andesite with or without olivine), Kitayama (olivine augite hypersthene andesite), and Ponmachineshiri (augite hypersthene andesite).
4. The last parasitic cone stage—The eruption of Akanfuji (olivine augite andesite).

Nakamachineshiri (1280 m) is a large strato-volcano consisting of

lava flows and fragmental ejectas of augite hypersthene andesite with or without olivine and quartz in petrographical character. The top part of Nakamachineshiri is surrounded by the first (outer) crater wall, 1100 m in diameter (Figue, 3). The second crater, about 500 m in diameter,

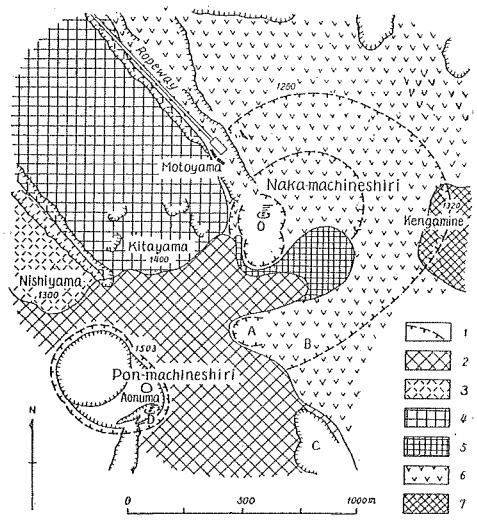

Fig. 3. Geological map around Nakamachineshiri of Volcano Meakan
1. Crater wall, 2. Ponmachineshiri lavas, 3. Nishiyama lavas, 4. Kitayama lavas, 5. Central cone lava, 6. Volcanic products from Nakamachineshiri, 7. Kengamine lavas, O, "Ôfuki" deposit. A, "Tôbu" A deposit. B, "Tôbu" B deposit. C, "Tôbu" C deposit. D, New craters and fissures formed in 1955–56.

is formed concentrically in the first shallow-dish-like crater, and the central cone consisting of augite hypersthene andesitic lava stands about 50 m high on the south wall of the second crater. Breaking the north-west part of this cone, the explosion crater generally called the central crater was formed. On its bottom and along its wall, sulphataras are scattered. The most violent sulphatara at the central part of the crater is called "Ôfuki" (great spout). The sulphur ore deposit being now worked has been accumulated in this crater, and is called the "Ôfuki" ore deposit. Also at the south side of the central cone, an explosion crater exists half covered with ejectamenta from Ponmachineshiri. Sulphur deposits formed in and around the above explosion crater are called the "Tôbu" (East) A and B ore deposits respectively. The Tôbu C deposit found on the outer-slope of Nakamachineshiri, to the south-east of the above two, is of the sublimation type.

Ponmachineshiri (1503 m) is the highest cone standing on the south shoulder of Nakamachineshiri; it has a large crater, about 500 m in diameter, on its top part. This crater consists of two smaller ones; the east one is shallow in depth and embraces two maar-like craterlets in it, while the west is the later formed explosion crater, about 100 m in depth,

One of two craterlets in the east crater has been called Aonuma (blue lake), as it is always filled with blue-coloured water. Another one called "Koakanuma" by some geologists, neighbouring to the above at its east side, had issued fumes violently from sulphataras in it. Which of the above two craterlets was the one filled with boiling water which Yokoyama observed actually on Ponmachineshiri in 1890, is not clear [ISHIKAWA and YOKOYAMA, 1894].

No eruption of this volcano was recorded before its recent activity beginning November 19, 1955 [SAKUMA, KATSUI, SUZUKI and MURASE, 1956], though rumblings and earthquakes had been often heard and felt at its north-east foot in 1927, 1952 and 1954 [TANAKADATE, 1927; ÔNO and MINAMI, 1952; YAMAGUCHI and ÔNO, 1953]. At the first recent eruption new craters and two fissures were opened at the south-eastern part of the east crater of Ponmachineshiri, and enlarged by the later explosions in the following year.

The mode of occurrence of the Akan sulphur mine deposits

The main ore deposit of the Akan sulphur mine being now worked is that of the "Ôfuki", deposited in the central explosion crater of Nakamachineshiri. The Tôbu A, B and C deposits are smaller in scale and not yet mined; the "Aonuma" deposit was lost by the explosion in November, 1955. Therefore the present paper deals mainly with the "Ôfuki" deposit.

At the beginning of working the "Ôfuki" deposit, only the sublimated sulphur was mined from the uppermost ash bed, but as the mining advanced, abundant sulphur ores of impregnation, replacement and even sedimentation types appeared successively at its lower part (Figure, 4). So far as the writers observed, the main ore deposit is classified from the lower as follows;

(1) Lower banded ore bed
(2) "Aoban" ore bed
(3) Upper banded ore bed
(4) Sublimated ore mass

(1) The lower banded ore is gray or grayish white in colour, comparatively compact and fissile. It consists of fine volcanic ash and sulphur whose percentage of ore is 25 to 30, and sometimes intercalates pale black muddy bands of ash. Native sulphur is sublimated along cracks and fissures opened obliquely to the bedding plane. This ore bed occurs

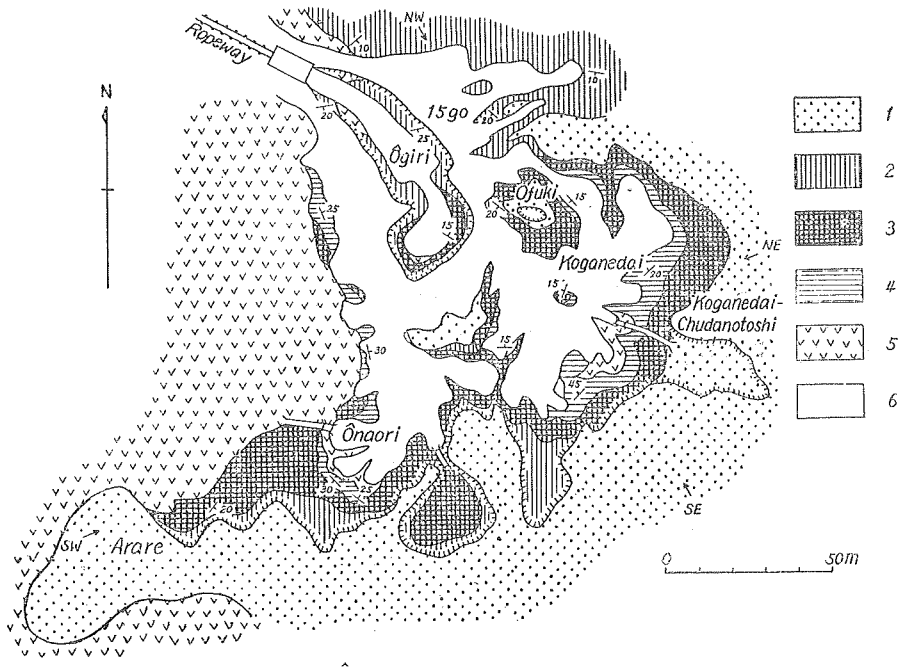

Fig. 4. Geological map of the "Ôfuki" deposit area.
(1) Volcanic ash bed (2) Upper banded ore bed (3) "Aoban" ore bed
(4) Lower banded ore bed (5) Altered andesite (6) Present working floor

only in the outer zone of the deposit or of the crater and dips 10° to 20° to the central zone, in which part it does not develop.

(2) "Aoban" (blue ore) is the local name given to the bluish green coloured high-grade ore containing 50 to 60 percent sulphur. It constitutes the main ore body of the "Ôfuki" deposit. The "Aoban" ore can be farther classified into three sorts on the basis of textures: brecciated coarse grained, green coarse grained and pale-greenish gray fine grained ores. The "Aoban" ore bed generally consists of the above three sorts of ore in the succession of description from the lower upward. It occurs always thicker at the central part of the deposit and thinner at the margin. Each ore of the three sorts is rather lenticular in body shape and is not uniform in thickness as a bed. Original materials mineralized by impregnation and replacement of sulphur are fine and coarse ashes, lapilli, pumice and scoria produced by pre-historic explosions in the central crater of Nakamachineshiri and the top crater of Ponmachineshiri. Native sulphur grains, 0.5 cm in size, and amoeba-like sulphur masses are sublimated in cavities of the ore.

(3) The upper banded ore bed is originally composed of coarser ash or tuff than those constituting the lower; it has a 28 percent sulphur content. It looks like sandy clay with frequent intercalated blackish layers composed of fine iron-sulphide grains, 7 cm in maximum thickness. Generally iron sulphide is synthetized by the reaction of hydrogen sulphide with ferric sulphate as shown in the following equations:

$$Fe_2(SO_4)_3+H_2S=2FeSO_4+H_2SO_4+S$$
$$FeSO_4+S+H_2S=FeS_2+H_2SO_4$$

Perhaps the sulphataric activity at the time of deposition must have been strong and supplied too much hydrogen sulphide to advance the following reaction, $2H_2S+O_2=2H_2O+2S$, although the place was near the earth surface where water and oxygen existed. Also formation of abundant sublimated sulphur ore just above the bed in question proves this phenomena. This ore bed becomes thick in the north and south parts of the "Ôfuki" deposit area. At some points of that bed, ash-pisolites occur grouping

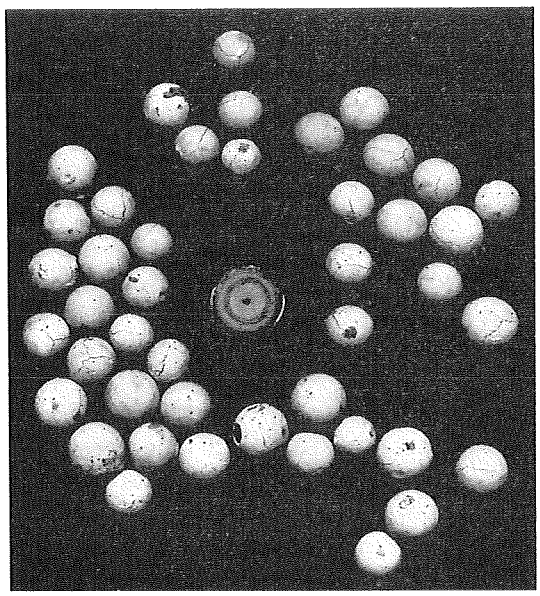

Fig. 5. Pisolites found in the upper banded ore bed. The central one shows concentric internal texture on the cross section. (×⅔)

in no relation with bedding plane of ore or rather in a pot-like form. Smaller pisolites, 0.5 to 1 cm in diameter, show perfect sphere shape with smooth surface (Figure 5), while the larger ones are more distorted and

uneven on their surface like snow balls. They are made of very fine gray ash intermixed with sulphur powder, and show concentric internal texture often around cores of lithic fragments. Similar pisolites have been found from Jigokudani explosion crater of Noboribetsu [SUZUKI, ISHIKAWA and ISHIBASHI, 1943], Seseki of Kunashiri Island, Kuriles [by Tadahiro NEMOTO in 1939], Horobetsu sulphur mine [KATO, WATANABE and NAKAMOTO, 1934] and Atosanupuri sulphur mine [by a miner in 1956]. ISHIKAWA, one of the present authors, considers that such pisolite is formed by rotation in the bubbling muddy sulphatara. It grows concentrically around some nucleus, but when the nucleus is large, its rotation may not be free and distorted pisolite is formed. Ellipsoidal or ovaloidal pisolites with uneven surface were found in groups in Jigokudani explosion crater of Volcano Tateyama [by ISHIKAWA in 1954].

(4) The sublimated ore is formed at the uppermost part of the deposit. At the south part of the "Ôfuki" deposit area, an ore mass disseminated with sublimated sulphur grains, 1 to 2 cm in idameter, develops above the "Aoban" ore bed. It shows a characteristic appearance, and is called "Arare" (hail) ore. At Koganedai-chûdan, the east part of the deposit area, a lenticular mass composed of sublimated sulphur, 7 to 8 m in thickness, still remains unmined.

From the above observations, the geological profiles of the present sulphur deposit may be shown as in Figures 6 and 7. The whole deposit is like a wash-basin in shape.

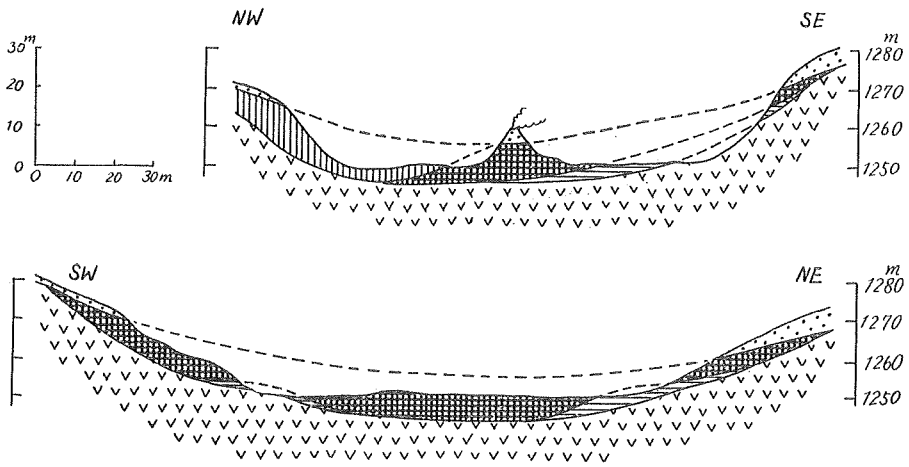

Fig. 6. Geological profile of the "Ôfuki" ore deposit.
(Symbols are the same as those in Fig. 4.)

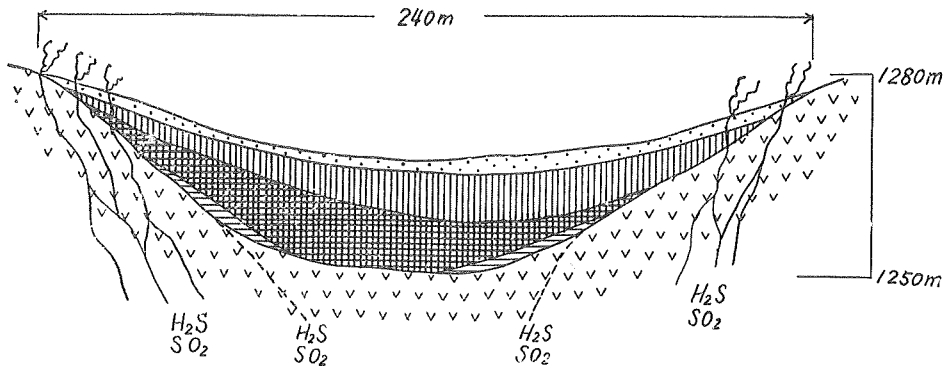

Fig. 7. Diagrammatic profile of the "Ôfuki" ore deposit.
(Symbols are the same as those in Fig. 4.)

Numerous sulphataras are scattered in the explosion crater, especially along its west inner wall bounding the central cone lava and the volcanic detritus filling the bottom part of the crater (Figure 8). A part of the central cone lava is impregnated with sulphur from sulphatara, and sometimes also "Aoban"-like ore is formed by intense impregnation of sulphur. At nearly the central point of the crater, the "Ôfuki" sulphatara is always emitting water vapour mixed with sulphur gas from the vent, about 5 m across, like a chimney (Plate I, Figure 2), and sublimated sulphur is being formed around it. Of other sulphataras, most are arranged in N-80°-W direction, and some change their activities as the mining advances. Fissures run in two directions of E-W and N-S, the former system being remarkable. Large cavities are found rarely in the deposit.

Next, the other deposits will be briefly touched upon. The Tôbu A deposit is formed in the explosion crater at the south of the central cone and about 500 m south from the "Ôfuki". Although the half of it is covered with ejecta from Ponmachineshiri, an area of 180 m by 150 m is strongly affected by sulphataric action and stained in yellow and white. Lapilli and ash beds are impregnated or replaced with sulphur, and also "Aoban" ore common in the "Ôfuki" deposit is found there. By prospecting, this deposit is known to be next to the "Ôfuki" in the ore body among deposits of the Akan sulphur mine, though far smaller than the latter in scale. The Tôbu B deposit is near by the above; it formed at the inner wall of the first crater of Nakamachineshiri. The mineralized area is about 60 m by 100 m, where sulphur is deposited in coarse ash bed. The Tôbu C deposit develops on the south outer slope of Nakamachineshiri, about 1000 m distant from the above two deposits. It is of the

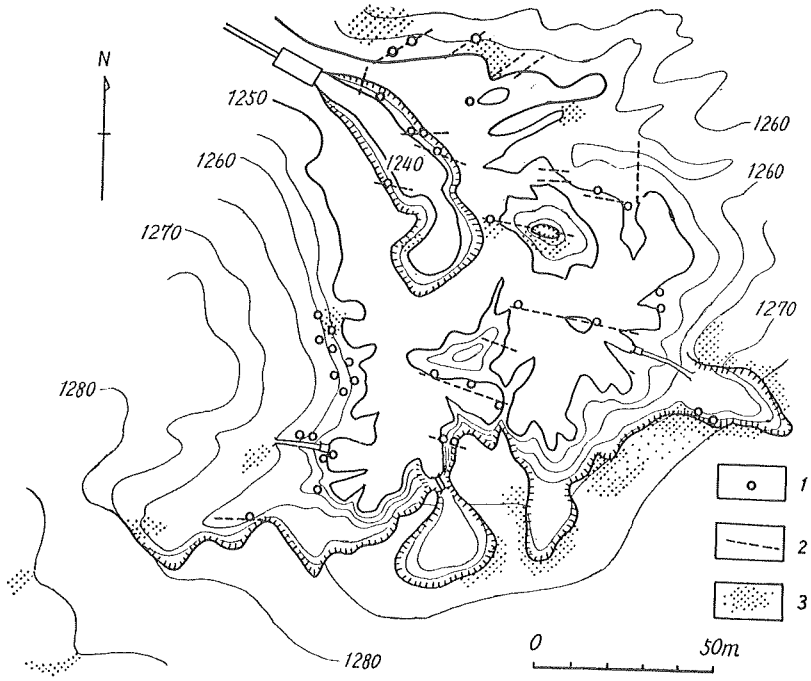

Fig. 8. Map showing distribution of sulphataras, fissures and sublimated sulphur ores in the "Ôfuki" deposit.
1. Sulphatara 2. Fissure 3. Sublimated sulphur ore

sublimation type. Good crystals of rhombic sulphur and prisms of sulphur grown like frost in the ground are beautiful. This sulphur deposit occurs in scoria bed and originates in sulphataras which occur in a linear arrangement about 150 m long.

The "Aonuma" deposit was formed in the "Koakanuma" (small red lake) craterlet neighbouring to the Aonuma at the inside of the top crater of Ponmachineshiri. This craterlet had several sulphataras in it, one of which was violently emitting sulphur gas of 121°C temperature and sometimes overflowing gray muddy sulphur out of its mouth on the craterlet bottom. But it was destroyed by the explosion on November 19, 1955.

Characters of the sulphur ores

The sulphur ores from the "Ôfuki" deposit may be classified into three sorts: sublimated, impregnated and banded sulphur ores.

(1) Sublimated sulphur ore

The sublimated sulphur ore is formed generally at the upper part of the "Ôfuki" deposit, especially around sulphataras. It is yellow to yellowish orange, and sometimes tinged with orangish red colour due to selenium content. It occurs as crystal group, disseminated grains of 1 to 2 cm in diameter and massive aggregation. The first is called also "Hanaiwô" (flower sulphur), the second "Arare" (hail) as already stated, and some of the third "Takanome" (hawk's eye). They are nearly pure sulphur, but there is no great deposit.

(2) Impregnated sulphur ore

The impregnated sulphur ore is commonly called "Gankô" (rock sulphur ore) in Japan, and that constituting the main part of the "Ôfuki" deposit is named conveniently "Aoban" (blue ore) from its colour as already stated. A part of the central cone lava constituting the west wall of the crater is impregnated with sulphur from sulphataras, and changed into sulphur ore of the "Gankô" type. The "Aoban" ore is of some different type from the common "Gankô". It is green-coloured and comparatively compact, sometimes contains grains or amoeba-like masses of native sulphur in cavities. The formerly noted three sorts of "Aoban" ore, viz. brecciated coarse grained, green coarse grained and pale greenish gray fine grained ores show all nearly the same character under the microscope. The matrix of original rock is replaced by sulphur and lithic fragments are opalized (Plate II, Figure 1, 2). Also some iron sulphide grains are included. The "Aoban" is a high-grade ore containing 50 to 60 percents of sulphur. An analyzed specimen contains 56% of S, 0.012% of Se, 0.001% of Te and some of Al_2O_3, SiO_2, H_2SO_4 and organic matter.

From the above characters, the "Aoban" ore is considered to have been formed by intense impregnation and some replacement of various ejecta beds composed of ash, lapilli and pumice with sulphur.

(3) Banded sulphur ore

The banded sulphur ore constituting the lower banded ore bed is yellowish or grayish white; it is made up of numerous bands, 0.5 to 1 cm in each thickness, which are composed mainly of fine grained ash (Figure 9). Under the microscope, minute sulphur grains, 0.05 mm in size, are arranged abundantly forming layers parallel to the bands of ore, and their interstices are filled with opals (Plate II, Figure 3). Chemically this ore contains 25 to 30 percents of sulphur on the average.

The upper banded ore bed is made up of rather coarser ash grains than those of the lower, and often has intercalating black bands rich in minute iron sulphide grains, 7 to 10 cm in thickness. Sometimes it

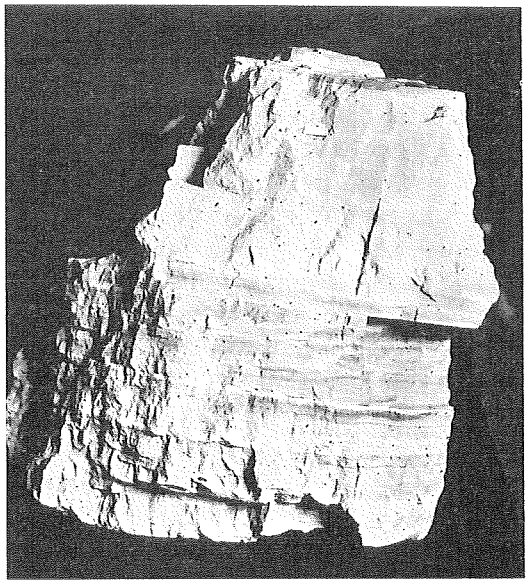

Fig. 9. Banded sulphur ore constituting the lower banded ore bed. ($\times \frac{1}{3}$)

includes pumice lapilli of 1 cm in size, breccia, and reddish brown ash layer. Under the microscope, lithic fragments are all opalized and cementing ashy parts are replaced by sulphur and iron sulphide (Plate II, Figure 4). Richness in black iron sulphide at the upper part of the sulphur deposit has already been noted also at the Matsuo and Horobetsu mines. [KATO, WATANABE and NAKAMOTO, 1934].

From such mode of occurrence and character of ore as above stated, the banded sulphur ore of this mine is considered to be of sedimentary origin and may be called "bedded sulphur ore" or "muddy sulphur ore". Similar ores are generally classified into yellow ore, brown or chocolate ore, banded ore and "Borokô" (rag ore) in Japan. The lower banded ore may correspond just to the third, while the upper banded ore resembles the fourth. Ores belonging to the other two sorts occur only in small amount at this mine.

Similar sulphur ore was early worked at the Iwaonupuri mine, Hokkaidô [ÔHINATA 1912; TANAKADATE, 1918], where three ore beds had developed in alternation with clay. "Senmaiko" (phyllitic ore) from the Okushiri sulphur deposit [TANAKADATE, 1931] is composed of an alternation of yellow and gray coloured layers, and seems to resemble the lower banded ore from the Akan sulphur mine, though the former is

harder and higher in grade than the latter. "Borokô" from the Okushiri mine may correspond to the upper banded ore from the Akan mine, though the former contains small black empty globules of sulphur as seen often at Ôyunuma explosion crater of Noboribetsu, Hokkaidô [SUZUKI, ISHIKAWA and ISHIBASHI, 1943]. The Kimobetsu sulphur deposit [TAKUBO, 1937] is composed of banded ore, yellow ore, brown ore and "Borokô." Among them, the banded ore is microscopically composed of fine ash, minute sulphur grains, organic and clay materials, and resembles the lower banded ore from the Akan sulphur mine. Also from the Horobetsu sulphur mine [KATO, WATANABE and NAKAMOTO, 1934] a similar banded ore composed of yellowish white and black bands was reported.

The sulphur ore of the just described type is considered to have been deposited on the bottom of "Yunuma" (hot water lake) or the explosion crater filled with hot water, as generally stated. [KATO, WATANABE and NAKAMOTO, 1934; WATANABE and KIMURA, 1951]. When the sulphataric activities are still violent on the bottom or inner wall of "Yunuma", fine sulphur powders in colloidal state and free sulphur separated from hydrogen sulphide by oxidation may be deposited like mud continuously on the bottom of the "Yunuma". During the deposition of sulphur, sand and mud also are naturally transported from the surrounding area and deposited on the bottom of the "Yunuma". Sometimes volcanic ash and lapilli fallen from the very crater or some other craters at their explosions may be deposited with sulphur. Thus sulphur ore deposits of bedded structure, variable in grade, are formed. The existence of gravel just below the upper banded ore bed at the north part of the "Ôfuki" deposit area and rain drops marked on the surface of the banded ore bed [UMEMOTO and MATSUMURA, 1956] will support this theory. Sulphur deposited on the bottom of the "Yunuma" may be in melting state, if the temperature is above 120°C and there is some water pressure.

Some considerations on the genesis of the Akan sulphur deposit

There is no need to say that the formation of a sulphur deposit is closely connected with volcanic activity. But the fact that sulphur deposits are rich in some volcanic zones, while poor or absent in others, as shown in Figure 1, suggests that the deposition of sulphur depends upon the character of the magma and the type of volcanic activity. The Chishima (Kurile) and Nasu zones where sulphur deposits are found widely are of the most calcic in the character of the magma; volcanoes

belonging to the both zones are made up mostly of pyroxene andesitic lavas of hypersthenic rock series. In the above zones, lava domes are often formed by the viscous lavas, and explosion craters and sulphataras opened around them generally keep their activities for a long time. Sulphur deposits are apt to be formed under such structural conditions.

Volcano Meakan is an active volcano belonging to the Chishima volcanic zone; the first record of eruption is dated November 19, 1955. The central crater of Nakamachineshiri was apparently emitting more smoke than that from the top crater of Ponmachineshiri before the latter's recent eruption; it keeps its sulphataric activities constantly as ever after that eruption. This crater was opened by explosion at the north-west part of the central lava cone or the central dome. Numberless sulphataras were formed in and around it and have emitted sulphuric gas. Thereafter pre-historic explosions must have occurred also in the top crater of Ponmachineshiri. Some of the explosion products from the above two craters might have been deposited in the central crater. Thus-formed ejecta beds are impregnated or sometimes replaced with sulphur from rising gas.

When the activity of a crater declines, the crater may be sometimes filled with water, if its wall is closed. Water is heated by high temperature gas from sulphataras on the bottom and inner wall of the crater, and then so-called "Yunuma" are formed. The lower banded ore bed of the "Ôfuki" deposit must have been deposited under such condition.

If the crater's activity is rejuvenated, explosions may occur repeatedly. The sulphur ores deposited formerly at the central part of the crater may be blown off, and the fragmental explosion ejectas are deposited newly at the bottom of the crater. Also some sinking may be caused at the central part of the crater after the explosions. Such ejecta beds are impregnated and sometimes replaced with sulphur from numerous sulphataras. The "Aoban" ore which is thicker at the central part of the crater may be formed through such process. The grades of the ore depend mainly on the sulphataric activity and original materials.

Then, if the activity of the crater is weakened, "Yunuma" may be formed and the banded sulphur ores deposited again. But the second "Yunuma" is shallower in depth than the former, as the crater bottom has been already over-lain with the formerly deposited materials. Or rather some sulphataric pools of various size may be formed in the crater, as Jigokudani of Noboribetsu [SUZUKI, ISHIKAWA and ISHIBASHI, 1943]. The upper banded sulphur ore bed might have been deposited under such condition as just stated. Accordingly the upper banded ore is naturally coarser in granular construction than the lower one. Also pisolites can be

formed in some muddy sulphataras. Further, the upper banded ore bed seems to contribute to the enrichment of the "Aoban" ore bed with sulphur from rising gas as the cap rock.

Now the crystallization of native sulphur results from the reaction of hydrogen sulphide or sulphurous anhydride gasses rising from deep in the earth with water and oxygen at the water level beneath the earth surface. The reaction may be shown in the following equations,

$$2H_2S+O_2=2H_2O+2S$$
$$H_2S+2SO_2=H_2SO_4+2S$$
$$\text{or}\quad 3SO_2+2H_2O=2H_2SO_4+S$$

Therefore the sublimated sulphur ore is apt to be formed at the upper part of the deposit, and also in the case of the "Ôfuki" deposit, sublimated sulphur masses are mostly formed above the upper banded ore bed. According to Hayase [1951], crystallization of native sulphur attains its maximum at temperatures between 109° and 120°C. Temperature of gas from the "Ôfuki" sulphatara, around which sublimated sulphur is formed abundantly, was measured as 135° or 136°C at a depth of 10 m from its mouth by Nishihara, chief in charge of mining, on December 8 and 12, 1955. Sulphur gas often enriches the content of sulphur in once formed ores while it passes through them; sometime it solidifies filling cavities, cracks or fissures.

Iron sulphide ore is generally considered to be precipitated at 90° to 110°C, lower than the crystallizing temperature of native sulphur, from iron sulphide solution. Accordingly the black iron sulphide layers are often seen at the upper part of the "Ôfuki" deposit or in the upper banded ore bed.

As above stated, the "Ôfuki" deposit which was simply considered to be a sublimated ore deposit before mining, is a very interesting sulphur deposit composed of ores of impregnation, replacement, sedimentation and sublimation types. It is noteworthy also that the study on the succession of the deposition of various sulphur ores throws light on the veiled history of the activity or change in the crater in question.

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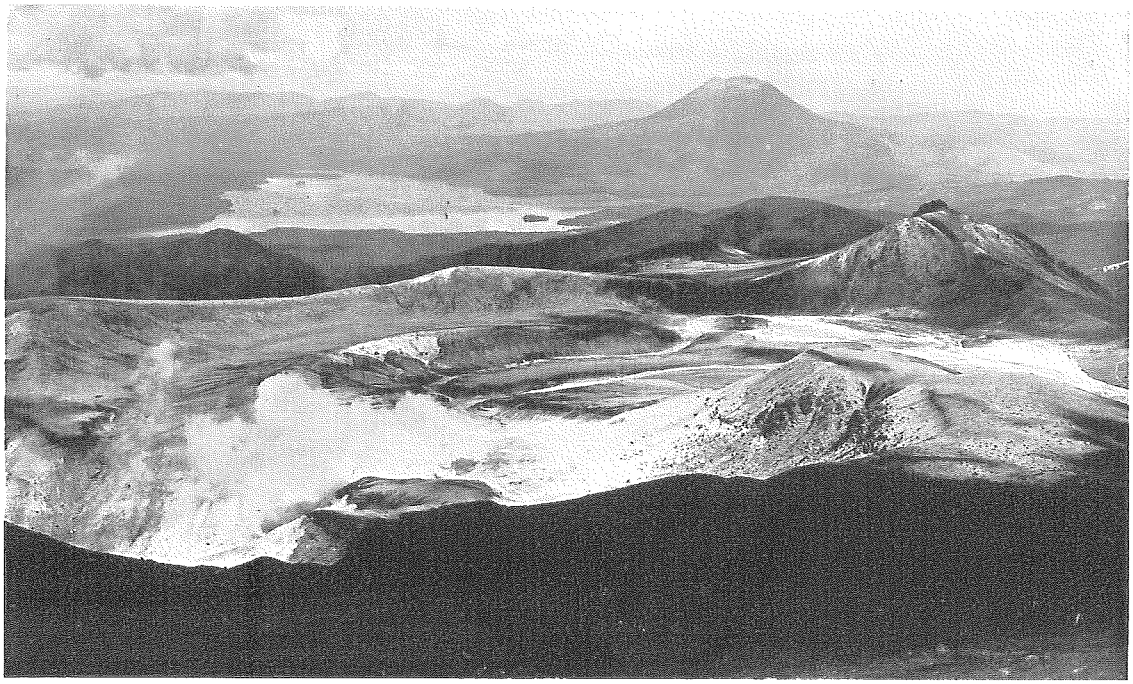
Explanation of Plate 1

Explanation of Plate 1

Fig. 1. The whole view of Nakamachineshiri, the main volcanic cone of Volcano Meakan, from the top of Ponmachineshiri, the highest cone of this volcano. The smoking crater is the central crater of Nakamachineshiri. A peak on the first crater wall (at right hand of the picture) is Kengamine and a cone in the front of it is the central cone of Nakamachineshiri. At the distance, Volcano Oakan and Lake Akan are seen.

Fig. 2. The central crater of Nakamachineshiri or the explosion crater at the north-west side of the central cone, where sulphur ores are worked at present. The vent issuing smoke at the central part of the crater is called "Ôfuki", which is given also as the name of the ore deposit area. Aerial photograph from the west, taken by Mr. Yuzuru Ôno of the Sapporo Meteorological Observatory.



Fgi. 1

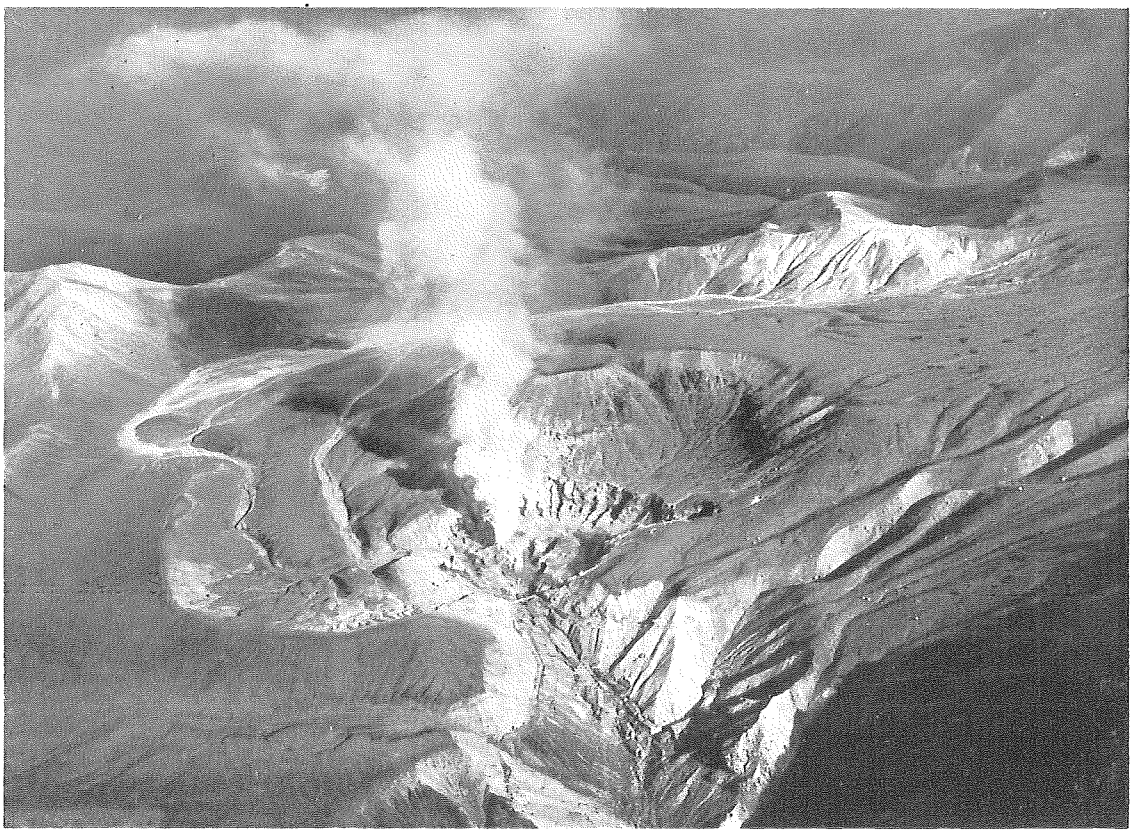


Fig. 2

SUZUKI, ISHIKAWA et al. Akan Sulphur Ore Deposits

Explanation of Plate 2

Explanation of Plate 2

Microscopical photographs of the sulphur ores from the Akan sulphur mine.
One nicol, ×48

Fig. 1. "Aoban" ore or the impregnated sulphur ore.
s—sulphur, opl—opal

Fig. 2. The pale greenish gray fine grained type of the "Aoban" ore.

Fig. 3. Banded sulphur ore constituting the lower banded ore bed.
s—sulphur, opl—opal.

Fig. 4. Banded sulphur ore constituting the upper banded ore bed.
Black part—iron sulphide ore.

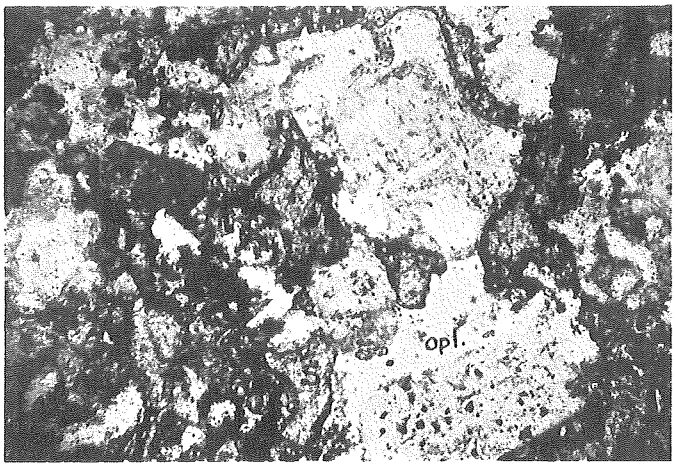


Fig. 1

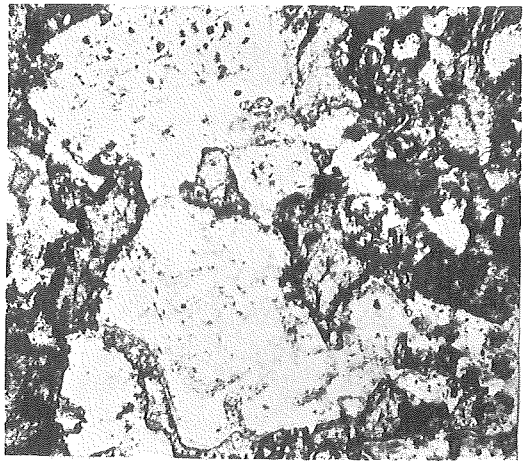


Fig. 2

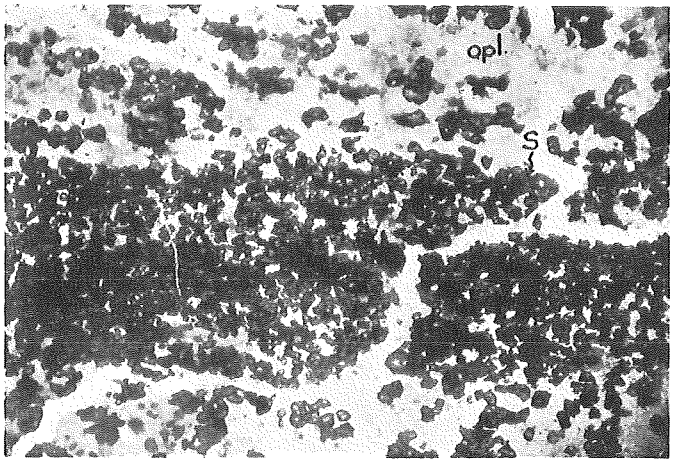


Fig. 3

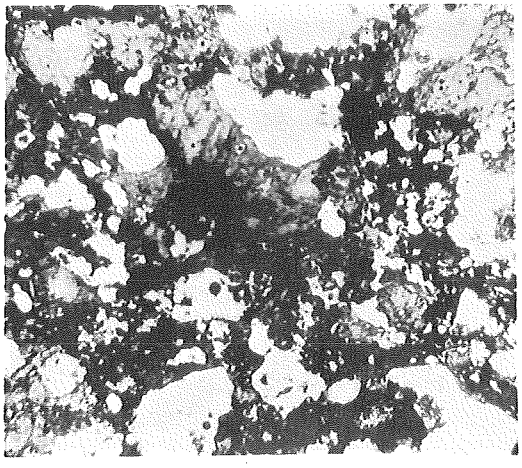


Fig. 4