

UBC SEG Field Trip Report 2025

Theme: Volcanic Systems - Epithermal Gold and Kuroko-type VMS deposits in Japan

University of British Columbia Student Chapter of the Society of Economic Geologists (SEG)

Date: 11-24 May 2025

Route: Fukuoka – Kagoshima – Miyazaki – Akita – Sendai



Sakurajima, Kyushu, Japan



Acknowledgement:

We gratefully acknowledge the Prospectors and Developers Association of Canada (PDAC) for their continued support through the Field Trip Funding, which has served as the cornerstone of funding for initiating our field excursion. We also thank the Society of Economic Geologists (SEG) and the Canadian Society of Petroleum Geologists (CSPG) for their generous financial support.

We extend our sincere appreciation to our industrial sponsors, including Teck Resources, B2Gold Limited, Galore Creek Mining Corporation, Snowline Gold Corporation, Precision Petrographic Limited, SJ Geophysics and SGS. Their sponsorships have allowed students to fully engage in field-based learning activities. In particular, we are deeply grateful to Teck Resources for their ongoing support over the years and for serving as the premier sponsor of this trip.

We thank our industrial representatives, Linda Dandy and Jean Pautler for their generous donation towards the trip. Finally, we would like to thank the SEG Student Chapters at Kyushu University and Akita University for their invaluable logistical support, facilitation of industry contacts, and guidance throughout the field trip.



Trip Overview:

From May 11 to 24, 2025, the UBC SEG Student Chapter embarked on its annual international field trip, this year to the Kyushu and Akita regions of Japan. The trip included a total of 31 participants. Of these, 17 joined the entire excursion, while 7 students and professors from Kyushu University and Akita University participated in their respective regional segments. The primary focus of the trip was to study the geology of epithermal gold and Kuroko-type volcanogenic massive sulfide (VMS) deposits and their relationship with active volcanic systems.

Japan lies at a tectonic triple junction, where the Philippine Sea and Pacific plates subduct beneath the Eurasian plate. This dynamic geological setting has led to the formation of numerous epithermal gold and VMS deposits across the country. Among these, the Kyushu and Akita regions are particularly prospective, due to their long history of mining. Mining activity in Japan dates back to 708 AD at the Osarizawa Mine, one of the oldest known mines in the country. Today, several exploration projects are ongoing in Kyushu and Akita, reflecting renewed interest in these historical mining areas. During the trip, we visited several active exploration sites, including the Hoshino Project, Akeshi Mine, and Tamayama deposit. We also explored a variety of geothermally active areas and gained firsthand insights into the geology of active volcanic systems.

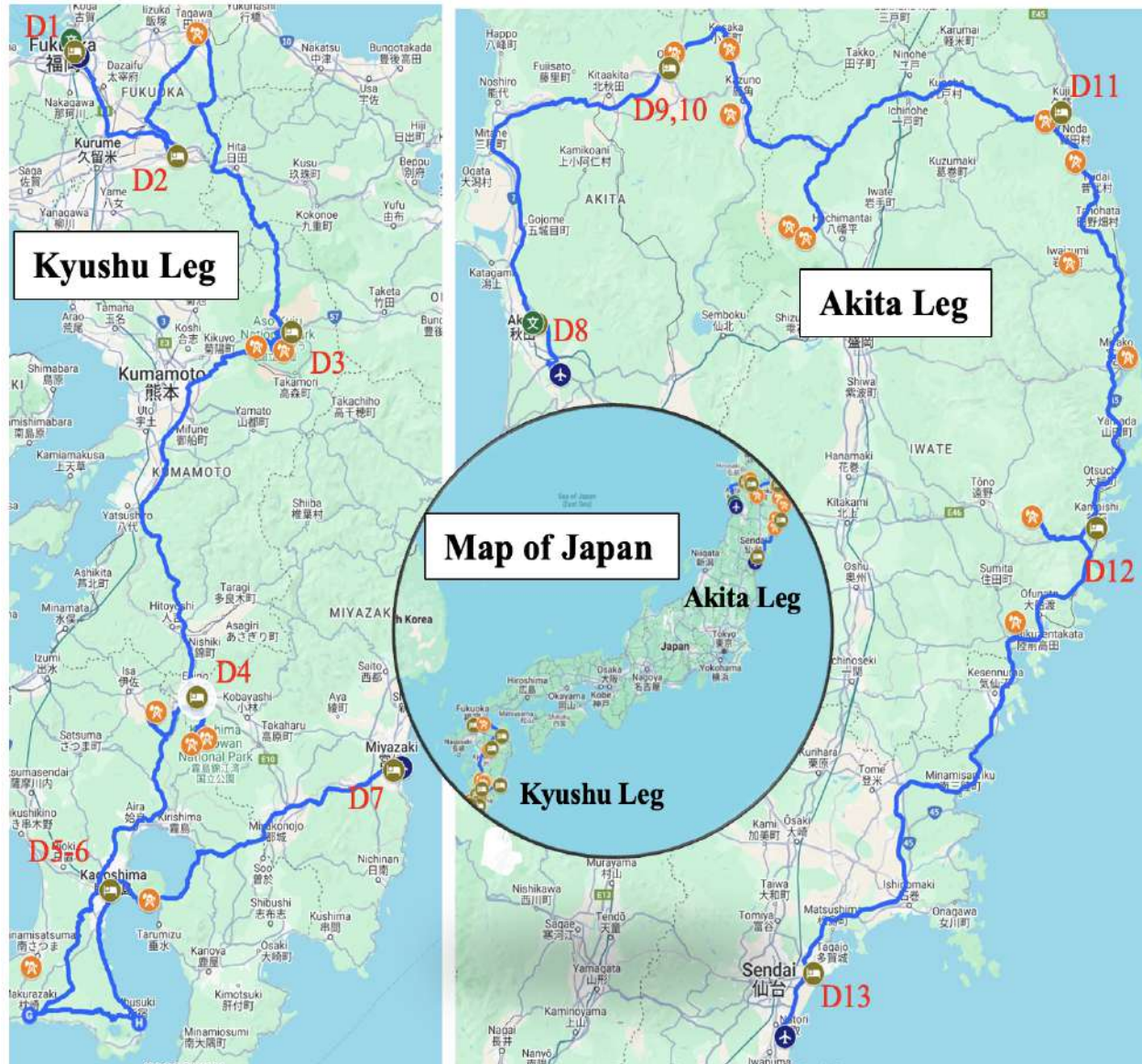
Each site visit was complemented by geological presentations. Students had the opportunity to examine outcrops and drill cores in detail and engage in interpretive discussions with on-site geologists. Interactions from industry professionals further enriched our understanding of mineralization processes and the regional geological framework.



List of Participants:

#	Name	Affiliation	Status	Leg
1	Sze Yui (Gary) Fung	University of British Columbia	PhD student	Both
2	Cassis Lindsay	University of British Columbia	MSc student	Both
3	Maya Aviva Saldanha	University of British Columbia	BSc student	Both
4	Hiroshi Nasuno	University of British Columbia	BSc student	Both
5	Carolina Marín Suárez	University of British Columbia	MSc student	Both
6	Zoe Lynn	University of British Columbia	MSc student	Both
7	Warren Wegener	University of British Columbia	MSc student	Both
8	Raghvi Sharma	University of British Columbia	BSc student	Both
9	Tenoch Galeana Comejo	University of British Columbia	MSc student	Both
10	Spyridon Fragkou	University of British Columbia	PhD student	Both
11	Mareike Leiter	University of British Columbia	MSc student	Both
12	Maxwell Porter	University of British Columbia	MSc student	Both
13	Nicole Moerhuis	University of British Columbia	Postdoctoral research fellow	Both
13	Linda Dandy	Independent	Industrial Representative	Both
14	Sipke (Syd) Visser	SJ Geophysics Ltd.	Industrial Representative	Both
15	Alex Visser	SJ Geophysics Ltd.	Industrial Representative	Both
17	Jean Pautler	Independent	Industrial Representative	Both
18	Kotaro Yonezu	Kyushu University	Professor	Kyushu
19	Akane Ito	Kyushu University	Professor	Kyushu
20	Say Sokvireak	Kyushu University	PhD student	Kyushu
21	Novero Joshua	Kyushu University	PhD student	Kyushu
22	Kazushi Otani	Kyushu University	BSc student	Kyushu
23	Ayaka Nakase	Kyushu University	MSc student	Kyushu
24	Kizaki Kosuke	Kyushu University	MSc student	Kyushu
25	Masahiro Sunada	Akita University	PhD student	Akita
26	Agangi Andrea	Akita University	Professor	Akita
27	Yasuhiro Awano	Akita University	MSc student	Akita
28	Ran Takeda	Akita University	MSc student	Akita
29	Kazuya Fujita	Akita University	MSc student	Akita
30	Naohiro Kishi	Akita University	MSc student	Akita
31	Manuel Nopeia	Akita University	Postdoctoral research fellow	Akita

Trip Itinerary:





UBC SEG Field Trip Report 2025



D #	Date	Event		Lodging
0	10th May (Sat)	(Fly from Vancouver YVR to Fukuoka FUK)		N/A
1	11th May (Sun)	Arrival in Fukuoka		montan HAKATA
2	12th May	Morning	Visit Kyushu University Ito campus	AZ hotel Ukiha
		Afternoon	Hoshino exploration outcrops	
3	13th May	Morning	Hoshino exploration site core shed	Kurokawa Mori no Cottage
		Afternoon	Chikuhō coalfield: Tagawa coal museum, Coalseam outcrop)	
4	14th May	Morning	Aso volcanoes: Daikanbo view, Nakadake crater, Aso volcano museum	Ramune Onsen Senju no Sato
		Afternoon	Ebino Eco-museum centre, Kirishima stemming ground	
5	15th May	Morning	Ogiri geothermal powerplant	Kagoshima Art Hotel
		Afternoon	Sakurajima: Yonohira, Arisato, Beach, Buried Shrine gate	
6	16th May	Morning	Akeshi mine visit (High-sulfidation epithermal Au deposits)	Kagoshima Art Hotel
		Afternoon	Hinokami sea stack, Kaimondake volcano viewpoint, Ibusuki sand bath	
7	17th May (Sat)	Morning	Yoshino park graben viewpoint	Miyazaki Mango Hotel
		Afternoon	Satsuma-Kinzangura (Old Kushikino epithermal Au deposit)	
8	18th May (Sun)	Morning	Fly from Miyazaki to Akita	Crowne Plaza Akita
		Afternoon	Networking with Akita SEG/ Free time	
9	19th May	Morning	Akita – UBC Symposium, Mineral Industry Museum	Grand Park Hotel Odate
		Afternoon	Drive to Odate	
10	20th May	Kosaka mine visit (Kuroko-type VMS deposit)		Grand Park Hotel Odate
11	21st May	Morning	Osarizawa Mine	APA Hotel Hachinohe
		Afternoon	Goshogake and Tamagawa hot springs	
12	22nd May	Morning	Kuji Amber Museum	Hotel Route Inn Miyako
		Afternoon	Noda Tamagawa Mn deposit, Ryusendo cave and Jodogahama Beach	
13	23rd May	Morning	Kamaishi mine office	ANA Holiday Inn Sendai
		Afternoon	Tamayama Au deposit	
14	24th May (Sat)	Fly from Sendai SDJ to Vancouver YVR		N/A

12th – 13th May (Mon- Tue): Hoshino Exploration Project

On our first day in Fukuoka, we visited the Hoshino Exploration Project, about 30 km from Fukuoka city. The project targets epithermal gold deposits in the Middle Kyushu Epithermal Gold Province, hosted by Pliocene volcanic rocks with hydrothermal alteration and quartz veins. At the site, sinter deposits and shallow hydrothermal features indicate surface mineralization. After a safety briefing and geological overview from the project geologists, the group visited two outcrops. One outcrop near the drilling area revealed a N30E/70–80-oriented quartz vein (1–10 m thick) (Figure 1A), showing argillic alteration with smectite and iron oxides. Crustiform (Figure 1B) and bladed textures (Figure 1C) in the veins suggested gold deposition during boiling events

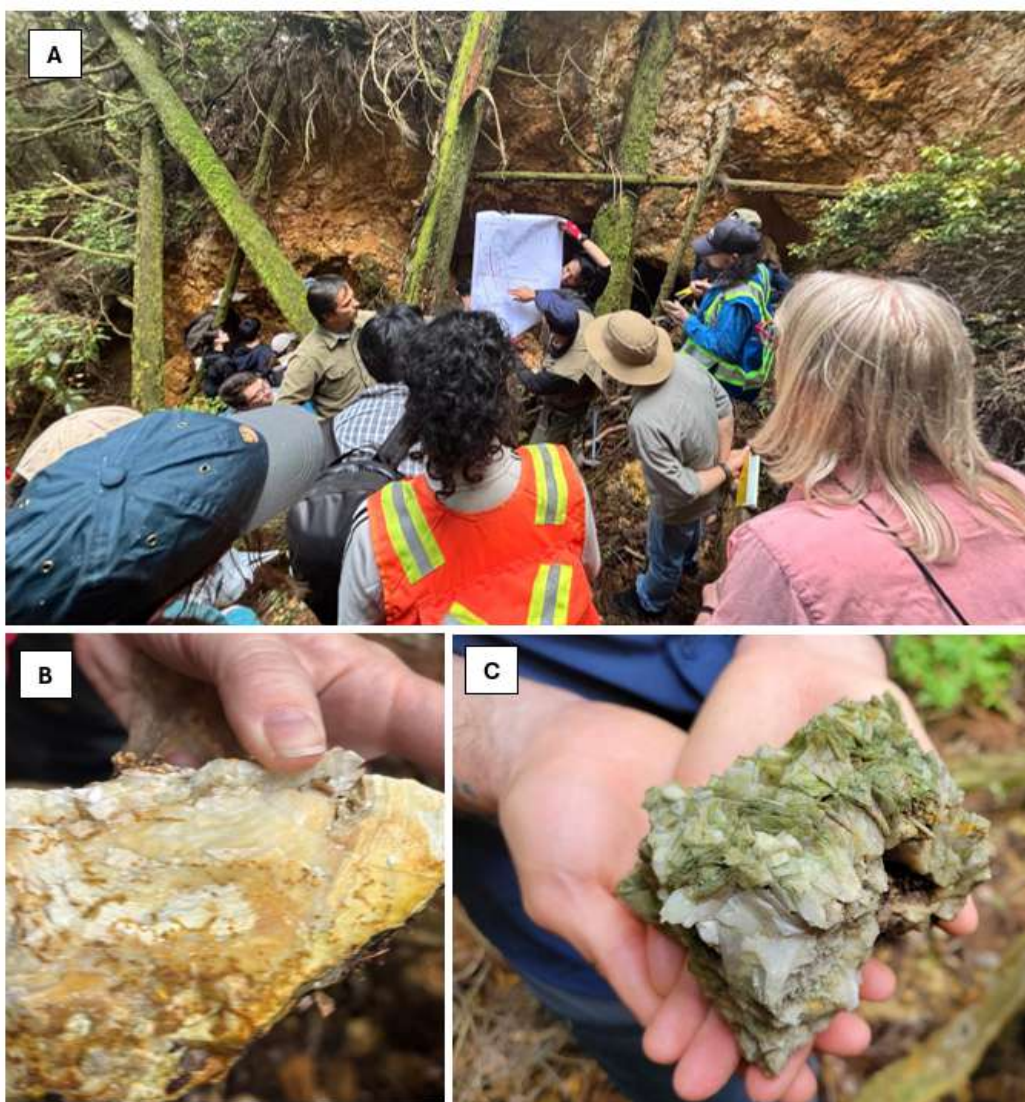


Figure 1: (A) Image of Outcrop 1, where the project geologist indicates the orientation of the quartz vein. (B) Rock sample showing crustiform texture. (C) Sample displaying bladed texture.

The second stop was a sinter outcrop, which showed crustiform textures and moldic cavities, features that are commonly considered pathfinders for mineralization. The presence of sinter, which forms from hydrothermal activity, is characteristic of the Hoshino area.

On the second day in Fukuoka, the group visited the Hoshino project's core shack (Figure 2A). The geologists provided further geological context. Within the core, we observed volcanic breccias, andesites, and hydrothermal breccias. These rocks hosted quartz veins with disseminated and clustered pyrite. Some hydrothermal breccias showed sulfide cement, and quartz veins ranging from 2 millimeters to 20 centimeters in width, often accompanied by disseminated pyrite and pyrite-only veins of variable thickness.



Figure 2: (A) Image of the group at the Hoshino Project core shack. (B) Drill core sample showing a quartz vein in hydrothermal breccia; the cement is composed of pyrite. (C) Pyrite vein in volcanic breccia.

The alteration observed in the drill core showed a clear vertical zonation. Near the top, argillic alteration with iron oxide staining was present, particularly marked by jarosite. This gradually transitioned into a quartz-sericite alteration zone, with abundant silica, quartz veins, and interbedded intervals of chloritic alteration.

At the final outcrop visited, a contrast between chloritic and argillic alteration was observed. This site featured hydrothermal breccias with sub-angular clasts in a siliceous matrix (Figure 3). The rocks contained disseminated sulfides, with pyrite being the dominant sulfide mineral.



Figure 3: Image of a hydrothermal breccia with silica cement and subangular to angular felsic volcanic clasts with disseminated pyrite.

13th May (Tue): Chikuhō Coalfield- Tagawa City Coal and History Museum + Coal Outcrop

Our group visited the Tagawa City Coal and History Museum in Fukuoka Prefecture, Japan, to explore the rich history of coal mining in the Chikuhō region. Before the visit, student's presentation provided an overview of the Chikuhō Coalfield's geology and highlighted its significance as Japan's most historically significant coal-producing area. Located in the northern part of Kyushu, the Chikuhō Coalfield was a major contributor to Japan's industrialisation from the late 19th century through the post-WW2 era. The coalfield comprises three principal stratigraphic groups: the Nōgata, Ōtsuji, and Ashiya Groups, with the Nōgata Group being the main coal-bearing formation. The coals are broadly classified as low-grade bituminous, with varying quality throughout the field.



Figure 4: Group photo outside the Tagawa City Coal and History Museum.

The museum, situated within the Coal Memorial Park, offers a comprehensive look into the history of coal mining in the region (Figure 4). The First Exhibition Hall provided insights into the formation and mining of coal, as well as the lives of coal miners. We observed models of mining equipment, including a replica of the Ita Shaft, which was once the largest in the Chikuhō area. The Second Exhibition Room showcased paintings and essays by coal miners, offering a personal perspective on their experiences. Notably, the museum houses a collection of works by Sakubei Yamamoto, a former coal miner, whose pieces were registered as Japan's first UNESCO Memory of the World in 2011. The collection can be viewed online at crossroadfukuoka.jp/fukuokajet.com+3artsandculture.google.com+3visit-tagawa.fukuoka.jp+3. The Third Exhibition Room displayed historical materials relating to the history and people of the

Tagawa region, providing context to the coal mining industry's impact on local communities. From the museum's balcony, we had a clear view of the preserved smokestacks (Figure 5) and the Statue of a Coal Miner and His Wife ("炭坑夫之像") (Figure 6).

In the afternoon, we visited a coal seam outcrop which revealed three parallel horizontal black beds within the sedimentary package, providing a clear view of the coal seams in the lithological sequence (Figure 7). This firsthand observation was valuable in understanding the geological context and structure of coal deposits.



Figure 5: Preserved twin brick smokestacks of the former Mitsui Tagawa Mine, visible from the Tagawa City Coal and History Museum.



Figure 6: Statue of a Coal Miner and His Wife ("炭坑夫之像") outside the Tagawa City Coal and History Museum. The monument honours the contributions and sacrifices of coal miners and their families during the peak of coal production in the Chikuhō Coalfield.



*Figure 7: Students observe coal seams within a sedimentary outcrop in the Chikuhō Coalfield.
The parallel black coal-bearing beds are clearly visible.*

The visit to the Tagawa City Coal and History Museum and the coal outcrop was both educational and inspiring. It deepened our appreciation for the Chikuhō region's pivotal role in Japan's industrial history and the resilience of the communities involved in coal mining. The museum's exhibits, particularly the personal accounts of miners, highlighted the human aspect of this industrial era. Additionally, the opportunity to observe the seams in outcrop further enhanced our geological understanding of coal formations.

14th May (Wed): Aso volcano

We visited the Aso volcano, starting off with the Daikanbo Caldera Geosite. At Aso, four super-eruptions occurred between 90,000 and 270,000 years ago which caused the land to subside and a caldera to form. Daikanbo Geosite provided an amazing panoramic view of the caldera, including the still-active Mt. Nakadake, and the city that now exists within the caldera (Figure 8).



Figure 8: Group photo at Daikanbo Geosite.

Then the group headed to the Nakadake crater where we saw a green, bubbling crater lake and could smell the sulfur in the air (Figure 9). Around the crater were solidified lava flows and volcanic bomb shelters, which were interesting to see and showed how active the area really is.

Then we went to the Aso Volcano Museum, where we learnt more about volcanoes in Japan and watched a short film titled '*Life and Culture in Aso*', which focused on how local communities live alongside an active volcano. We took a lunch break, where some group members tried horse meat, a local delicacy in Kumamoto Prefecture.

In the afternoon we visited the Ebino Eco museum which is located on the slopes of Mt. Karakuni in the Kirishima Geopark. The museum had a broad display of the local biodiversity, history and geology in the form of panel displays, videos and mounted specimens (Figure 10). In the distance we could see steam rising, originating from hydrothermal activity in the region.



Figure 9: Group photo at Nakadake crater, Aso volcano caldera.



Figure 10: Butterfly specimen display in Ebino Eco museum.

Making our way to the accommodation, we stopped at a roadside steaming ground (Figure 11). We marveled at the thick clouds of steam coming up and enjoyed the heated floor in the parking lot (Figure 12).



Figure 11: Roadside steaming ground featuring a discussion between Cassis and Tenoch.



Figure 12: Participants enjoying the heat from the floor at the steaming ground.

15th May (Thurs): Ogiri geothermal powerplant and Kirishima Steaming Ground

We spent the first half of the day visiting the Ogiri geothermal powerplant in the West Kirishima area at around 700 to 900 m elevation. We were given a presentation about the history and the operation of the powerplant. The region has seen extensive volcanic activity since the Pleistocene leading to high potential for geothermal energy. Geothermal reservoirs developed along abundant ENE-WSW striking faults. The area was surveyed from 1980 and first production began in March 1996. The installed capacity is 30 MW and can be supplied to approximately 10,000 households. After the presentation we had a look at core samples from the drilling phase of the project (Figure 13). We saw different low grade metamorphic minerals like Prehnite and Laumontite. After strengthening our mineral ID skills, we took a tour around the facility.



Figure 13: Discussion on the drill core to understand the hydrothermal alteration in the region.

The powerplant consists of a production and a reinjection site. At the production site, hot water and steam are taken at a production well with a temperature of $\sim 137^{\circ}\text{C}$ (Figure 14). Steam and water get separated and the hot water is reinjected at the reinjection site. For this the pH is regulated to a slightly acidic value, to prevent precipitation, and in consequence reducing permeability. The steam is used in a turbine to generate power. Afterwards it gets cooled down and lead into a stream at approximately 29°C . Keeping a stable production over time at a geothermal powerplant is difficult, showing the importance of surveying for new sources. Reasons for this are a temperature drop due to the reinjection of the hot water, a pressure drop due to overproduction beyond natural recharge and well problems and interferences.

We first spent time at the production site. We admired the huge turbine, saw a big waterfall for cooling purposes and enjoyed the shade provided by the steam on the hot sunny day. Then we

visited the reinjection site where a labyrinth of pipes was used to reinject the water via a natural flow-down system by elevation. We ended the visit by taking a group photo (Figure 15) and made our way towards Mt. Sakurajima.



Figure 14: Guided tour of the well, condensation facilities and pipes at the production site.



Figure 15: Group photo at the Ogiri geothermal powerplant production site.

15th May (Thurs): Sakurajima

In the afternoon, we witnessed an active eruption of the Sakurajima volcano, located in the southern part of Kyushu, within Kagoshima Prefecture (Figure 16). Once an island, Sakurajima is now a peninsula due to volcanic activity that connected it to the mainland. It is part of the larger Aira Caldera volcanic system. Sakurajima lies within the Ryukyu volcanic arc, a zone of intense tectonic activity caused by the subduction of the Philippine Sea Plate beneath the Eurasian Plate. The volcano is situated at the northern rim of the 20 km-wide Aira Caldera, a massive depression formed approximately 22,000 years ago during a cataclysmic eruption that deposited the widespread Osumi pumice. Sakurajima is a stratovolcano primarily composed of andesite and dacite. It consists of three main summits: Kitadake (1117 m), Nakadake (1060 m), and Minamidake (1040 m). Minamidake has been the primary vent for eruptions since the 20th century. The volcano's magmas are typically rich in volatiles and generate explosive activity, pyroclastic flows, and large ash plumes.



Figure 16: Pyroclastic eruption of Sakurajima, Kagoshima Prefecture.

Our group took a car ferry from the city of Kagoshima to the Sakurajima peninsula to visit several overlooks at a safe distance. During our few hours there, we witnessed a continuous ash plume and several volcanic bombs erupted from the vent. We also visited the Kurokami Torii gate, an approximately 3-meter-tall shrine gate that was almost entirely buried in volcanic ash during the month-long 1914 eruption of Sakurajima that connected the island to Kagoshima's eastern peninsula (Figure 17). While we visited the gate, volcanic ash from the ongoing eruption was actively falling on us, and several trip participants took the opportunity to sample the fresh ash for research purposes. We finished our visit along the southern shoreline for a better look at the eruption and some reworked volcanic rocks from the extensive eruptive history of Sakurajima.



Figure 17: Group photo at the Kurokami Torii gate, which is an approximately 3-meter-tall shrine gate that was almost entirely buried in volcanic ash.



16th May (Fri): Akeshi epithermal Au deposits

Our day began promptly at 8:30 am as we departed from the hotel for our scheduled visit to the Akeshi Mine. Before leaving, a brief introduction on the geologic history and mineralization in the Akeshi region was given by one of our groupmates. We arrived at the site at 10:00 and were warmly welcomed by the staff of the currently operating Akeshi mine. They presented about mining in the main silica bodies of the deposit at Akeshi, and how there was also resultant gold from the processing of the silica. Notably, the grade of gold was not disclosed, but there is speculation that it must be enough to be economically beneficial to mine this site.

Following the presentation, we put on our PPE (masks, helmets, and goggles) because it was time to go into the active open-pit mine! It was interesting to see the mining operation up close with the machines still processing as we marched into a sector of the mine. At the site, beautiful, rainbow-coloured goethite ore (Figure 18) awaited us, and we were able to collect some samples (Figure 19).

We scoped around for different minerals such as sulfur, magnetite, covellite, and regrouped after a bit to discuss all that we'd seen. The conditions in the pit were sweltering, so we only spent about an hour and a half there before heading back to the main building. Thankfully, the mine staff provided complimentary refreshments upon our return which was greatly appreciated. Overall, our visit to the Akeshi mine was informative and will be remembered by the cool pictures and samples we were able to bring back.



Figure 18: Goethite, which is a secondary minerals in iron-rich environment, were found in the Akeshi mine open pit. It is diagnostic by the rainbow color.



Figure 19: Open pit of the Akeshi mine, participants are discussing geology and collecting samples.

19th May (Mon): Akita x UBC Research Symposium and Mineral Industry Museum

This marked the first day of the second leg of our trip. After collecting our new cars and belongings, we headed to the Akita University Tegata Campus for an icebreaker with our colleagues for the next few days. Upon arrival, we met with the Akita University students and professors for an icebreaker, in the form of a half-day symposium (Figure 20). Each university had a few representatives to talk about their personal research, and/or local geology. From UBC we had introductions to MDRU and the Diamond Exploration Laboratory, as well as personal presentations from Spyros, Cassis and Max on their personal research, while from Akita University, we had a talk from Professor Andrea on the local geology and mineralization in the Tohoku region (Northeastern Japan), and two personal research presentations from Manuel and Koseki, also within the region.



Figure 20: Gary gave an opening speech and overview of the field trip in the beginning of the Akita-UBC SEG Symposium.

After freshening up with lunch, we were left to wander the museum, which we were surprised to learn was known as one of the most interactive and comprehensive geological museums in Japan. The museum consisted of many samples from the area, such as the renowned Kuroko, or 'black ore', as well as any fossils found in the area. But the museum also had a lot of specimens from around the world, with more than 2200 specimens of more than 500 kinds of mineral and ore being displayed on the first floor alone (Figure 21). The second floor consisted of a detailed exhibit of rocks and fossils, with some samples originating from deep undersea, to even from beyond our atmosphere. The final floor had some background history for the mining industry in Akita, and a few exhibits for equipment used in mining, and related professions. Much thanks to the folks at Akita University, for putting up a museum worthy of Japan's renowned Hokuroku Mining district.



Figure 21: Group picture in front of the Mineral Industry Museum at Akita University, Akita Prefecture.

20th May (Tue): Kosaka Mine Kuroko-type VMS

The focus of this day was to explore the stratigraphy related to the Kuroko-type VMS deposits. Kuroko deposits are stratabound massive Zn-Cu-Pb sulphide-sulphate ore bodies with underlying stockwork ores. They have a zoned ore distribution, containing a sphalerite-rich black ore, chalcopryrite-rich ore, and a stockwork siliceous Cu ore. Our first field stop was to observe the unmineralized andesite occurring at the base of the sequence. The second fieldstop (Figure 22), was to observe the rhyolite domes that are spatially associated with Kuroko-type orebodies. These domes have minor quartz veins, no quartz phenocrysts and are intensely weathered. The third field stop was to large boulders of black ore that have been mined for Zn, Cu and Pb (Figure 23). The fourth field stop was to visit basalt that occurs at the top of the related stratigraphic sequence, deposited after the mineralization event.



Figure 22: Students investigating an outcrop exposure of the regional rhyolite domes which are spatially correlative with Kuroko-style mineralization.

The word 'Kuroko' means 'black ore' in Japanese and refers to the massive sulphide ore consisting dominantly of sphalerite and galena. The Kuroko-type VMS deposits have played a key role in researching volcanogenic massive sulphide deposits (VMSD) and were first recognized as being of submarine, exhalative origin (Ohashi, 1991) and have become the classical model defining all VMSDs. These deposits are formed by hydrothermal fluids that have undergone extensive changes in temperature and composition through interaction with country rocks. Igneous intrusions act as the primary heat source, significantly increasing the temperature of seawater and generating convective circulation of pore fluids. These pore fluids leach metals from the country rocks, with metals being precipitated as the 'black-ore' mineral assemblages.



Figure 23: Exposed boulders of Kuroko sphalerite-rich 'black ore'.



21st May (Wed): Osarizawa Mine, Goshogake and Tamagawa hot springs

The Osarizawa Mine, located in Kazuno City, Akita Prefecture (northern Tohoku), is one of Japan's oldest and most historically significant hydrothermal copper deposits. First opened in 748, it produced copper, gold, iron, and quartz for over 1,200 years. During its peak in the 1940s, it employed around 4,500 workers and yielded up to 100,000 tons of copper per month. In 1963, the mine produced 807,000 tons of crude ore annually, averaging 1.07% Cu, 0.19% Pb, and 0.13% Zn. The mine closed in 1978 due to declining ore quality and global copper prices and now operates as a museum. Osarizawa was initially interpreted as a volcanic massive sulfide (VMS) deposit due to its stratified ore zonation, which closely resembles typical Kuroko-style deposits. The sequence includes a lower barren zone composed of quartz and chlorite, a middle zone rich in sulfides such as pyrite and chalcopyrite, and an upper zone enriched in gold and silver—features commonly observed in classic VMS systems. However, Osarizawa eventually categorized as a vein-type hydrothermal deposit formed during Tertiary igneous activity and is hosted in Neogene (20–23 Ma) green tuff, lava, and siliceous mudstone of the Shigenai Formation—part of the Miocene Hokuroku Caldera complex. The mineralization, consisting of approximately 470 veins over a 2×3 km area, is dominated by pyrite and chalcopyrite, with galena and sphalerite. Osarizawaite, a yellowish-green trigonal sulfate mineral discovered at the mine in 1961, occurs in oxidized zones alongside malachite, azurite, and brochantite, particularly in the Shotoku 6b and Utori 2 veins near fault zones.

During our visit at the Osarizawa underground mine we identified three different types of mineralization. The most common type of mineralization were the Cu-rich veins with chalcopyrite and secondary malachite, due to oxidation, crosscutting the siliceous mudstone (Figure 24B). Massive sulfide horizons consist of sphalerite, pyrite and minor chalcopyrite crosscutting the siliceous mudstone (Figure 24A). Moreover, a small amount of epithermal veins were identified containing mainly pyrite at the rims of the veins (Figure 24C).

Furthermore, the same day we visited the Goshogake and Tamagawa hot springs. Tamagawa is an extremely acidic ($\text{pH} = 1.2$) hot spring with steaming vents and deposition of native sulfur. During our visit we identified many active fumaroles that are associated with active deposition of native sulfur (Figure 25B). On the contrary, during our visit at the Goshogake hot spring we identified the presence of extensive active mud volcanoes (Figure 25D).

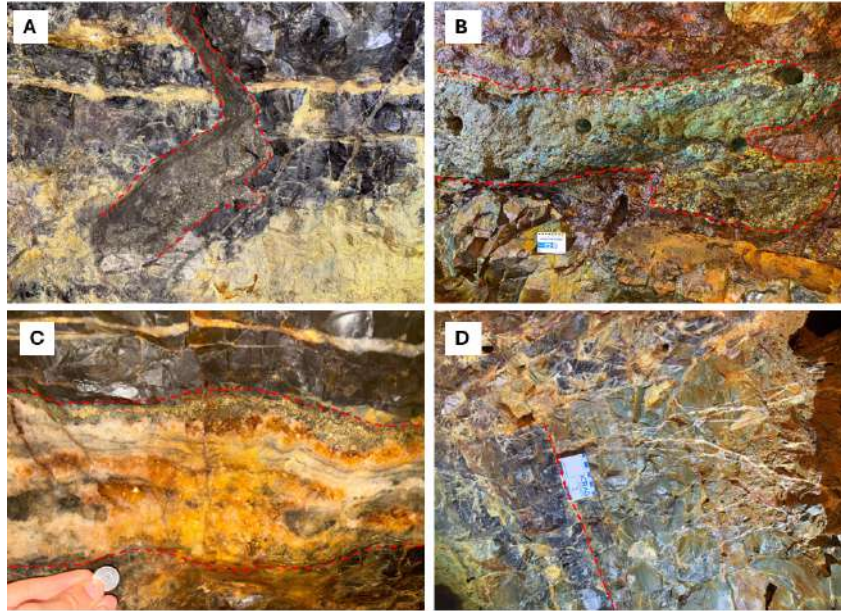


Figure 24: Representative mineralization textures and lithologies of Osarizawa underground mine. (A) Massive sulfide ore bodies crosscutting the siliceous mudstone. (B) Cu-rich vein with chalcopyrite and secondary malachite crosscutting siliceous mudstone. (C) Epithermal quartz-pyrite vein with crustiform texture. (D) Contact of dark siliceous mudstone (left) and siliceous green tuff (right) crosscut by late quartz veins.

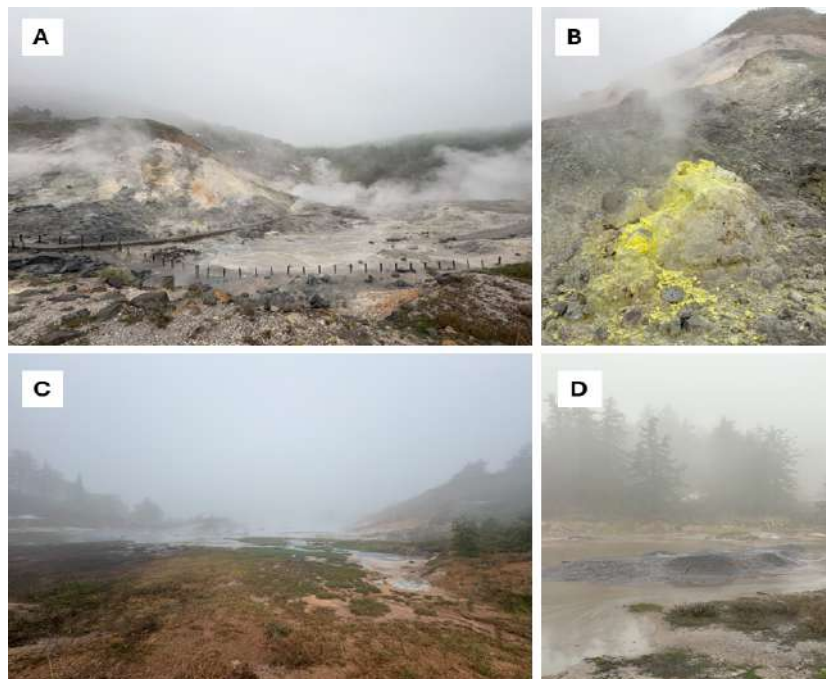


Figure 25: Hydrothermal features of the Goshogake–Tamagawa hot springs. (A) General view of Tamagawa hot spring. (B) Native sulfur deposition at a fumarole vent (C) General view of the Goshogake hot spring. (D) Mud volcano of the Goshogake hot spring.

22nd May (Thurs): Kuji Amber Museum, Noda Tamagawa Mn deposit and Ryusendo cave

We started our day in the Kuji Amber Museum. The amber of the Kuji area dates to the late Cretaceous period in the Mesozoic Era. The museum is divided in three main areas: Discovery Park, Amber Illumination and Amber Gallery. The Discovery Park consists of a recreation of Kuji 85 million years ago, this is an immersion of a primeval forest and exhibits the origins of amber, in this section insects' fossils are shown and are insect relics that got trapped into the amber (Figure 26A). In this same section there is the amber laboratory, where you can learn about amber properties.

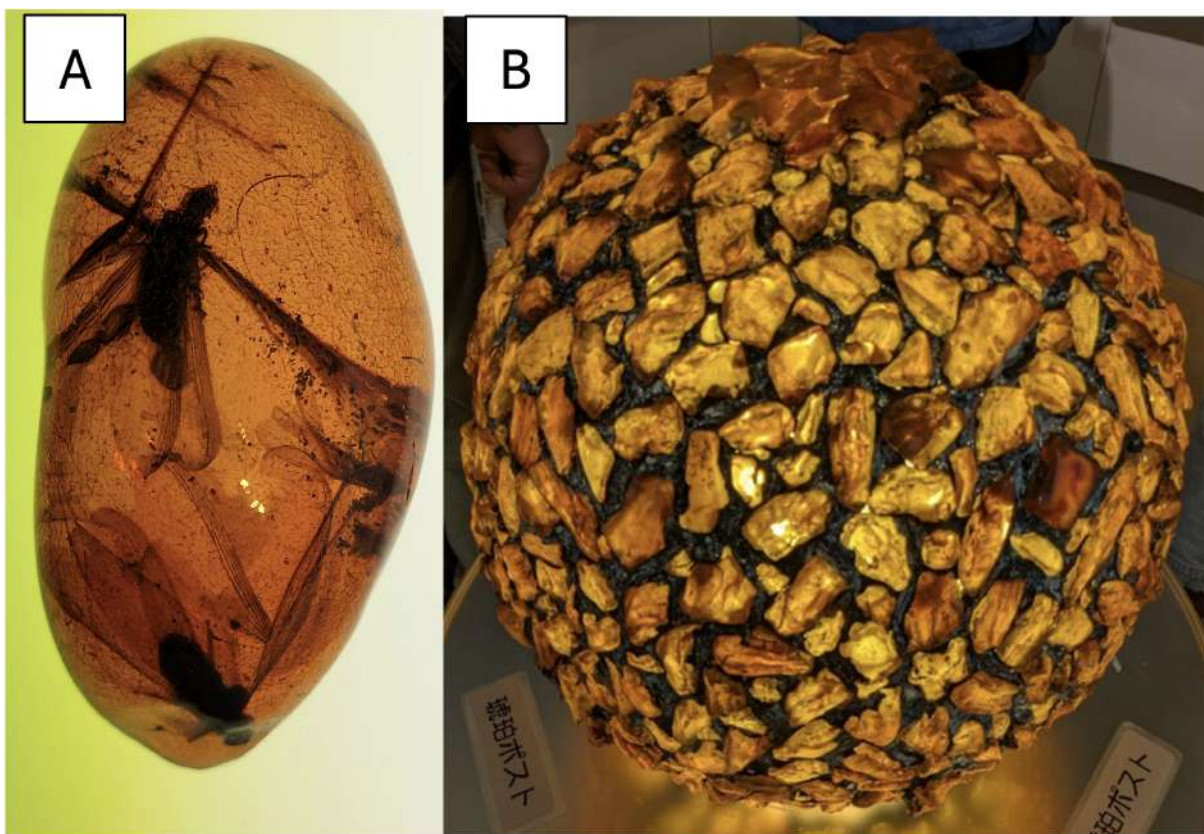


Figure 26: (A) Insect fossils trapped in amber. (B) Amber lamp.

Then there is the Amber Illumination (Figure 26B), which is a room with different visual shows where a range of hues and amber crafts are displayed. This experience focuses on the healing and peaceful properties of amber. Lastly, in the amber gallery we could appreciate the amber artwork, which included the world's largest amber mosaic of Buddha.

Our next stop was the Noda Tamagawa Mn deposit which lies within the Kitakami Mountain Range, which hosts several manganese deposits. Once considered one of the largest manganese

deposits in Japan, the Noda-Tamagawa mine was opened in 1905 and closed in 1985. It had estimated reserves of about 800,000 tonnes with an average grade of 30% Mn. The geological evolution of the Noda-Tamagawa deposit includes sedimentation, diagenesis, and metamorphism. The manganese ores are hosted in a chert-rich sequence lithologically divided into six units: lower bedded chert, lower black shale, massive chert, manganese ore, upper black shale, and upper bedded chert. These units represent a depositional transition from anoxic to oxic conditions. The Noda-Tamagawa deposit is classified as a bedded-type sedimentary manganese deposit that has undergone thermal metamorphism. Rhodochrosite was likely the dominant primary manganese mineral, which transformed into manganese silicates and oxides such as pyrochroite, hausmannite, and rhodonite during metamorphism (Figure 27A). Nowadays the mine is close and it is home to the Manganese boys, which are mannequins that represent the daily life of a miner (Figure 27B).

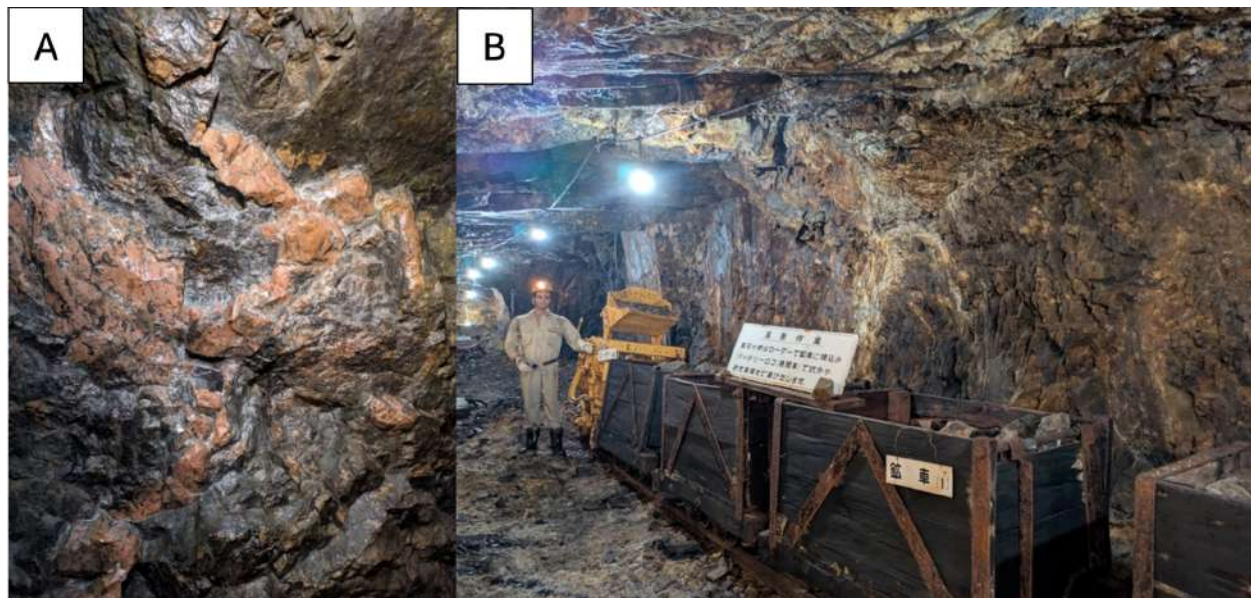


Figure 27: (A) Mn-silicate ore. (B) Demonstration of miner and mining carts.

Our last stop was Ryusendo Cave, renowned for its unique geological features. This cave is the result of a complex karst process, with calcite and aragonite as the main minerals, creating a stunning underground landscape characterized by intricate stalactites, stalagmites, and vast chambers (Figure 28). The cave also holds anthropological significance, as it once served as a refuge for ancient humans; consequently, both human and animal bones have been discovered there. Lastly, the cave is well-known in the region as a romantic attraction for couples and is filled with old lovers' tales.



Figure 28: Chamber in the Ryusendo cave, where we see speleothems and underground waterfall.

23rd May (Fri): Kamaishi mine office and Tamayama Au deposit

The last day of the trip, we set out early to the site of the historic Kamaishi mine, which is located in the southern Kitakami Mountains of Iwate Prefecture. This site was one of Japan's largest and most influential mining operations. The mine supplied the country with iron and steel for over a century, including throughout Japan's Industrial Revolution. The deposit hosts skarn bodies formed in Permian to Carboniferous limestone at the contact of a granodiorite intrusion and was discovered in the Tokugawa era (1600's). Artisanal mining continued until the development of the modern mine in 1857. Although the mine initially produced only iron, copper was also produced starting in 1952. Production records from 1958 show 1.04 million tons of ore averaging 28.6% Fe. The mine was closed permanently in 1993. We toured the old mine offices, which have been turned into a museum with multitudes of rock samples. The museum had artifacts from the lives of all the people and families the mine used to employ. It was easy to see what an impact the mine had on life in this prefecture, bringing electricity and other benefits.

The regional geology consists of Mesozoic to Paleozoic sedimentary rocks intruded by Cretaceous-age granites to granodiorites. The Kamaishi mine comprises approximately 15 skarn ore bodies. The Shinyama ore body was the largest, at 400 m long, 80 m wide, and 550 m high. Locally, the skarn composition shows variation between ore bodies but generally includes garnet, clinopyroxene, epidote, amphibole, and plagioclase. The main ore minerals found in the skarn are chalcopyrite, magnetite, pyrrhotite, cubanite, and pyrite, with minor sphalerite and pentlandite. The magnetite-rich ore bodies were mined for iron, while the chalcopyrite-cubanite ore bodies were mined for copper, although they also contained non-economic amounts of gold and silver. Just outside of the mine office were several boulders of ore. They contained spectacular examples of garnet, magnetite, and chalcopyrite (Figure 29).



Figure 29: Garnet, representing prograde mineralization, in Kamaishi skarn deposit.

After a lunch from konbini (Japanese convenience store), we drove to the Tamayama native gold mine. This deposit is also in the southern Kitakami Mountains and is located in a similar setting to the Kamaishi mine. This mine has been known since 749. As a Canadian, it was really special to be at a gold mine so old. In the 16th century, artisanal placer operations ceased, and underground mining commenced. During modern production, the average gold grade was 12.7 g/t with an estimated reserve of 1 million tons.

The gold-bearing quartz veins at this mine are hosted in a granodioritic pegmatite phase within an older Paleozoic granite, although the validity of the pegmatite is disputed (it could simply be a very coarse-grained rock). The age of mineralization is not well constrained. The surrounding rocks at Tamayama include Paleozoic sedimentary rocks, Cretaceous intrusives, and the Paleozoic Hikami granite, which is variably mylonitized and cataclastic. Sulfide-bearing skarn is also present at Tamayama, although it was not mined in the modern period. The presence of a Paleozoic granite hosting the ore body sets this deposit apart from the Kamaishi mine, where the skarn is hosted at the contact between a Cretaceous granodiorite and Paleozoic limestone. Current exploration and small-scale mining are still happening at Tamayama. This would mean that Tamayama has seen almost two thousand years of mining activity. We got to tour the old mill facility and pan for gold. A few students managed to find some visible gold in their pans (Figure 30) and in some quartz veins nearby. What a great way to end the trip!



Figure 30: Panning gold at the Tamayama gold deposit.



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