The El Desierto Sulfur Mine
Potosí, Bolivia

Alfredo Petrov
Cochabamba, Bolivia
e-mail: alfredopetrov@earthlink.net

In July of 1999, at the instigation of Mr. Rock Currier, who wanted a sea container (8 tons) of crystallized native sulfur for his wholesale mineral business in California, I set off for the remote El Desierto sulfur mine in Bolivia to check on the progress of our specimen-mining project.

VISITING THE SITE

El Desierto is one of about sixty sulfur deposits in Bolivia, all located on the chain of volcanoes that forms the Western Andes cordillera along the border between Bolivia and Chile. At most of these deposits, the native sulfur is massive, occurring as the cementing agent in volcanic ash, but in three deposits, including El Desierto, good crystals of sulfur are found.

El Desierto is two days’ drive from civilization (i.e. my home town of Cochabamba) across the southern Altiplano, the dry high-altitude plains (over 13,000 feet) that cover much of southwestern Bolivia. July is winter here and night-time temperatures can drop to −20°C (−4°F). So I loaded my much-abused four-wheel-drive vehicle inside and out with sleeping bags, extra blankets, food, water, cans of gasoline, and a Bolivian friend who is adept at keeping jeeps alive under conditions not anticipated by the manufacturer.

He knew all sorts of useful local tricks, like covering the car engine with blankets at night, and urinating into the brake fluid receptacle to keep the brakes working after we ran out of brake fluid. On the first night we pulled into the dust-blown town of Sevaruyo, which looks remarkably like a trading post in a post-apocalyptic nuclear holocaust film, but it does boast the only hotel for a hundred miles around. Even at $1.50 per bed in the large communal sleeping room it was overpriced: candlelight only, no toilet, and my pillow felt greasy and smelled of hair cream (I don’t use hair cream). In the wee hours of the morning we were awakened by a horde of smugglers stomping groggily into “our” room, looking for a place to rest after their freezing overnight drive on rough, unmapped tracks coming from Chile.

On the second day out the scenery became even more desolate. The hundreds of kilometers of volcanic mountains made the landscape appear more and more like Mars the further we drove. We encountered very few human beings, only a handful of farmers who grow quinoa (a fine-grained cereal grown locally), and smugglers. We met only one vehicle all day, a truck carrying yareta firewood, the only burnable plant which can survive the intense ultraviolet radiation and the temperature extremes in this area.

By late afternoon we reached the northern shores of the Salar de Uyuni, the world’s largest salt flat, three million acres of absolutely flat, blinding white salt stretching to the horizon. At only 12,000 feet above sea level, the Salar De Uyuni is the lowest part of the Altiplano. It also happens to be by far the best “highway” in the Republic of Bolivia, made by nature and not by the Servicio Nacional de Caminos. Driving into the Salar is easy—just follow the tracks of previous vehicles across the muddy shores. There the tracks disappear.

Once on the hard salt we drove at high speed, at least as fast as my poor old car would go, for some 50 or 60 miles to the southwestern shore of the salar. On the way we saw islands of stone that rose from the horizon as we approached them. They are the remnants of pyroclastic flows covered in part with collapsing stromatolite deposits. These islands have benches of rounded
volcanic pebbles formed by the wave action of the ancient lake, when it had water at higher levels.

That was the easiest part of the trip. Getting out of the salar, however, is not as easy as getting into it. Over the hundreds of miles of shoreline there are only about a dozen places where it is possible to drive out. Most of the shore is bordered by soft mud or mushy wet salt where runoff from the surrounding mountains has reached the salar. We got lost and couldn’t find the exit. Daylight was failing. We started remembering the local horror stories about cars and buses full of people sinking into brine-filled caves to be lost forever, or perhaps to surface in some future millennium as human pickles. (The good thing about these brine caves is that they may hold very fine crystal groups of halite).

After driving carefully parallel to the soft shoreline for 20 miles, we found some black stones that other travelers had left on the salt to mark the hard-surface way off the salar. In the last light of the long summer day we wound our way westward up into the mountains. We passed a little hot spring where boiling water bubbles out of the ground and crude (mostly abandoned) “hot tubs” have been made by locals for bathing purposes. Finally at 9:00 pm we arrived at the Bolivian Military post on the border with Chile.

We found a few soldiers, a few sulfur miners, five children and one young schoolmistress. They had been without water and fuel for four days. The schoolteacher and some of the miners complained that they had not been paid for months. The soldiers’ diet is frugal by American standards, but they can earn a few extra morsels by moonlighting in the sulfur mine. Nightlife in the village is limited. Miners sit around by candlelight drinking pure cane alcohol out of plastic cups after briefly setting it on fire, a process which they believe drives off the impurities responsible for hangovers. The upper classes, i.e. the mine owner and the sergeant, have extensive collections of X-rated videotapes and a 12-volt videocassette player. The only two women in the community, the mine camp cook and the pretty young schoolteacher, wisely stay out of sight at night.

In the morning we went out to inspect the specimen-mining project. The miners were tunneling up fractures in the quarry walls. The fractures opened into crystal-lined pockets every few feet. They had become quite expert at dynamiting out delicate vugs and saving the specimens intact. Five tons of specimens were already boxed or else awaiting the arrival of more wrapping materials. Some of the fissures in the quarry wall were emitting hot stinky gases. The miners, all working for Rock Currier, were being paid about eight times more per week than the average Bolivian miner gets, but they were earning every penny of it the hard way. Their eyes were burned bright red by the acidic sulfate dust. Their clothes

Figure 2. Salar de Uyuni with Mt. Tunupa at the north end of the salar. Rock Currier photo.
and shoes were also being destroyed by the acid. No one had had a bath in six weeks. One miner had arrived at the work site with his wife and two small children, and everyone in the family was infested with lice. After two days at the mine, the lice were dropping off dead. (A visit to this mine would probably also be a rapid cure for stubborn fungal infections of the skin!)

On the second night, a tremendous howling wind lifted up the tin roof of the shack I was camping in, and slammed it back down with enough force to break off bits of the adobe wall, which rained down on my head. My hair was a dust-caked uncombable mass, I stank, and my clothes reeked of sulfur. After two days at El Desierto I was most eager to head back home. The schoolteacher, also desperate to escape the place but having no transportation and being unwilling to walk the 60 miles across the salt, begged to come with me. I regretfully refused to save her from her fate; the car was full, and anyway I didn’t want to leave the children without a teacher.

The long drive home was uneventful. Not so the complicated transport routes and Byzantine bureaucratic hurdles which had to be overcome to get the sulfur specimens from El Desierto to the port in Arica, Chile and then on to the United States—but that is another long story . . .

Most of the sulfur crystals at El Desierto are found growing on a white sulfate-rich rock, but a few are found on a contrasting black manganese oxide-coated matrix. Colorless crystals of potassium alum are not uncommon. Several other sulfates are also present in small quantities. Botryoidal hyaline opal is the only other common mineral, although it is usually overlooked because it is almost invisible on the white matrix rock.

*Figure 3.* Isla Comaña, a volcanic hill rising out of the Salar de Uyuni. Rock Currier photo.

*Figure 4.* Halite crystals collected by Alfredo Petrov out of cavities at the base of a small satellite volcanic island near a larger island. Rock Currier photo.
LOCATION AND OWNERSHIP

The El Desierto mine and the neighboring Concepción mine are actively worked sulfur quarries associated with the dormant Cayte (also spelled Caite) volcano, located at 20°32’/H11032’/S, 68°31’/H11038’/W, roughly 5 miles south of the abandoned village of San Pablo de Napa, at the southern end of the Salar de Empexa, and only a few hundred meters from the Chilean border, in Daniel Campos Province, Potosí Department, Bolivia. Both mines belong to the Empresa Minera Clavijo (EMICLA), which also owns sodium carbonate and sulfate deposits further south.

PRODUCTION AND RESERVES

When mining commenced in the early 20th century, the sulfur ore at El Desierto was the richest in Bolivia, averaging 80% sulfur! By 1941, between 400 and 500 tons per month were being produced for export to Argentina and Brazil for the production of sulfuric acid. At present the ore averages about 50% sulfur, and yearly production does not exceed 2,000 tons, mostly destined for a sugar refinery in Santa Cruz, Bolivia. Estimated reserves are 320,000 tons at 56% sulfur for the El Desierto mine. Other references give a combined reserve for both mines of 500,000 tons at 50% sulfur, and 3,000,000 tons at 33% to 50% sulfur. A serious hindrance to increasing production is the lack of fuel for the sulfur refining plant. At present the only fuel available is the mostly underground and very slow-growing resinous yareta “bush” (it looks like a low growing mound of moss). This plant has already been exterminated across an area of a few tens of kilometers around the mine.

GEOLOGY

Although most Bolivian sulfur mines are located at very high altitudes in the craters of several volcanoes of the Western Andes, the San Pablo de Napa deposits occur at a more tolerable altitude on the lower slopes of the Cayte volcano, hosted in an old debris avalanche. The host rock is a Pliocene volcanic ash bed, from 50 to 100 cm thick, dipping 15 to 20° north. The surface area of the deposit measures about 400 meters by 2.5 km. At its upper elevation, 4,300 meters above sea level, the sulfur is covered by lava. At its lowest elevation, 3,750 meters, almost on the shores of the Salar de Empexa, the sulfur crops out at the surface. Weak fumarolic activity is still evident in several fissures in the sulfur quarries. (Occasionally, parts of the sulfur deposit accidentally catch on fire, resulting in strong “pseudo-fumaroles” that cannot be extinguished by covering them with dirt; they have to be put out
with water, a scarce resource there!) Very acidic warm springs (31°C) flow at the borders of the Salar de Empexa, near the El Desierto mine, and there is at least one geyser, which tends to erupt once a day, soon after dawn. The greenish-yellow sulfate crust on one area of the Salar might indicate the presence of sub-salar fumaroles. At Quebrada Malpaso, an alkaline (pH 8.3) spring, enriched in lithium and boron, flows into the salar. Although the water temperature is only 78°C, it is boiling because of the low air pressure at such high altitude. Unlike the Salar de Uyuni, which is covered by a halite crust with minor sylvite and gypsum, the Salar de Empexa’s crust is composed mainly of gypsum, halite, clay and calcite, with minor sodium sulfate; 210–580 ppm Li, 0.77–2.0% K, 0.85–2.3% Mg. (The Salar de Empexa is the fourth largest salar in Bolivia, although it covers only 191 km², compared to over 11,000...
Figure 9. The face of one of the open cast pits at the El Desierto sulfur mine, showing mined-out fissures that were once lined with sulfur crystals. Rock Currier photo.

Figure 10. Sulfur crystal, 8 cm, from the El Desierto mine. Jaroslav Hyrsl photo.

Figure 11. Sulfur crystals in place at the El Desierto mine. Rock Currier holding rock hammer for scale.
Figure 12. Sulfur crystals on matrix, 10 cm (the largest crystal measures 1 cm), from the El Desierto mine. Jaroslav Hyrsl photo.

Figure 13. Sulfur crystals on matrix, 5.5 cm (the largest crystal measures about 9 mm), from the El Desierto mine. Jaroslav Hyrsl photo.
km² for the Salar de Uyuni.) From 1900 until 1941, the Salar de Empexa was the most important ulexite producer in Bolivia, with a 60-cm-thick bed of ulexite, now worked out, at Boratera Laqueca, and a 30-cm to 40-cm bed at Boratera Isma, likewise mined out.

MINERALS
Sulfur, well-crystallized in a wide array of crystal habits ranging from equant to acicular (possibly the habit is dependant on the temperature of deposition) is the most abundant and well-known mineral from these deposits. The sulfur is quite pure, with some of it containing just traces of arsenic and selenium. Crystals average about 1 cm in length, but a few can reach 10 cm. The chemical reaction that probably forms the sulfur is \( \text{H}_2\text{S} + \text{SO}_2 = \text{S} + \text{H}_2\text{O} \). The matrix rock for the sulfur crystals is highly-altered volcanic material consisting now mainly of clay minerals, opal (hyalite), alunite, gypsum and minor films of manganese oxides.

Other fumarolic minerals present include potassium alum, as sharp, complex colorless crystals and as colorless to white “rams horn” growths, often with millimeter-sized gemmy sulfur crystals sprinkled on them, proving that the sulfur was deposited later (and presumably at an even lower temperature) than the alum. Coquimbite occurs rarely as pale violet-colored crusts. Other minor associated minerals include kalinite, mirabilite, alunogen, pickeringite and melanterite. Several blue and orange-colored sulfates have not been positively identified but probably include romerite, voltaite, metavoltine and chalcanthite. The alunogen and melanterite are probably the minerals responsible for the acidic properties of the matrix, which destroys the paper used to wrap the specimens.

CARE AND FEEDING
To prepare the specimens for sale it is necessary to soak them in water to which ammonium hydroxide has been added. This neutralizes the acidic component of the matrix, and thus prevents the specimens from eating up any paper or cardboard that they might come in contact with. A small amount of sodium bifluoride is added to the water to help neutralize the acidity.
added in order to complex iron. Without this treatment, the matrix of many specimens would gradually turn a pale brown.

CURRENT COLLECTING STATUS
The owner of the mine is usually happy to give visiting collectors permission to dig. Remember that a bottle of fine liquor, a sack of fruit or vegetables, some foreign tobacco and a raunchy video all make much-appreciated gifts in this luxury-starved landscape of unwilling ascetics. Bring especially lots of drinking water and food for yourself, in case the camp has run short. A face mask with a good dust filter is advisable for those collectors who might feel some discomfort when the tears and mucus in their eyes and nose turn into sulfuric acid.

REFERENCES
AHLFELD, Federico (1941) Los Yacimientos Minerales de Bolivia. Dirección General de Minas & Petróleo, La Paz.