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# A Pahoehoe Lava Made of Sulfur Was Found at Mountain Flank of Shiretokoiozan Volcano, Hokkaido, Japan

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Pahoehoe lava made of sulfur (pahoehoe sulfur) was found at a mountain flank of Shiretokoiozan volcano, Hokkaido Japan. The specimen found by the author had been preserved in a small space under a large rock along the subsidiary stream branched from the much larger main flow of 1936-eruption. The specimen which had been created by cooling of low viscosity molten sulfur has pahoehoe's characteristic ropy patterns on the top surface. This pahoehoe sulfur is extremely rare and valuable, and it deserves natural monument designated by the government of Japan as a common property of mankind.

## Introduction

Pahoehoe lava made of sulfur (pahoehoe sulfur) was found at a mountain flank of Shiretokoiozan volcano, Hokkaido JAPAN on July 30, 2017 by the author. Watanabe (1940) reported a huge amount of molten sulfur was expelled at Crater I at the mountain flank and flowed into the Kakonosawa dry creek and the Kamuiwakka creek in 1936. The molten sulfur formed a structure on the surface resembling pahoehoe lava near Crater I and it seemed that there were plenty of pahoehoe sulfur lumps near Crater I. However almost all the amount of 116,523 tons of sulfur (The Geological Survey of Japan 1967) was mined for resources and today only some pieces of sulfur can be observed in the small holes and cracks in the rocks located in the course of the 1936-molten sulfur flow.

Pahoehoe lava created when low viscosity molten lava cools has characteristic ropy patterns on the top surface resembling a bunch of ropes. Mostly pahoehoe lava can be observed in the volcanoes which erupt molten lava with less viscosity like the Kilauea volcano and the lava is often composed of silicate magma. Pahoehoe lava composed of sulfur or "Pahoehoe sulfur" is extremely rare. The specimen of pahoehoe sulfur found by the author had been preserved in a small space under a large rock along the subsidiary stream branched from the much larger main flow. Because the pahoehoe sulfur had been confined in almost closed space, it had been protected by wind, rain, snow, direct sun shine and illegal collecting by visiters and kept in good condition.

The author documented the surrounding environment, location, and conditions of the specimen and then collected it carefully and transported to the Shiretoko Museum. Collection was permitted by ministry of the environment of the government of Japan.

Pahoehoe sulfur can also be seen in other volcanic areas e.g. the author has observed some at Jigokudani Tateyama in Toyama Pref. and Tokachidake in Hokkaido Pref. but still the pahoehoe sulfur cannot be seen so often. In the case of Shiretokoiozan, in author's knowledge, because this is the only perfect sulfur specimen with ropy patterns on the almost pure yellow sulfur and air bubble cavities, and it had survived after the huge destruction of sulfur-mining during and after the 1936-eruption, the specimen is extremely rare with academically high value. It ideally corresponds to the criteria of natural monument "extremely precious specimen of rocks, minerals and fossils" (Agency for cultural affair of the government of Japan 2010) and the author strongly propose that the specimen should be designated to the natural monument by the government of Japan.

## Location of the pahoehoe sulfur

As shown in Fig. 1 the specimen had been 70 meters west from Crater I where the molten sulfur was expelled in 1936. The location was out of the main flow but along the subsidiary stream. Most of the molten sulfur flowed in the main stream in a gully in the several meters deep just out of

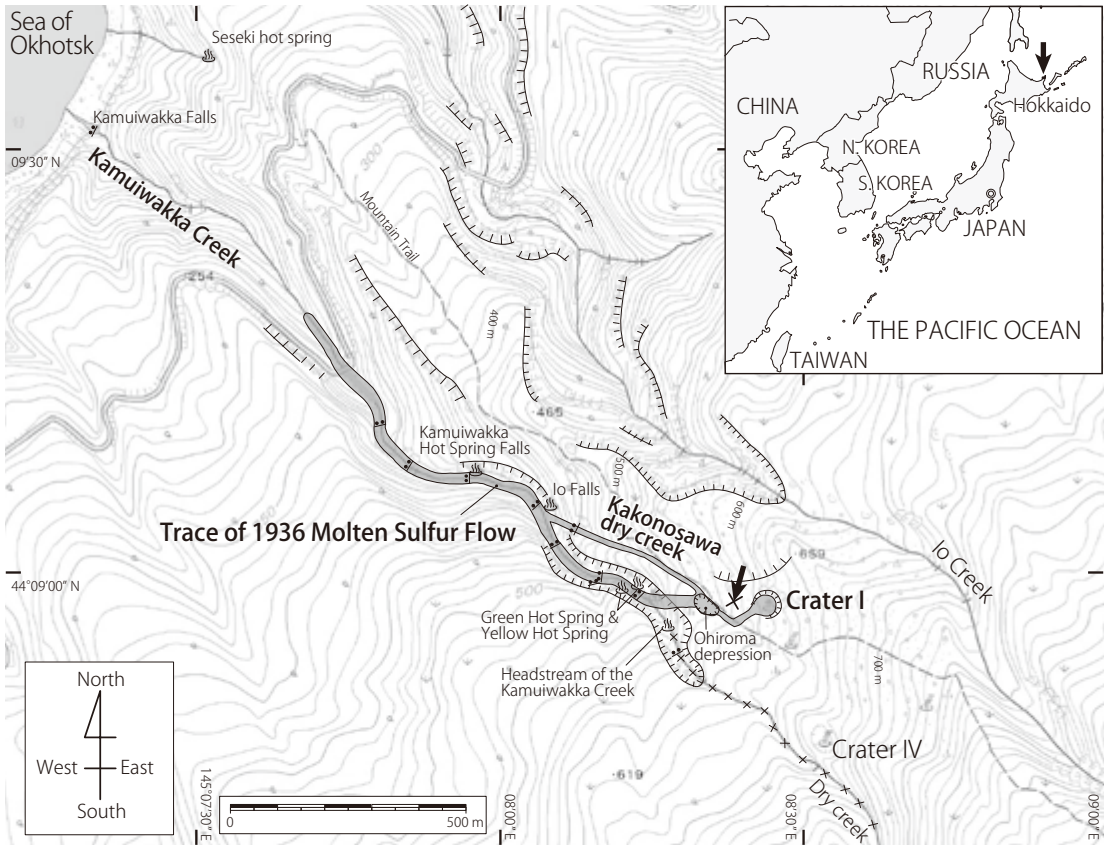


**Fig. 1.** Location of the pahoehoe sulfur.

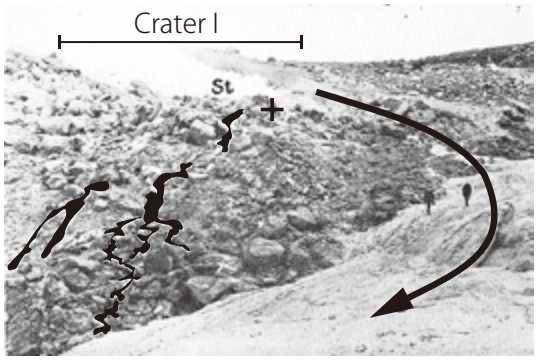


**Fig. 2.** Subsidiary stream (areas in black) and the location of the pahoehoe sulfur (+) in the photograph taken on Sept. 1936 by Watanabe & Shimotomai (1937). Arrow means main stream of molten sulfur from Crater I. **St**: Steam expelled.

Crater I and the subsidiary stream came from the main flow by overflowing. The subsidiary stream can be identified in the photograph of Watanabe (1937) shown in Fig. 2.

## The environment surrounding the pahoehoe sulfur

As the author has already mentioned, the specimen had been confined in the space under the large rock located along the subsidiary stream of 1936-molten sulfur flow and further detail is shown in Fig. 3. At the side of the subsidiary flow on the large rock, a narrow tunnel in ten or twenty centimeters wide had been formed with the large rock above and other medium sized rocks and the tunnel is connected and cascaded to the wider space where the specimen was found. The strike and dip of the top surface of the pahoehoe sulfur was N 60° E and 15° S (Fig. 4). It largely deviates from the average dip of the slope around the location of the specimen and surrounding rocks. It is implied that the molten sulfur from the subsidiary stream had branched and flowed to the space through the narrow tunnel and then cooled.

It is noteworthy that 1. the specimen had been moved for probably ten or twenty centimeters

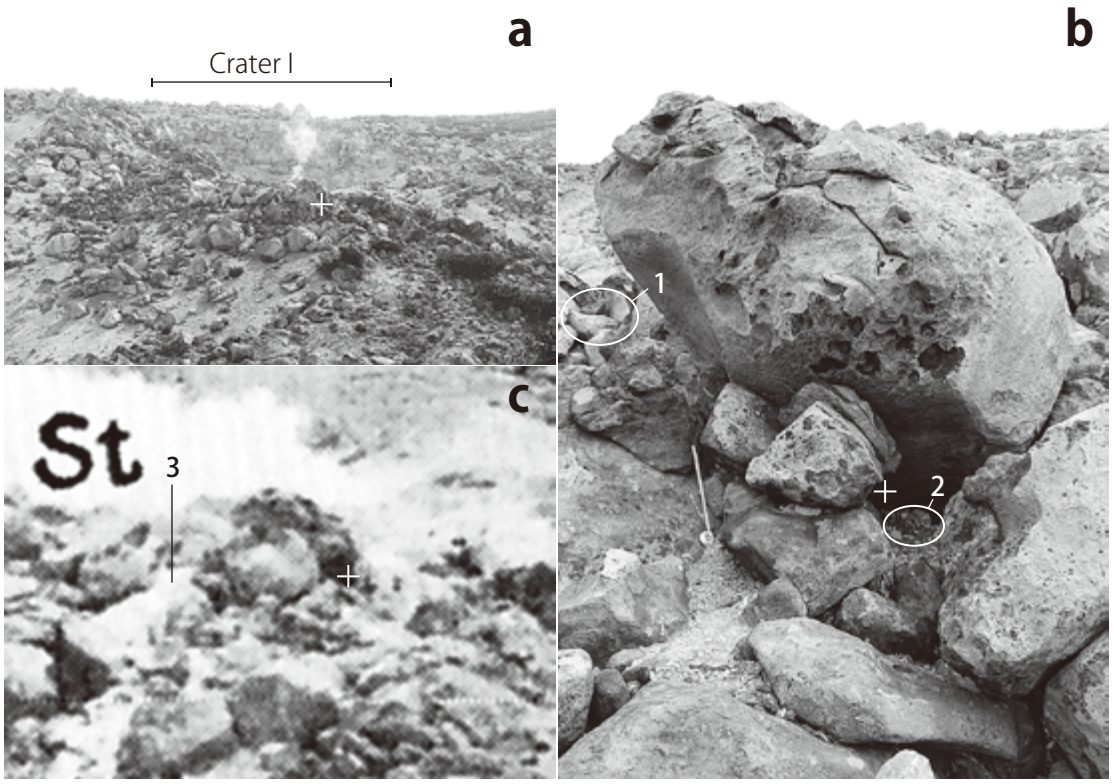


**Fig. 3.** Exact location of pahoehoe sulfur (+) and 1936-molten sulfur flow shown in the photograph of Watanabe & Shimotomai (1937) (c). **1**: Present aspect at the location where a branch stream of molten sulfur flowed in 1936. **2**: Broken sulfur pieces. **3**: Subsidiary stream of molten sulfur. **a**: July 19, 2017. **b**: July 31, 2017. **c**: Sept. 15, 1936.

from its original place, because the contact zone on the specimen's surface had not touched to any rock surface when it was found, 2. the specimen had been broken into a half (portion 2 and 3), 3. many small broken pieces of sulfur scattered around the specimen. Those evidences imply that the pahoehoe sulfur was intentionally left at the location by a miner.

This is the author's imagination: a miner found the pahoehoe sulfur under the rock. Because the shape of the sulfur lump was perfect and he understood its precious value, after once he took out the lump, he returned it to the original place hoping someone might find it years later, while any other sulfur lumps around the specimen were mined.

## The feature of the pahoehoe sulfur

The specimen is composed of three portions as shown in Fig. 5.

Portion 1 was found in the narrow tunnel connecting the site of subsidiary stream of mol-


**Fig. 4.** Pahoehoe sulfur in the under-rock space. Strike and dip of the sulfur are N60°E and 15°S respectively.


**Fig. 5.** Three portions of the specimen taken out of the under-rock space. Right: Portion 1 (Fig. 6). Middle: Portion 2 (Fig. 7). Left: Portion 3 (Fig. 8).

ten sulfur (no sulfur lump can be seen today) and the under-rock space. Portion 2 and 3 used to be one lump but it had been broken into a half. Those portions of specimen are light green to yellow in color.

The specimen contained rock fragments in a few millimeters in diameter and they can be observed on the surface and fracture. When the sulfur was liquid, it contained those rock fragments in it but whether they had been involved during the way flowing to this site or they were originally came from Crater I is unknown.

Air bubble cavities are observed on the fracture surface of portion 2 and top surface of those three portions of specimen but those cavities are not seen so much around the quenching margin contacting to the ground and surrounding rock surface. It indicates that when the molten sulfur flowed into the under-rock space, the bottom of the sulfur lump and contact zone cooled and hardened immediately. As the molten sulfur cooled some substances (for instance hydrogen sulfide) doped in the melted sulfur came out as gas forming the bubble in the liquid. Those bubble transported upward and escaped from the surface while making the cavities.

Rounded small particles in green in several millimeters in diameter are observed on the bottom surface of the specimen as shown in the enlarged bottom view of Fig. 6. They are Tear-Drop sulfur grains reported by Yamamoto (2017).

Portion 1 indicates relatively large proportion of contact area with surrounding rock surface because it went through a narrow tunnel (Fig. 6). Unfortunately the author could not identify the direction of the specimen at the tunnel because the space was so narrow that it was hard to observe inside the space. However it seems that the molten sulfur flowed leftward as the arrow showing in the upper left photograph of Fig. 6 because the end of the specimen has no fracture. At the exit of the tunnel the molten sulfur dripped on the boss of portion 2.

Fig. 7 shows the portion 2. The molten sul-

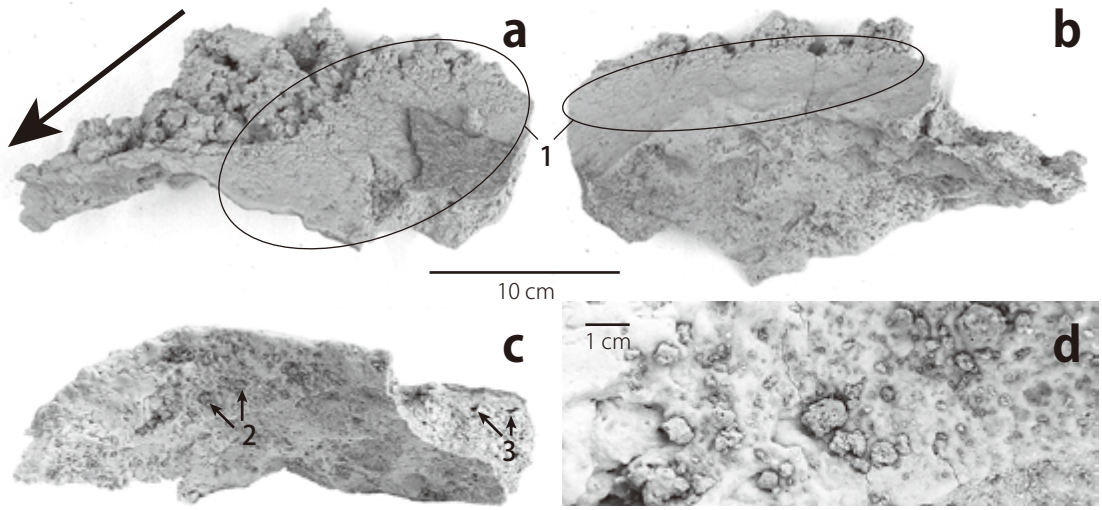


**Fig. 6.** Portion 1. The upmost stream of molten sulfur flow in those three portions. **a, b**: Side biew. **c**: Bottom view. **d**: Enlarged bottom view. **1**: Contact surface with rock surface. **2**: Tear Drop sulfur. **3**: Air bubble cavities. Arrow means assumed flow direction.

fur was supplied at the boss towering at a part of the top surface of portion 2 from the narrow tunnel and spread out in the under-rock space. The top surface of the portion 2 has a ropy pattern which means the top surface of the molten sulfur cooled and hardened at first while the inner body of molten sulfur was still hot with low viscosity and it flowed while dragging the top surface. Air bubble cavities are especially obvious on the top surface and rock fragments are also observed. On the surface of fracture, air bubble cavities are especially well observed. However cavities are not observed in the quenching margin while more cavities are seen in the upper part of the fracture surface because the volcanic gas transported upward after bubbling.

The Fig. 8 shows the portion 3 and ropy pattern is well observed on the top surface. Molds formed by contacting to the ground and Tear-Drop sulfur grains sinking to the main body are observed on the bottom view.

## How was this pahoehoe sulfur created

It seems that the pahoehoe sulfur was created at later stage of 1936-eruption because the sulfur came from the subsidiary stream deviating from the main flow which had been fulfilled the flow course and the molten sulfur overflowed to form the subsidiary stream. The narrow stream of the molten sulfur went into a narrow tunnel under

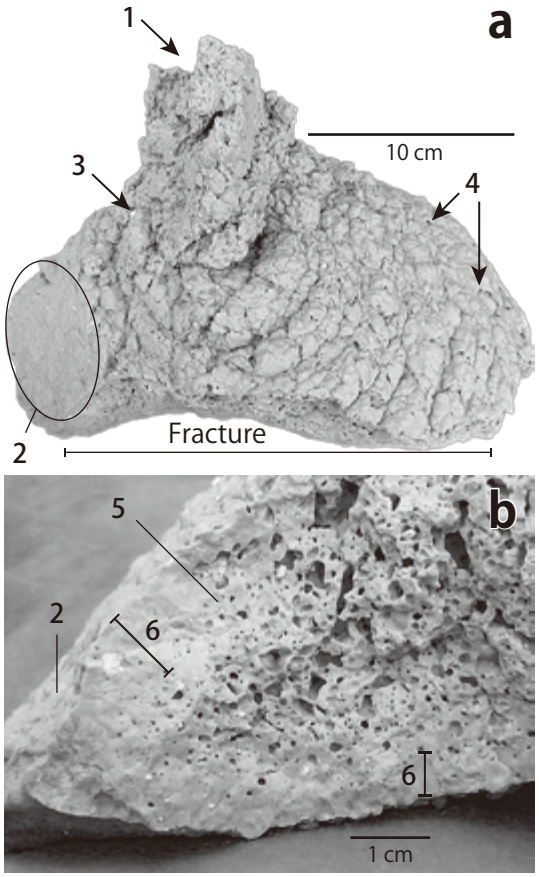


**Fig. 7.** Portion 2. **a**: Top view. **b**: Enlarged side view. **1**: Towering boss on which molten sulfur dripped. **2**: Contact surface with rock surface. **3** Rock fragment. **4**: Air bubble cavities. **5**: Fracture surface. **6**: Quenching margin.

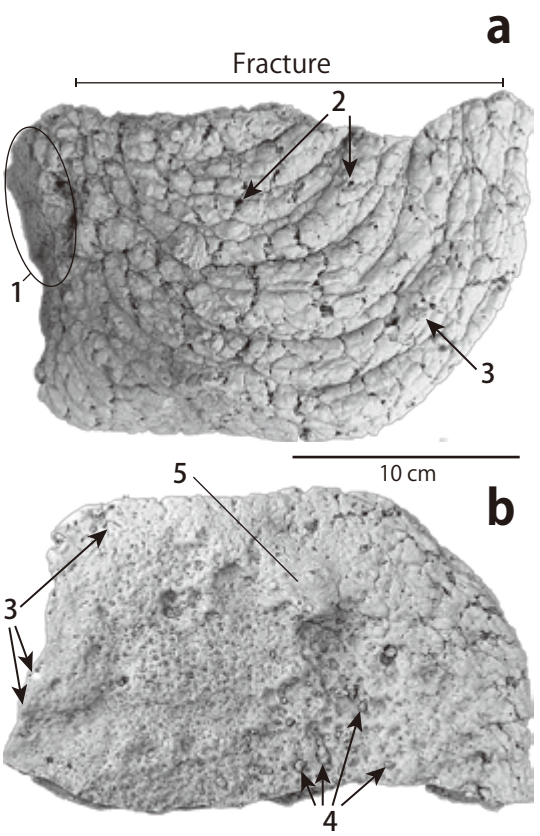


**Fig. 8.** Portion 3. **a**: Top view. **b**: Bottom view. **1**: Contact plane with rock surface. **2**: Air bubble cavities. **3**: Rock fragments. **4**: Tear Drop sulfur. **5**: Contact surface to the ground.

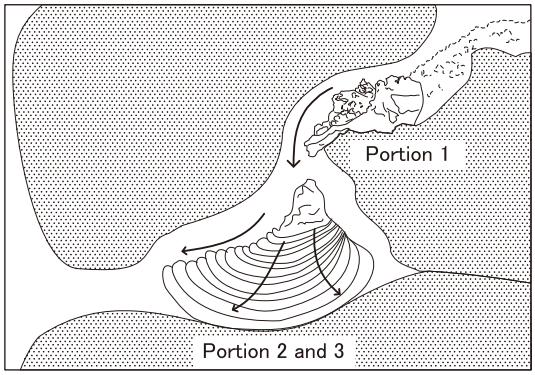


**Fig. 9.** Schematic diagram of the molten sulfur flow which formed the pahoehoe sulfur in 1936.

the large rock and then cascaded to the underrock space to form the pahoehoe sulfur (Fig. 9).

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**日本の北海道知床硫黄山山腹で硫黄でできたパホイホイ溶岩が発見される：山本睦徳**

硫黄でできたパホイホイ溶岩「パホイホイ硫黄」が北海道の知床硫黄山で発見された．筆者が発見したパホイホイ硫黄は，1936年噴火溶融硫黄流の本流からはずれた支流沿いの岩の下の空間にあった．採取した試料は，低い粘性の溶融硫黄が冷え固まることにより形成されたもので，パホイホイの特徴である縄目状模様を表面に持つ．試料は非常に貴重で価値のあるものである．このパホイホイ硫黄は人類共通の遺産として国の天然記念物に指定される十分な価値を有している．