YAMAGUCHI PREFECTURE FIELD TRIP

SEG KYUDAI REPORT

BY

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March and August 2022

Observation of Granite types and related Skarn deposits at Yamaguchi Prefecture, Southwestern Japan.

Field Trip Itinerary

Schedule			
Date	**Time**	**Location**	**Activity**
19/03/2022	9:30	Kyushu university Ito campus	Observation and magnet susceptibility measurement of Granite outcropped in The campus
	10:00		Departure
	12:00	Restaurant	Lunch
	13:00	Naganobori mine	Observation of Naganobori skarn deposit and related granite porphyry (measurement of magnet susceptibility)
	16:00		Departure
	18:00	Toyoko-Inn	Stay overnight
	8:00		Departure
	9:00	Yamato mine	Observation of Yamato skarn deposit And related granodiorite (measurement of magnet

20/03/2022			susceptibility)
	10:30		Departure
	11:00	Akiyoshido limestone cave	Observation of limestone cave related to Naganobori skarn deposit
	12:30		Departure
	13:00	Restaurant	Lunch
	16:00	Fukuoka	Back to Fukuoka
11/08/2022	9:00	Kyushu university	Departure
	10:00	Kawara skarn province	Observation of Kawara skarn deposit and related granites
	12:00	Restaurant	Lunch
	13:00	Kawara skarn province	Observation of Kawara skarn deposit and related granites
	17:00	Fukuoka	Back to Fukuoka

Geology of Kyushu Prefecture

Northern Kyushu, southwest Japan, is underlain regionally by Cretaceous granitic complexes that associate some bodies of metamorphic rocks (Fig. 1; Karakida, Tomita, Shimoyama, & Chijiwa,1994; Nishimura, 1998,)

High-pressure and low-temperature metamorphic complexes make up the northern part of Kyushu. These are divided into the Carboniferous to Permian Renge metamorphic complex and Triassic to Jurassic Suo metamorphic complex and are intruded by a lot of granitic complexes in the Cretaceous.

Stop 1: Itoshima Granodiorite

On the first day the Itoshima Granodiorite was visited. The area in the northern part of Kyushu has six Cretaceous granitic complexes. The older complexes such as the Fukae Granite and the Itoshima, Kitazaki, and Shikanoshima Granodiorites are foliated whereas the younger complexes such as the Sawara and Saga Granites are mostly massive (Fig.1).

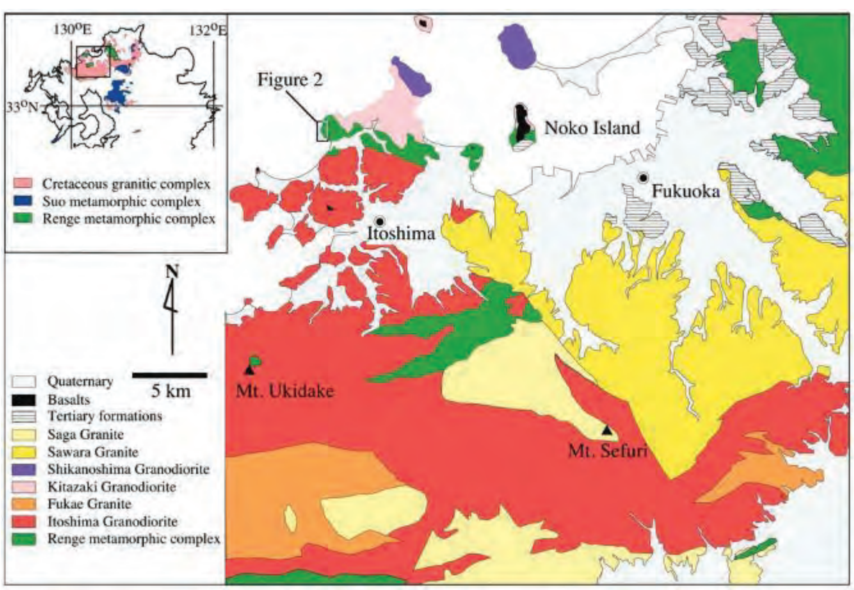

Figure 1 Geological map of the Renge metamorphic complex and Cretaceous granitic complexes in northern Kyushu, southwest Japan, simplified after Karakida et al. (1994).

Ito campus, the main campus of Kyushu University lies on the Itoshima Granodiorite that has intruded in the Early Cretaceous as a basement of western Fukuoka prefecture. The Itoshima Granodiorite is mainly composed of plagioclase, quartz, biotite, hornblende, while accessary minerals are K-feldspar, titanite, apatite, zircon, iron oxides, epidote, etc. Although the intrusion is widely distributed in the region, there is scarce mineralization except the Lithium pegmatite in Nagatare deposit. The Itoshima granodiorite could be classified into the magnetite-series granites, as Ishihara et al (1979)., reported. They have also pointed out that granite types (granite series such as magnetite series and ilmenite series) differ in the western and eastern of Kokura-Tagawa fault zone (Fig.2). In the excursion, we measured the magnetic susceptibility by using Magnetic Susceptibility Meter in the first day morning and compare the magnetic susceptibility in the afternoon of first day and second day morning at Naganobori deposit and Yamato deposit (Fig.3).

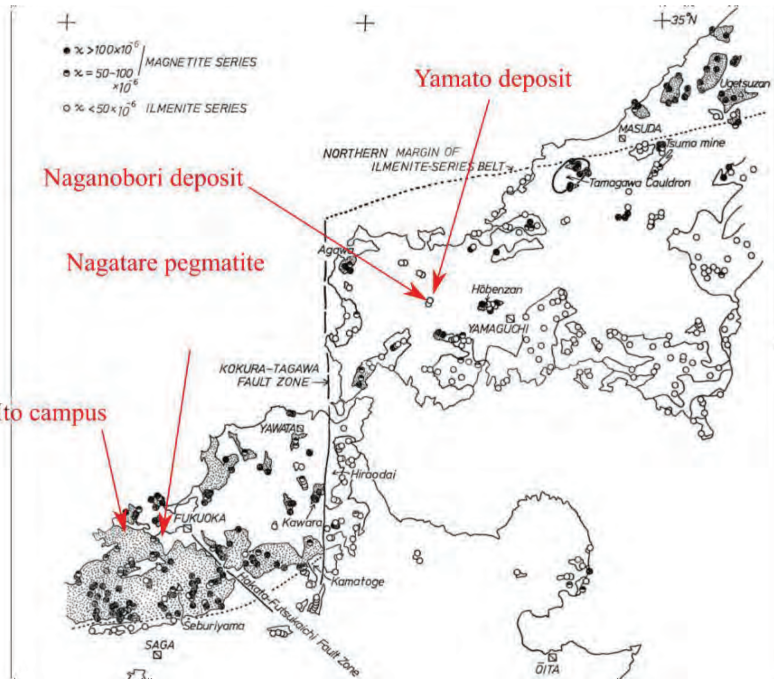

Figure 2 Distribution of the magnetite series and ilmenite series granitoids in the northern Kyushu. Domain of small dot corresponds to sample location where magnetic susceptibility were measured (modified from Ishihara et al., 1979) .

Figure 3 (a) Observation and group discussion of granite outcrop at Kyushu University, Ito Campus. **(b)** Magnet susceptibility measurement of magnetite series granite.

Geology of Yamaguchi Prefecture

Skarn deposits in Japan are related to felsic magmatic activity and are associated with granitic rocks. The skarn deposits of the Cretaceous to Paleogene age are associated with the Sanyo-Naegi granitic activity and are distributed along the boundary between the Sanyo-Naegi and Sanin- Shirakawa belts in southwestern Japan (Shimazaki, 1968, 1980; Nagashima et al., 2021). Some of these deposits are located in the Akiyoshi Plateau in the central part of Yamaguchi Prefecture. The Paleozoic accretionary complexes made up of the Akiyoshi Limestone Group host the skarn deposits in the area. They are a result of Cretaceous ilmenite-series granitic intrusions into the limestone. The skarn deposits of the Naganobori, Yamato, Kitabira, and Sanjo mines are the main ores that occur in the Akiyoshi Plateau (Fig. 4) (Kato, 1916; Oruga, 1921; Suzuki, 1932; Kato, 1937; Watanabe, 2009; Nagashima et al.,2021).

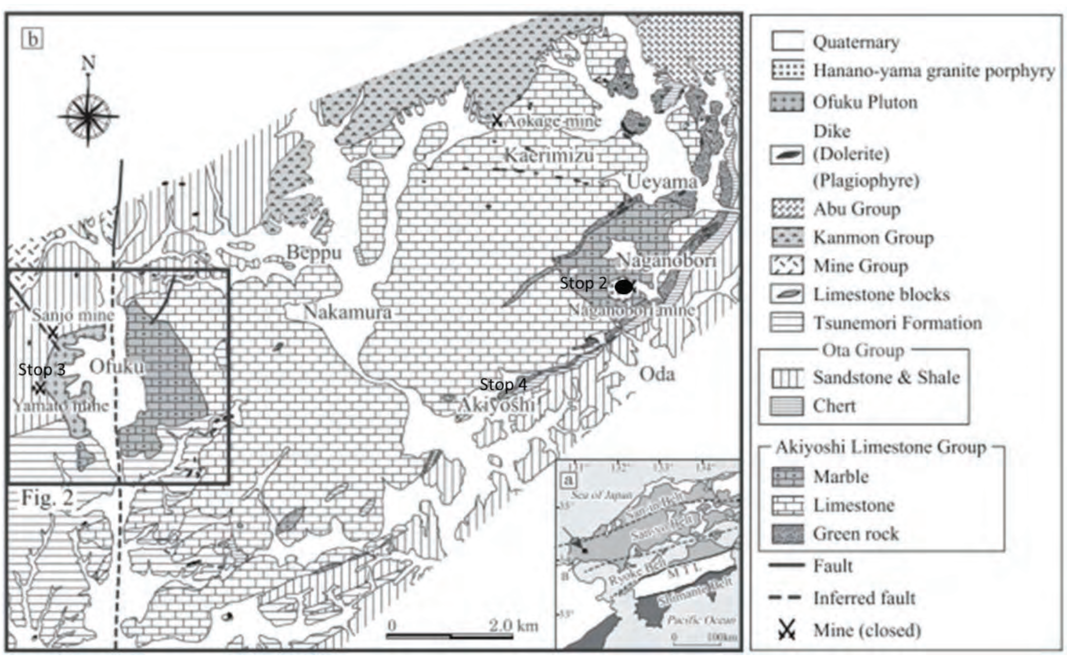

Figure 4 The geological setting of the Akiyoshi Plateau, Yamaguchi Prefecture, Japan (Ota, 1976).

Stop 2: Naganobori Mine

In the afternoon, team visited the second stop which is Naganobori mine. This is one of Japan's oldest copper mines, having been in operation since the seventh century (Ueda, 2002). In the period between 1908 and 1912, 1144 tons of copper were produced from the Umegakubo and Oda deposits of the Naganobori mine (Kato ,1916) (Fig.5). The copper deposits of the Naganobori skarn type are related to granitic rocks known as the Hanano–yama granite porphyry with low magnetic susceptibility (0.26) (Fig.6). Sixteen principal skarn type deposits are distributed near to the Hanano–yama granite porphyry and its vicinity. Among those the Imori, Eboshi, Hanano–yama, Hakujiki, Ogiri, and Oda deposits all form part of the Naganobori copper mine. Imori deposit, previously known as the Naganobori deposit, occurs along the bedding plane between the limestone and greenstone, and the others occur along the contact with limestone (Kato, 1916, Ikeda, 2015). Eboshi deposit occurs in the contact between the granite–porphyry and limestone. It occurs as a large irregular mass, rudely tabular inform, of about 100 m in length, 10 m maximum width and the depth of more than 75 m. The deposit elongates in a west-to-east direction and has an inclination of around 65° towards south. The orebody mainly comprises of hedenbergite and garnet skarns mingled with metallic ores (Nagashima, 2021). The occurrence and chemical compositions of hedenbergite and garnet (andradite) skarns, indicate that significant quantities of iron and silica were injected from the consolidating granite–porphyry magma to the limestone. Hence the main deposit or the skarn mass has been formed by the process of metasomatism (Fig.5).

Figure 5 (a, b) Observation of copper ore minerals at Naganobori copper mine- museum. **(c)** Explanation on the history of mining activities including the copper smelting process at the Naganobori copper mine- museum.

Figure 6 (a) Granitic rocks related to the copper deposits of the Naganobori skarn type. **(b)** Low magnetic susceptibility of related Ilmenite series granitic rocks near Naganobori mine.

Stop 3: Yamato Mine

Yamato mine previously known as Ofuku mine (until 1940), located at Ofuku, Yamaguchi Prefecture, Japan was one of the major producers of Cu ores in 1915 until the cessation of mining in January 1962 (Fig.8) (Shimazaki, 1968, 1980: Miyake and Akatsuka, 1963). The skarn deposits at Yamato mine are associated with ilmenite series granitic activity and the mine occurs near the western part of the Akiyoshi limestone (Fig.7a). Three main skarn type deposits in the Yamato mine are the Fukuju, Daido, and Dotoko deposits (Fig. 4) (Suzuki, 1932; Ueno and Doi, 1956). The skarn deposits in the Yamato mine are hosted by lens or small, massive bodies of limestone within the latest Paleozoic cherts and slates. The Cretaceous granitoids known as the Ofuku granitic rock intruded the sedimentary formations above. The ores at the Yamato mine are of two types, primary sulfide type with skarn minerals and an oxidized type containing secondary Cu-bearing minerals such as malachite and Chrysocolla. The latter is an alteration product of the former. Primary sulfides are associated with fractures in gangue minerals and wall rocks in the massive ore. Ore minerals such as chalcopyrite, galena, bornite, sphalerite, arsenopyrite, pyrite and molybdenite, and gangue minerals including garnet (Fig.7b), hedenbergite, wollastonite, diopside, calcite, epidote, tremolite, vesuvianite, mica, scheelite, and quartz are some of the minerals identified at Yamato mine (Fig.7c-d). (Ueno and Doi, 1956). Preisingerite with an ideal formula of $Bi_3(AsO_4)_2O(OH)$ and philipsburgite $(Cu, Zn)_5Zn(AsO_4,PO_4)_2(OH)_6.H_2O$ were recently reported at Yamato mine (Ohnishi et al., 2007; Shirose and Uehara, 2011). In 1952-1953 the copper and silver contents of ores produced from the Yamato mine were 4.2-7.8% and 40-220g/t, respectively. The scheelite-rich part produced tungsten contents of 5-10wt% WO_3 (Ueno and Doi, 1956).

Figure 7 (a) Entry of the Yamato mine deposit. **(b)** Garnet associated with skarn mineralization observed at Yamato mine. **(c-d)** Observation of ore minerals and the associated gangue minerals at Yamato mine.

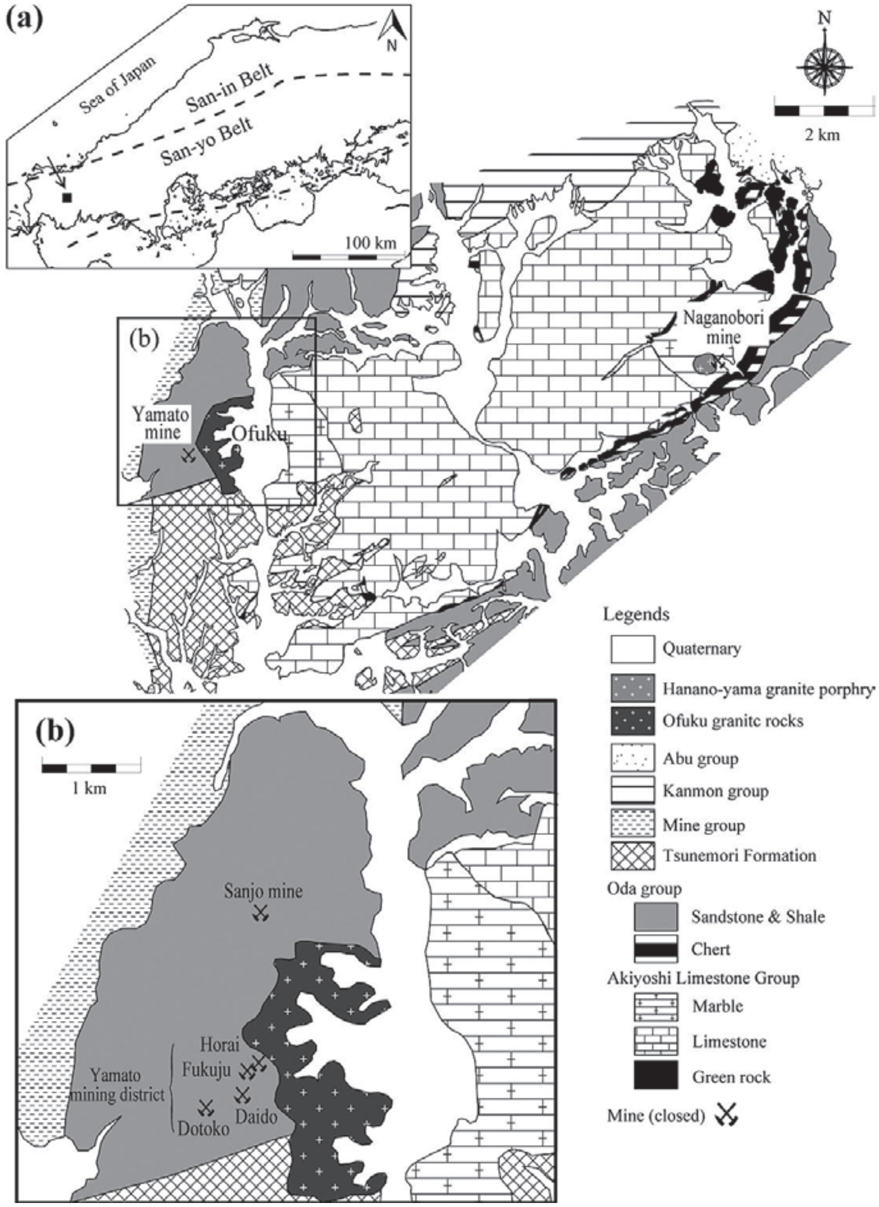

Figure 8 Geological maps illustrating the geology of the Akiyoshi plateau and the periphery and the distribution of ore deposits within the Yamato mining area (Ota, 1976; Kato, 1916).

Stop 4: Akiyoshido Limestone Cave

On the second day the Akiyoshido Limestone Cave was the first stop to be visited. This cave is one of the largest and longest limestone caves in Japan (Fig. 9). The Akiyoshi Plateau consists of the Akiyoshi Limestone Group, the Ota Group, and the Tsunemori Formation of the Permian accretionary complex. The Akiyoshi limestone occurs in the mine city in the center of Yamaguchi Prefecture, Japan (Fig. 4b and Fig. 8). The Akiyoshi Limestone Group consists of Carboniferous, Permian limestone, and small Cretaceous igneous intrusions (Ota, 1976). The Carboniferous to Permian basalts in the Akiyoshi Limestone Group are overlain by shallow-water limestone. Limestone in the Akiyoshi Limestone Group can be divided into four facies such as skeletal-oolitic grainstone, muddy limestone, muddy limestone-skeletal grainstone and reefal limestone (Fig.9a) (Sano, 2006). The green rocks are narrowly distributed to the east of Yeyama, through the southwest of Naganobori to Akiyoshi and the overlying limestone is widespread in the Akiyoshi Plateau (Fig.10). Marble was produced by contact metamorphism to the limestone in Naganobori and Ofuku by igneous intrusions (Fig. 4b). The skarn deposits in the Akiyoshi Plateau occur at or near the contacts of the Hanano-yama granite porphyry and the Akiyoshi limestone. These were visited as the final stop of the first section of the field excursion (Fig.9a-c).

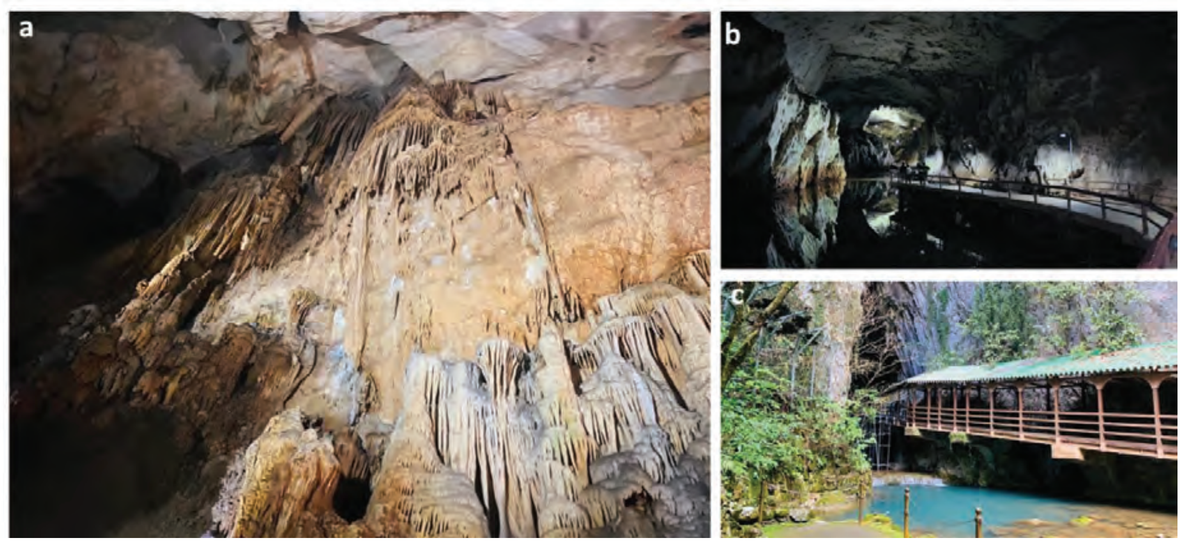

Figure 9 (a) Limestone observed at the Akiyoshido Limestone Cave. **(b)** The sightseeing course in the cave, which is about 1 km in length, with a constant temperature of 17 °C. **(c)** The entrance of the cave in Yamaguchi prefecture.

Figure 10 Observation of the Akiyoshidai limestone from the Akiyoshi plateau.

Stop 5: Kawara skarn province

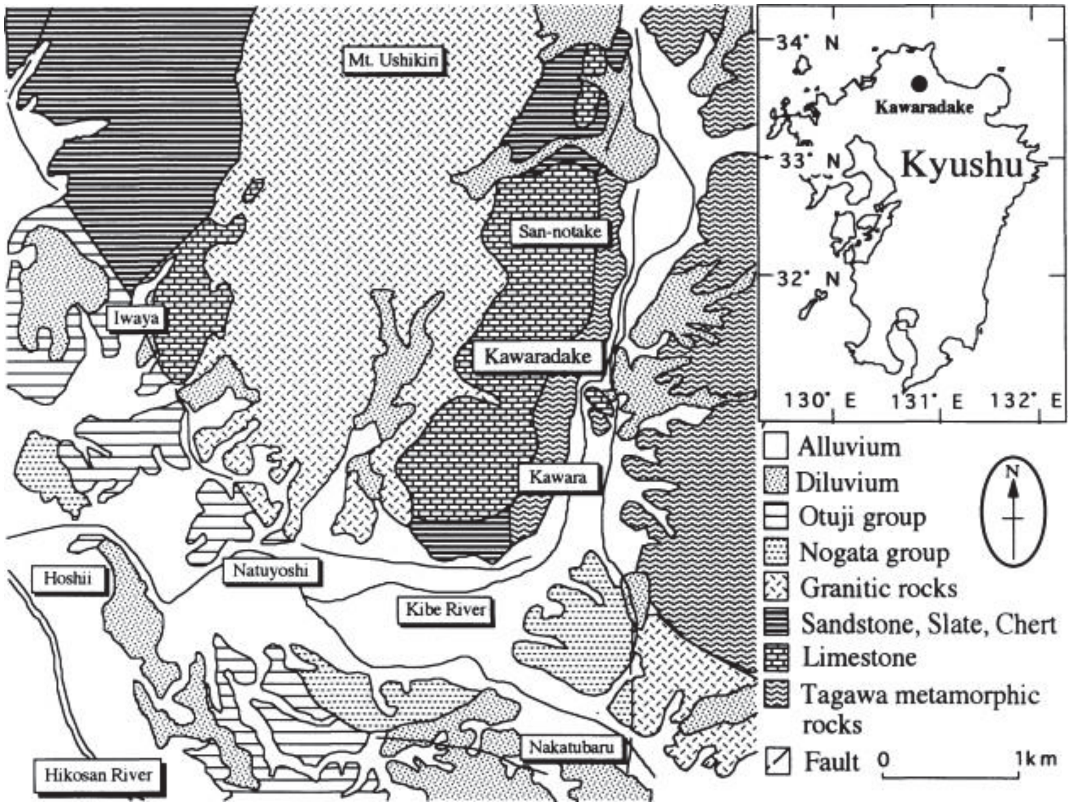

Figure 11 Geological map illustrating the geology of Kawara province (Ohara and Tomita, 1978)

On the final section of the field excusion the team visited the Kawara skarn province. Mt. San-notake host several contact metasomatic hydrothermal ores distributed in the contact between Paleozoic limestone and Kawara granodiorite intrusion that occurred in the Cretaceous period (Fig.11) (Ueno et al., 1996). Granite intrusion at Kawara is a magnetite series granite, (oxidized granite) and we can observe the mineralization of copper, iron, bismuth, and tellurium (Fig.12). Skarn mineralization in the area can be divided into the clinopyroxene and garnet zone. The two zones can be further divided into subzones based on the mineralogical assemblages. The clinopyroxene zone is subdivided into three zones, A, B, and C. A-zone consists of minerals such as plagioclase, alkali feldspar, quartz, hornblende, clinopyroxene, actinolite, and opaque minerals. B-zone is composed of quartz, clinopyroxene, garnet, and

opaque minerals. C-zone consists of clinopyroxene, garnet, calcite, and opaque minerals. The garnet zone is also subdivided into zones D and E. D-zone consist of garnet, clinopyroxene, chlorite, epidote, and opaque minerals, and lastly the E-zone comprises of garnet, calcite, epidote, actinolite, quartz, and opaque minerals. Zones C, D, and E, as well as limestone host sulfide mineralization. The common ore minerals include chalcopyrite, pyrite, pyrrhotite, and sphalerite. Bi-Te and Ag minerals were recorded as accessory minerals such as bismuthinite, native bismuth, tetradymite, hessite, wittichenite, gustavite, aleksite, cuprobismutite, cosalite, and argentite (Fig 12a).

Figure 12 (a-b) Kawara skarn province outcrop and measurement of magnetic susceptibility of the skarn deposit related granodiorite intrusion.

References

Ishihara, Shunzo, Yoshifumi Karakida, and Kouhei Sato, Distribution of magnetite- and ilmenite-series granitoids in the Kitakyushu-Western Chugoku area, especially in the Kokura-Tagawa fault zone, Geological Magazine, 1979, v. 85, no. 1, p. 47-50 (In Japanese).

Kato, T. (1916) The Ore Deposits in the Environs of Hanano–yama, near the Town of Oda, Province of Nagato, Japan. The Journal of the Meiji College of Technology, 1, 1–95.

Kato, T. (1937) New geology of ore deposits. pp. 757, Fuzambo, Tokyo (in Japanese).

Miyake, H. and Akatsuka, K. (1963) Geological notes of the Yamato mine, Yamaguchi Prefecture. Geological Report of the Hiroshima University, 12, 381–399.

Nagashima, M. Morishita, Y. Imoto, Y. and Imaoka, T. (2021). Ore and skarn mineralogy of the Eboshi deposit of the Naganobori copper mine, Yamaguchi, Japan. Journal of Mineralogical and Petrological Sciences, 200818.

Ogura, T. (1921) Investigation report of the Naganobori mine and Oda mine. Report, Geological Survey of Japan, 82, 49–72 (in Japanese).

Ohnishi, M., Kusachi, I., Kobayashi, S., Fujiwara, Y. and Nishida, K. (2007) Preisingerite from the Yamato mine, Yamaguchi Prefecture, Japan. J. Mineral. Petrol. Sci., 36, 61–65 (in Japanese with English abstract).

Ota, M. (1976) Geologic map of the Akiyoshi district. Bull. Akiyoshi-dai Museum, Natural History, 12, 1–34.

Sano, H., 2006. Impact of long-term climate change and sea-level fluctuation on Mississippian to Permian mid-oceanic atoll sedimentation (Akiyoshi Limestone Group, Japan). Palaeogeogr. Palaeoclimatol. Palaeoecol. 236, 169e189.

Sasaki, Y., Imaoka, T., Nagashima, M., Nakashima, K., Sonehara, T., Yagi, K., & Itaya, T. (2016). The Cretaceous Ofuku Pluton and Its Relation to Mineralization in the Western Akiyoshi Plateau, Yamaguchi Prefecture, Japan. Resource Geology, 66(2), 85-113.

Shimazaki, H. (1968) Genesis of pyrometasomatic ore deposits of the Tsumo mine, Shimane Prefecture. Japanese Journal of Geology and Geography, 39, 73–78.

Shimazaki, H. (1980) Characteristics of skarn deposits and related acid magmatism in Japan. Economic Geology, 75, 173–183.

Shirose, Y. and Uehara, S. (2011) Philipsburgite from the Yamato mine, Yamaguchi Prefecture, Japan. J. Mineral. Petrol. Sci.,

Suzuki, J. (1932) The contact metamorphic ore deposits in the environs of the Ofuku mine, province of Nagato, Japan. Journal of Faculty of Science, Hokkaido Imperial University, Series 4, Geology and Mineralogy, 70, 750–769.

Ueno, M. and Doi, K. (1956) The copper deposits of the Yamato mine, Yamaguchi Prefecture. Bull. Geol. Surv. Japan, 7, 167–176 (in Japanese with English abstract).

Watanabe, M. (2009) Naganobori mine. In Chugoku (Editorial Committee of Chugoku, Geological Society of Japan Eds.). Regional Geology of Japan, 6. Asakura Publishing Company, 453–454 (in Japanese).

References

Ishihara, Shunzo, Yoshifumi Karakida, and Kouhei Sato, Distribution of magnetite- and ilmenite-series granitoids in the Kitakyushu-Western Chugoku area, especially in the Kokura-Tagawa fault zone, Geological Magazine, 1979, v. 85, no. 1, p. 47-50 (In Japanese).

Kato, T. (1916) The Ore Deposits in the Environs of Hanano–yama, near the Town of Oda, Province of Nagato, Japan. The Journal of the Meiji College of Technology, 1, 1–95.

Kato, T. (1937) New geology of ore deposits. pp. 757, Fuzambo, Tokyo (in Japanese).

Miyake, H. and Akatsuka, K. (1963) Geological notes of the Yamato mine, Yamaguchi Prefecture. Geological Report of the Hiroshima University, 12, 381–399.

Nagashima, M. Morishita, Y. Imoto, Y. and Imaoka, T. (2021). Ore and skarn mineralogy of the Eboshi deposit of the Naganobori copper mine, Yamaguchi, Japan. Journal of Mineralogical and Petrological Sciences, 200818.

Ogura, T. (1921) Investigation report of the Naganobori mine and Oda mine. Report, Geological Survey of Japan, 82, 49–72 (in Japanese).

Ohnishi, M., Kusachi, I., Kobayashi, S., Fujiwara, Y. and Nishida, K. (2007) Preisingerite from the Yamato mine, Yamaguchi Prefecture, Japan. J. Mineral. Petrol. Sci., 36, 61–65 (in Japanese with English abstract).

Ota, M. (1976) Geologic map of the Akiyoshi district. Bull. Akiyoshi-dai Museum, Natural History, 12, 1–34.

Sano, H., 2006. Impact of long-term climate change and sea-level fluctuation on Mississippian to Permian mid-oceanic atoll sedimentation (Akiyoshi Limestone Group, Japan). Palaeogeogr. Palaeoclimatol. Palaeoecol. 236, 169e189.

Sasaki, Y., Imaoka, T., Nagashima, M., Nakashima, K., Sonehara, T., Yagi, K., & Itaya, T. (2016). The Cretaceous Ofuku Pluton and Its Relation to Mineralization in the Western Akiyoshi Plateau, Yamaguchi Prefecture, Japan. Resource Geology, 66(2), 85-113.

Shimazaki, H. (1968) Genesis of pyrometasomatic ore deposits of the Tsumo mine, Shimane Prefecture. Japanese Journal of Geology and Geography, 39, 73–78.

Shimazaki, H. (1980) Characteristics of skarn deposits and related acid magmatism in Japan. Economic Geology, 75, 173–183.

Shirose, Y. and Uehara, S. (2011) Philipsburgite from the Yamato mine, Yamaguchi Prefecture, Japan. J. Mineral. Petrol. Sci.,

Suzuki, J. (1932) The contact metamorphic ore deposits in the environs of the Ofuku mine, province of Nagato, Japan. Journal of Faculty of Science, Hokkaido Imperial University, Series 4, Geology and Mineralogy, 70, 750–769.

Ueno, M. and Doi, K. (1956) The copper deposits of the Yamato mine, Yamaguchi Prefecture. Bull. Geol. Surv. Japan, 7, 167–176 (in Japanese with English abstract).

Watanabe, M. (2009) Naganobori mine. In Chugoku (Editorial Committee of Chugoku, Geological Society of Japan Eds.). Regional Geology of Japan, 6. Asakura Publishing Company, 453–454 (in Japanese).

Financial statements

The SEGKyudai Field excursion was financially supported by the Stewart R. Wallace funding and the participants. Specifically, the Stewart R. Wallace Funding of 169467 JPY and 114 JPY from the participants were used to cover excursion expenses. They were used for car rental fee, accommodation fee, Cave entrance fee, highway fee, gas fee. Details are in the following table and receipts are on file at SEG HQ.

Table.1 Details of the fieldwork expenses

Date	Income(JPY)	Payment(JPY)	Remarks	Reciept number
	169467		Fund from SEG	
	114		Fund from participants	
2022/3/18-3/19		37510	Car rental	No 0658679, No 4023015344
2022/3/19		45600	Acommodation at Toyoko-inn Hotel	No 4029237
2022/3/20		13000	Cave fee	No 0222-0004
2022/3/19-3/20		14900	Highway fee	
2022/3/20		6952	Gas fee	No 7190-06, No 3499-01, No 1703, No 1702
2022/8/11		44660	Car rental fee	No 0650323, No 0650321, No 0650335
2022/8/11		3149	Gas fee	No 6237-05, No 6239-05, No 6143-05, No 6133-02
2022/8/11		3810	Highway fee	
Total	169581	169581		