

Field Trip Report

“Hydrothermal Ore Deposits of Northern Mexico”

McGill University Student Chapter of the Society of Economic Geologists



Chapter members investigating carbonate replacement + skarn Ag-Pb-Zn mineralization (Santa Eulalia District, Chihuahua, Mexico) along with geologists from Reyna Silver and Grupo México; students from Universidad Autónoma de Chihuahua; and industry attendees from Western Alaska Minerals and i-80 Gold.

Introduction

In May 2023, the McGill University Student Chapter of the Society of Economic Geologists successfully completed its 16 day trip to Northern Mexico. Ten members visited nine deposits in three states — Chihuahua, Sonora, and Baja California Sur. Across each of these three legs of the trip, we learned alongside and from students and professors from three local universities: Universidad Autónoma de Chihuahua, Universidad de Sonora, and Universidad Autónoma de Baja California Sur. This successful endeavor marked the strong return to our international trip tradition, which had been suspended since 2019 due to the COVID-19 pandemic.

Participants

	Name	Type	Affiliation	Legs Attended
1	Robert Collar	Student (PhD)	McGill SEG	1, 2, 3
2	Gary (Sze Yui) Fung	Student (MSc)	McGill SEG	1, 2, 3
3	Bernardo de Carvalho Filgueiras	Student (PhD)	McGill SEG	1, 2, 3
4	Regina Gonzalez Moguel	Student (PhD)	McGill SEG	1, 2, 3
5	Evan Slater	Student (PhD)	McGill SEG	1, 2, 3
6	Jake (Lone Jie) Tiong	Student (PhD)	McGill SEG	1, 2, 3
7	Kevin Ng	Student (PhD)	McGill SEG	1, 2
8	Elizabeth Sullivan	Student (BSc)	McGill SEG	1, 2, 3
9	Ariane Legault	Student (BSc)	McGill SEG	1, 2, 3
10	David Martineau	Student (PhD)	McGill SEG	1, 2, 3
11	Lauren Megaw	Industry Attendee + Chihuahua Trip Leader	Reyna Silver	1
12	Patrick Quillen	Industry Attendee	i-80 Gold	1
13	Sage Langston-Stewart	Industry Attendee	Western Alaska Minerals	1
14	Lenin Rascon	Local Student (Recent Grad)	Universidad Autónoma de Chihuahua	1
15	Jorge Emmanuel Avidrez Ruelas	Local Student	Universidad Autónoma	1



		(Recent Grad)	de Chihuahua	
16	Jesus Manuel Morales Mendez	Local Student	Universidad de Sonora	2
17	Lucia Espinoza Morales	Local Student	Universidad de Sonora	2
18	Jesús Valenzuela	Local Student	Universidad de Sonora	2

Deposit visits

In designing the trip itinerary, we organized deposits into two educational themes: the “porphyry-epithermal spectrum” and “basin-hosted” deposits. Many of the most famous and economically important deposits in Northern Mexico fall in the first category, in particular the globally significant carbonate replacement deposits (CRDs) for which the region is arguably best known. Deposits in this category are fundamentally the result of hydrothermal processes tied to the emplacement of one or more large intrusions. By systematically investigating deposits formed at variable distances from their causative intrusions, we came away with a strengthened understanding of the controls on mineralization style and metal composition in such systems. Deposits investigated in this category include (from proximal to distal relative to their causative intrusion) porphyry Cu-Mo, Cu skarn, Ag-Pb-Zn CRD, and Au/Ag epithermal.

“Porphyry-Epithermal Spectrum”

	Name	Type	State	Host
1	La Colorada	Au epithermal	Sonora	Argonaut Gold
2	Cerro Los Gatos	Ag-Pb-Zn epithermal	Chihuahua	Gatos Silver
3	Naica	Ag-Pb-Zn CRD	Chihuahua	Industrias Peñoles
4	Santa Eulalia	Ag-Pb-Zn CRD + skarn	Chihuahua	Reyna Silver, Grupo México, Aquiles Serdán
5	Terrazas	Cu skarn	Chihuahua	NA
6	Buenavista del Cobre (Cananea)	Cu-Mo porphyry	Sonora	Grupo México

Our second category encompasses deposits formed due to processes operating in sedimentary basins and include phosphorite, evaporite gypsum, and sediment-hosted Cu-Co-Mn-Zn. Each is tied to the rift basins resulting in the Gulf of California, though in the case of the phosphorite deposit, rifting provided a mechanism to expose pre-existing marine mineralization.



“Basin-hosted”

	Name	Type	State	Host
1	San Juan de la Costa	Phosphorite	Baja California Sur	Rofomex II
2	San Marcos	Gypsum	Baja California Sur	COMSA
3	El Boleo	Sediment-hosted Cu-Co(-Zn-Mn)	Baja California Sur	Minera y Metalúrgica del Boleo

Itinerary

In order to modularize our itinerary, we split the trip into three legs, one for each state (i.e., Chihuahua, Sonora, and Baja California Sur). Doing so enabled planning of each to be siloed and efficiently split between participants. It also provided natural breaks that enabled industry attendees and local students to participate in the subsets of the trip most geologically or geographically relevant to them. The itinerary is as follows:

Day	Leg	Activities
Day 1, May 16	1	Fly to la Ciudad de Chihuahua, Chihuahua
Day 2, May 17	1	Cerro Los Gatos Mine visit
Day 3, May 18	1	Naica Mine visit
Day 4, May 19	1	Santa Eulalia District visit
Day 5, May 20	1 → 2	Terrazas Deposit visit; Fly to Hermosillo, Sonora
Day 6, May 21	2	Free day (San Carlos beach trip)
Day 7, May 22	2	La Colorada Mine visit
Day 8, May 23	2	Buenavista del Cobre (Cananea) Mine visit
Day 9, May 24	2	Research presentations @ Universidad de Sonora
Day 10, May 25	2 → 3	<u>Fly to San José del Cabo, Baja California Sur</u>
Day 11, May 26	3	San Juan de la Costa Mine visit
Day 12, May 27	3	Long drive + free day (snorkeling at Isla Coronado)
Day 13, May 28	3	San Marcos Gypsum Mine visit



Day 14, May 29	3	El Boleo Mine visit
Day 15, May 30	3	Long drive back down the Baja Peninsula
Day 16, May 31	3	Fly from San José del Cabo

Trip account

Before the start of the trip, Dr. Peter Megaw (President, IMDEX/Cascabel; Co-founder, MAG Silver and Minaurum Gold; and a successful exploration geologist across Northern Mexico) presented a comprehensive overview of the regional geology and metallogeny of Northern Mexico. This provided attendees with a strong foundation on which to build their trip experience. This experience is documented below:

Leg 1: Chihuahua

Day 1, May 16

The first day! Chapter members flew into la Ciudad de Chihuahua (Chihuahua), with many arriving from Montreal, others from the McGill field school in the Mojave Desert (CA+NV, USA), and a couple from elsewhere in Mexico. We picked up rental cars and headed to the hotel to get a good night’s sleep ahead of our first visit.

Day 2, May 17

At 8 am, a bus sent by Gatos Silver, accompanied by a security vehicle, met us at the hotel and we were whisked away on our 2.5 hour drive to Cerro Los Gatos, an epithermal Ag-Pb-Zn deposit. Upon reaching the mine site, we were greeted by the waving, vermilion-tipped arms of the ocotillo — a striking first introduction to desert flora for many trip attendees.

After an introductory presentation on the deposit, we loaded into a handful of pickups and made our way underground, where we observed and sampled sterling examples of Ag-Pb-Zn mineralization, with particularly spectacular examples of galena and banded sphalerite. Back at the surface, we wrapped up our visit with a stop at the core shed, where we investigated representative samples of mineralization and the key geological units in the project area.

With the ocotillos waving goodbye, we sped back to Chihuahua and headed to the airport, where we picked up our industry attendees — and CRD experts — Lauren, Patrick, and Sage, who work for Reyna Silver, i-80 Gold, and Western Alaska Minerals, respectively. Each focuses on carbonate replacement deposits, of which Naica and Santa Eulalia, our next visits, are premier examples. On these visits, they provided valuable perspectives born of their work on Reyna Silver’s Medicine Springs (NV, USA) and Guigui (Chihuahua, MX) projects (Lauren), i-80



Gold's Ruby Hill project (NV, USA; Pat), and Western Alaska Minerals' Waterpump Creek project (AK, USA; Sage).



Chapter members with the Gatos Silver team interrogating a geologic map of Cerro Los Gatos

Day 3, May 18

The trip's second visit was to Naica, a well-known Ag-Pb-Zn CRD system made famous globally for its caves containing enormous gypsum crystals. The most notable example is the Cave of the Crystals, in which some gypsum crystals have grown to 11 m in length!

On our way to the mine, we met up with two recent graduates from Universidad Autónoma de Chihuahua (UACH) — Lenin and Jorge — who joined us for the visit.

Upon arriving at Naica, we were met by the chief geologist, Roberto Carlos Reyes Rameriz, and operations manager Guillermo Hernandez Castañeda. Roberto gives an expansive presentation on the nature of mineralization, in particular its distribution between chimneys and mantos, as well as on the hunt for the causative intrusion. He also dove into the processes by which the famed gypsum caves formed. After an unexpected deviation from the schedule, we made our way to the core shed, where we examined endo- and exoskarn textures, as well as informative examples of both chimney and manto-hosted mineralization. In addition to the geology, a highlight was the cafeteria's delicious mole (admittedly a staple of southern rather than northern Mexican cuisine)!

After the visit, we headed back to Chihuahua and then made our way east into the heart of the Santa Eulalia mountains, host both to our next visit (to the Santa Eulalia District) and to our lodging for the night, las Cabañas Mina Vieja. The carbins are built on and adjacent to old mine workings, with the oldest — the Mina Vieja — representing the earliest mining conducted in the district, in the early 1700s.



Chapter members, industry attendees, and UACH recent grads with the Naica team.

Day 4, May 19

Upon awakening, we were greeted by desert bighorn sheep — a much more pleasant surprise than the miscellaneous dead scorpions encountered upon arriving at the cabañas! After a quick breakfast, we met up with the recent grads from UACH and a team of geologists from Reyna Silver, led by Rene Ramirez. Rene and Lauren provided an overview of the Santa Eulalia district from a spectacular viewpoint.

Our motley group then headed to Grupo México's Mina San Antonio, where we were met by head geologist Roberto Sanchez and his team. While the Santa Eulalia District is best known for its CRD mineralization, San Antonio represents skarn mineralization (i.e., more proximal to the causative intrusion). The Grupo México team led us along a sequence of outcrops displaying representative skarn textures.

After our San Antonio visit, we bounced around outcrops across the Santa Eulalia district, getting a sense of the distribution of faults and dikes and the scale of mineralization. Our next major stop was the abandoned workings of Mina Bustillos to see giant bodies of argentiferous manganese-oxide mineralization (AMOM). While AMOM is best known as a distal indicator for CRD mineralization, at Mina Bustillos, it was the target for mining.

Our last stop of the day was back in Chihuahua; we headed to Reyna Silver's core shed to take a look at core from their Guigui project. In addition to seeing great examples of CRD mineralization in natural light, we got a chance to view core in a dark room with UV. The fluorescent, Mn-rich calcite characteristic of CRDs is an incredible sight to see!



The pillars at Mina Bustillos, Santa Eulalia District are reminiscent of the Mines of Moria (Lord of the Rings)

Day 5, May 20

On our last day, we headed an hour north of Chihuahua to Terrazas, a Cu skarn mined in the past but since abandoned. Our visit there was led by Lenin, who completed a project on the deposit while at UACH, as well as Rene and Lauren. Terrazas is the most proximal deposit on the “porphyry-epithermal” spectrum visited so far.

After our visit, we parted ways with the Reyna Silver team and UACH folks and headed directly to the airport. There, we said goodbye to our industry attendees and hopped on a short flight across the Sierra Madre to Hermosillo, capital of the state of Sonora.



The group, with industry attendee Pat Quillen in the foreground, fanned out over outcrops and old tailings piles at Terrazas.

Leg 2: Sonora

Day 5, May 20

After touching down, we grabbed our bags and head to the hotel. We finally had a chance to catch a breath after a whirlwind four deposit visits in four days!

Day 6, May 21

We started the next day with a late morning and then headed to Universidad de Sonora (UNISON), where we met Jesus, a geology student there. Jesus led us to San Carlos, a town perched on the edge of the Gulf of California just an hour west of Hermosillo. There, we enjoyed the beach, fresh coconuts, stellar views, and great seafood! After a much needed rest day, we then headed back to Hermosillo.

Day 7, May 22

Just before the start of our trip, we were informed of the cancellation of our visit to La Herradura, Fresnillo's giant orogenic Au deposit. Fortunately, Dr. Guadalupe Espinoza, a professor of geology at UNISON, organized a last-minute visit to Argonaut Gold's La Colorada, an epithermal Au deposit just an hour outside of the city. We head there, where we met Dr. Espinoza, Jesus, and another UNISON student, Lucia.

The Argonaut Gold team led us to multiple of their past and currently producing pits before taking us to their core shed. La Colorada was originally interpreted to be an orogenic Au deposit, but the identification of a seemingly causative intrusion, in addition to textural evidence (e.g., bladed calcite), has more recently suggested its epithermal nature. We were fortunate to see some of this evidence in drill core. And though La Colorada is low grade, we did catch one glimpse of gold!

Upon completing the visit, we head back to Hermosillo and grabbed a late lunch at UNISON. We picked up a second UACH student named Jesus and headed four hours north to Cananea, near the US border.



Arturo Navarro, chief geologist at La Colorada, shows chapter members and UNISON students a geologic map of the project site.

Day 8, May 23

The next morning, we made our way to the giant mining complex at Buenavista del Cobre, one of the largest Cu-Mo porphyry deposits globally. There, Edgardo Barrera Moreno and his team arranged for us to descend down into one of the main pits. We saw prime examples of hypogene Cu-Mo mineralization, supergene enrichment, and tourmaline-cemented breccias. We wrapped up our visit with a quick stop in the core shed, where we viewed representative examples of multiple intrusive phases and the mineralization they host. After a quick lunch in the parking lot, we made our way back to Hermosillo.



Chapter members and UNISON students with the Buenavista del Cobre geology team.

Day 9, May 24

On our last full day in Hermosillo, we organized a research exchange with professors and students from UNISON. We headed to the university, where students from both groups gave short presentations on their research. These include the following from our chapter members:

- "Introduction to Crater Lake Scandium deposit" (Jake Tiong)
- "Avances del laboratorio de monitoreo de metano en ecosistemas Canadienses" (Regina Gonzalez)
- "Geology and Genesis of the Fenelon Gold Deposit: Implications for gold metallogeny in the northwestern Abitibi" (Evan Slater)



Chapter member Regina Gonzalez presenting her research at UNISON.

Day 10, May 25

The next day, we headed to the airport and caught a short flight across the Gulf California to San José del Cabo, Baja California Sur.

Leg 3: Baja California Sur

Day 10, May 25

Upon arriving in San José del Cabo, we picked up rental cars and headed to our hotel in Cabo San Lucas, at the southern tip of the Baja Peninsula.

Day 11, May 26

The next morning, we rose early and headed north towards the town of San Juan de la Costa, where Rofomex II operates its phosphorite mine. Just outside town we met up with Dr. Tobias Schwennicke, a professor at Universidad Autónoma de Baja California Sur who has published extensively on the phosphorite deposits in this region and organized the visit. Along with the Rofomex II team, he was our guide for the day.

At the mine site, we were given a deposit overview before being taken to the mine portals. There, we were loaded into pick-ups, though not of the normal variety! The tops of these trucks were lopped off and the floor dropped so that they could fit into the comically short adits, which follow the shallowly dipping phosphorite beds.

Upon emerging from our underground visit, we received an extensive tour of the processing plant and wrapped up the visit with a stop at the mine's tailings pond. We bid adieu to the Rofomex II team and Prof. Schwennicke and backtracked south to the port city of La Paz, where we spent the night.



The Rofomex II team providing an overview of the mining operation underground.

Day 12, May 27

The next morning, we hopped into the cars and started the four hour drive north along the Baja Peninsula to Loreto, one of the many towns strung out along the Gulf of California. In Loreto, we quickly dropped our belongings at the hotel and arranged a boat trip out to Isla Coronado, a young volcano (Holocene) about half an hour off the coast. Along the way we encountered flying fish, whales, and blue-footed boobies, and once there, we donned our snorkeling gear and spent the last hour of sunlight exploring a fish-filled cove.

Day 13, May 28

The next morning, we continued northward along the coast to the town of San Bruno. There we caught a water taxi out to Isla San Marcos, where COMSA's San Marcos gypsum operation is located. Once docked, we met Valente Salgado Muños, PhD candidate at University of Missouri-Kansas City (USA) and Director of Operational Technical Services for COMSA.

Valente provided us with a comprehensive tour, starting with the labs in which gypsum quality is evaluated. Gypsum at San Marcos is interpreted to have formed as a result of evaporation of



sea water early in the formation of the Gulf of California, a product of rifting along the western margin of the North American Plate. We continued to a zone of the operation that showcases the diversity of gypsum that can form in such an environment. The visit finished at a viewpoint, from which we watched gypsum being loaded onto a transport ship, with the Gulf of California and Baja Peninsula providing a spectacular backdrop.

With the visit over, we took a water taxi back to San Bruno and headed north to Santa Rosalia, a historic mining town clinging to the edge of the Baja Peninsula.



Visit leader Valente Salgado Muñoz describing variability in gypsum morphology at San Marcos.

Day 14, May 29

After the earliest wake-up of the trip, and with heavy eyelids, we headed just outside of Santa Rosalia to El Boleo, our last deposit visit. El Boleo is a sediment-hosted Cu-Co-Zn-Mn deposit first operated for Cu in the 19th century by the French. The town of Santa Rosalia exhibits much of their lingering influence! Today, however, El Boleo is operated by Minera y Metalúrgica del Boleo, controlled by the Korean state mining company KOMIR. Upon arriving at El Boleo, we are met by chief geologist Dae Hui Jo and his team. They, along with Valente, who studied El Boleo as part of his PhD work and worked as a geologist there beforehand, led our visit.

We started with an overview presentation and then quickly headed to the rocks. Over multiple stops we investigated and sampled great examples of manto mineralization. We then made our way to the core shed, which provided a critical opportunity to view fine grained mineralization unobscured by supergene processes. Curiously, in both the field and in the core shed we encountered “retaque,” the low grade material back-filled into underground workings by old-timers and easily identified when associated with wood (i.e., the timbering of those workings!).



Nowadays, low grade, high tonnage surface mining means that retaque is re-exposed and mined as ore.

We bookended our geological experience in Mexico with our last stop, at Arroyo Boleo. There, bedded gypsum is dominant and stratigraphically correlated with the mineralized siliciclastic sequence in the main mining area. Such gypsum is also thought to be correlated to that found at San Marcos, since displaced southward by transtensional rift-related faulting.

A visit to El Boleo wouldn't be complete without catching a glimpse of boleite, a strikingly blue oxychloride for which El Boleo is the type and best locality globally. Fortunately, Dae Hui Jo and the Boleo team ensured we didn't leave with that need unmet!



Chapter members and the Boleo geology team investigating mineralized manto 3.

Day 15, May 30

Our final full day was spent winding our way back down the Baja Peninsula towards La Paz, where we stayed the night. We celebrated a successful trip with dinner near the beach as the sun set.

Day 16, May 31

On the final morning, the group scattered, with most heading to the airport at San Jose del Cabo and a few remaining to enjoy a couple extra days in Baja California Sur.

Conclusion

We'd like to thank those who helped us to organize our trip, as well as our generous sponsors, in particular the Stewart R. Wallace Fund. These include the following:

- **Dr. Peter Megaw** (President, IMDEX/Cascabel, Co-founder, MAG Silver and Minaurum Gold), for logistical, educational, and fundraising support
- **Lauren Megaw** (Reyna Silver), for logistical and fundraising support, and for co-leading the Santa Eulalia and Terrazas visits
- **Rene Ramirez** (Reyna Silver), for logistical support and for leading the Santa Eulalia and Terrazas visits
- **Guillermo Gastelum Morales** (Fresnillo), for logistical support
- **Valente Salgado Muñoz** (University of Missouri, Kansas City and COMSA), for logistical support and for leading the Isla San Marcos visit and co-leading the El Boleo visit
- **Prof. Tobias Schwennicke** (la Universidad Autónoma de Baja California Sur), for arranging and co-leading the visit at San Juan de la Costa
- **Prof. Guadalupe Espinoza** (la Universidad de Sonora), for securing a visit to La Colorada at the last minute after our visit to La Herradura was cancelled
- **Prof. Francisco Javier Grijalva Noriega** (dept. chair at la Universidad de Sonora), for hosting us at la Universidad de Sonora
- **Prof. Diana Meza Figueroa** (la Universidad de Sonora), for organizing our research presentation meeting at la Universidad de Sonora
- **Prof. William X. Chavez Jr.** (New Mexico Tech), for logistical support
- **Industrias Peñoles, Gatos Silver, Grupo México, Minera y Metalúrgica del Boleo, COMSA, Rofomex II, Reyna Silver, and Argonaut Gold**, for hosting us at their deposits
- **Prismo Metals, IMDEX, Major Drilling, Reyna Gold, Reyna Silver, MAG Silver, Dynacor, Dahrouge Geological Consulting, Laurentia Exploration, Midland Exploration, PDAC, and the SEG Stewart R. Wallace Fund** for their financial contributions to the trip



With the help of those above, our chapter overcame significant logistical, security, and financial hurdles to execute a successful trip. We look forward to building on this momentum as we plan the next one!

Trip expenses

Expenses	Amount (CAD)
Accommodation	\$9,402.71
Car rentals	\$7,516.89
Domestic flights	\$3,862.21
Gas and tolls	\$1,276.11
Food - partially covered	\$1,017.94
Travel health insurance	\$465.81
Banner and car door magnets	\$457.82
Gifts for visited mines	\$286.50
Bank transaction fees	\$200.00
TOTAL	\$24,485.99