

Rare Chromates from Seh-Changi, Iran

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Phoenicochroite, fornacite, iranite and hemihedrite, all rare chromates of lead, zinc and copper, occur in association with cerussite, phosgenite, wulfenite, mimetite, diaboileite, willemite, hemimorphite, hydrocerussite, beta-duftite, massicot and chrysocolla in the Seh-Changi lead-zinc-copper deposit in eastern Iran.

LOCATION

The Seh-Changi deposit is situated in one of the least-known regions of Iran, the southern part of Khorassan near the far eastern border with Afghanistan. The region is completely desert with very moderate relief (the Lut Desert). The area is reached by desert tracks 207 km southeast of Tabas, near the settlements of Nayband and Dehuk, which lie at 55 and 90 km respectively from the mine workings.

DESCRIPTION OF THE MINERALIZED REGION

The mineralized formations near Darmian, Qolleha and Shurab to the east of Birjand are associated with essentially clastic sediments of Mesozoic age having little economic importance, but the metalliferous deposits worked in the district of Seh-Changi and Hauz-e-Rais to the west are in a thick, Eocene, volcanosedimentary series of economic interest.

This series, which is as much as 3000 m thick, has been studied in detail by Stöcklin *et al.* (1965) in the eastern part of the Sotori mountain range. It is representative of the formation generally recognized in the Lut Block, consisting of a succession of basaltic, andesitic, and dacitic tuffs (with fragments of quartz, biotite, plagioclase and iron oxides) between which are interstratified some red sandstones considered to be continental by Stöcklin. The beds are horizontal or subhorizontal, a characteristic that distinguishes this region from those in other parts of eastern Iran where the same Eocene volcanosedimentary facies are present. This whole succession follows innumerable mafic volcanic flows (complex ophiolites with radiolarite) of the Cretaceous "colored melange" in which the Iranian chromium deposits occur.

The formation containing the primary sulfide mineralization seems associated with post-volcanic activity and is controlled by the northwest-southeast fractures, along which are aligned most of the exploitation pits of the mine. According to Stöcklin, the tectonic movements have continued during the deposition of the sulfides, as

evidenced by fragments of sulfides which can be seen rolled in the mineralized volcanic breccia at the contact of the principal fault. This breccia is the principal element of the major subvertical vein which cuts the series; it has a thickness varying from 0.2 to 5 m (Burnol, 1968). The mineralization cements fragments of the enclosing rock, which is brecciated and bleached by hydrothermal alteration. These veins were the object of important workings in the past which have been deepened in pits that reach the watertable (at a depth of 40 m). Workings have more recently been reopened on the principal vein and later on others. The ores consist mainly of galena and sphalerite, in veins and crystallized seams, but also of chalcopyrite, bornite, pyrite and minerals of the tennantite-tetrahedrite series.

However, it is noted that the abundance of copper varies widely from one pit to another. Pyrite, chalcopyrite and tetrahedrite-tennantite (rare) are dispersed as inclusions in the other sulfides. Bornite and chalcocite are associated with crystals of chalcopyrite; sulfides become progressively more important below the 40-m level (Burnol); the gangue is composed of late quartz and calcite. According to Burnol, the emplacement of the hypogene mineralization corresponds to a single phase of deposition with a normal order of succession.

The oxidation zone in a desert regime, which especially interests us here, is developed above 40 m. It includes many secondary minerals. All the crystals are small, their dimensions rarely exceeding 2 mm. Besides the chromates (iranite-hemihedrite, fornacite, phoenicochroite) are found cerussite, phosgenite in small transparent crystals, hydrocerussite in the form of yellow powder, wulfenite and mimetite in colors varying from yellow to bright red, diaboileite in blue plates 1 to 2 mm long, and willemite in doubly terminated transparent prisms. The crystals of hemimorphite and descloizite from this deposit are also of small size. Coatings of beta-duftite, massicot and chrysocolla are fairly common.

In an arid climate it is commonly accepted that the direction of



Figure 1. The Seh-Changi mine in 1969.

Figure 2. Locations of the principal Iranian chromate deposits.



the percolating solutions, which determines the formation of the oxides at the expense of the primary sulfides, is from the bottom up; that is to say from the top of the watertable up to the topographic surface in connection with the intense evaporation in these regions. The repercussions of this are important to the environment of formation and its evolution, and also to the movement of diverse elements.

MINERALS OF THE OXIDATION ZONE

The chromates of lead are the most remarkable minerals of the Seh-Changi deposit, although the first Iranian chromates (iranite, phoenicochroite, fornacite) were discovered in 1960 on the dumps of the small abandoned mine of Sebarz, situated in the Anarak region. They are associated with cerussite, atacamite, diaboite, chrysocolla and diopside. In 1970, hemihedrite, another chromate of lead discovered in Arizona, was described by S. A. Williams and J. W. Anthony. In 1972, Adib, Ottemann and Nubar published on two other chromates of the Anarak region (Chah-Khuni mine): "khuniite" and "chrominium." "Chrominium" was very soon realized to be identical to phoenicochroite, and an examination of the original specimens of iranite and of "khuniite" later revealed that these two names designated the same species. We had earlier (1963) discovered another occurrence of iranite at the Seh-Changi mine (region of Nayband). On the other hand, several visits to the Sebarz mine in 1961 and 1963 did not permit us to find in place the chromates found in 1960 on the dumps. More recently, in 1973, we rediscovered in the underground workings of the Chah-Khuni mine the chromates described by Adib *et al.* (1972). In comparing these specimens to those from Sebarz, we have come to the conclusion that the specimens of iranite and phoenicochroite discovered in Sebarz came from Chah-Khuni. It is well known that many ores originating from other mines were treated and stocked at Sebarz about 50 years ago. Long discussions with old miners in the region have confirmed that this was frequently the case. It was the same at Bagherog, where the ores of Talmessi were smelted before the installation of the foundry there.

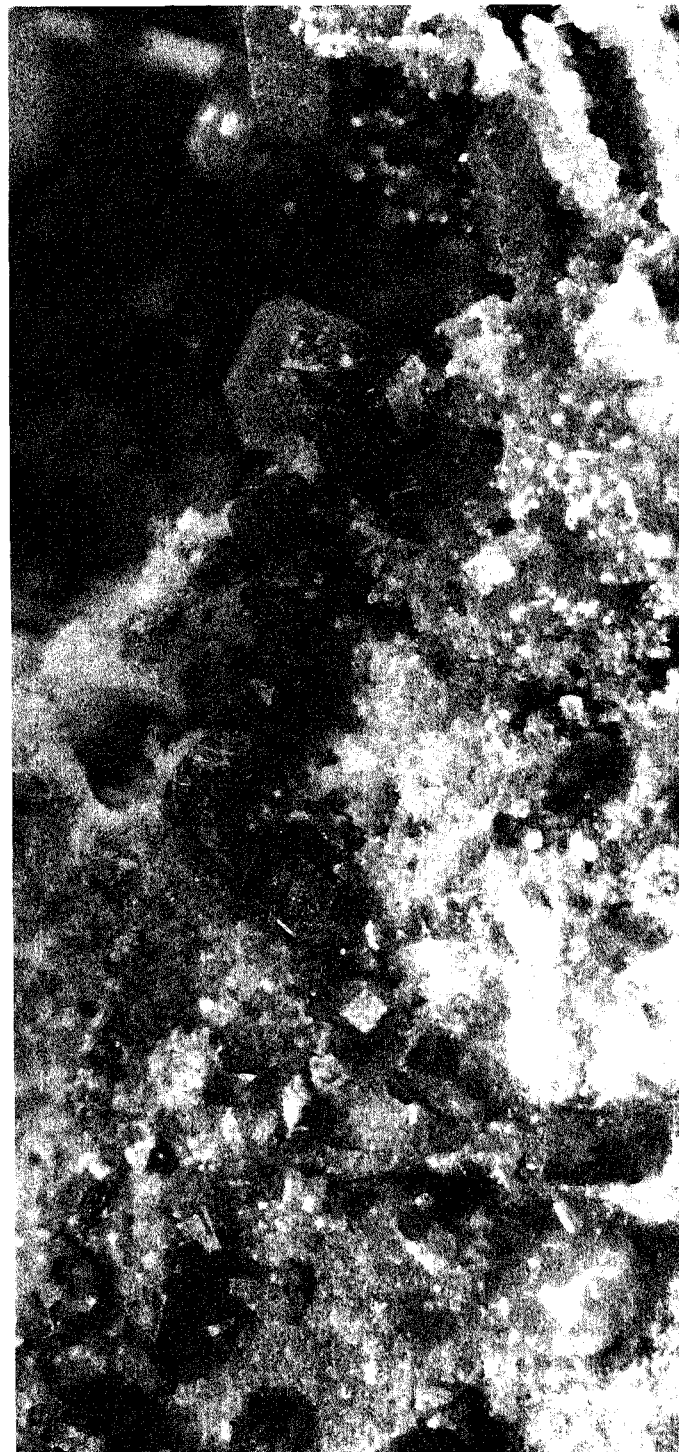


Figure 3. Iranite crystals, dark brown in color, measuring about 0.1 mm in size, from the Seh-Changi mine.

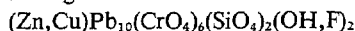
Figure 4. Dark iranite crystals to 0.1 mm, with larger red wulfenite crystals and extremely small, yellow mimetite crystals on matrix, from the Seh-Changi mine. (Photos by Nelly Bariand.)

Iranite-hemihedrite series chromates are exceptionally abundant at Seh-Changi and are, in general, associated with wulfenite, mimetite and fornacite, with which they form very attractive specimens. The small crystals (rarely over a millimeter) occur in two rather different forms: (1) simple prisms terminated by several faces, and (2) more isometric crystals often doubly terminated, where the extension of various faces from one specimen to another renders the orientation difficult.

The color goes from brown to orange, the powder is saffron-yellow. The mineral crystallizes in the hemihedral class of the triclinic system; in using the orientation proposed by S. A. Williams for hemihedrite, we obtain the following parameters: $a = 9.57 \text{ \AA}$, $b = 11.42 \text{ \AA}$, $c = 10.84 \text{ \AA}$, $\alpha = 120^\circ 23'$, $\beta = 92^\circ 27'$, $\gamma = 56^\circ 06'$, very close to those found by that author for crystals from the Florence mine, which are: $a = 9.50 \text{ \AA}$, $b = 11.44 \text{ \AA}$, $c = 10.84 \text{ \AA}$, $\alpha = 120^\circ 30'$, $\beta = 92^\circ 06'$, $\gamma = 55^\circ 50'$. Bariand and Herpin (1963)



have proposed a different orientation for iranite from Chah-Khuni, difficult to use since the axes chosen by these authors to define the morphological cell are different from those used to define the X-ray orientation, and the change to the Williams cell gives differences of several degrees, especially in the α angle. In reality, the variations of parameters between hemihedrite and iranite are very small. These two species have the general formula:



Hemihedrite and iranite form a continuous series varying in the ratio Zn:Cu; type hemihedrite from the Florence mine corresponds to the simplified formula: $\text{ZnPb}_{10}(\text{CrO}_4)_6(\text{SiO}_4)_2(\text{OH,F})_2$, and type iranite from Chah-Khuni to: $\text{CuPb}_{10}(\text{CrO}_4)_6(\text{SiO}_4)_2(\text{OH,F})_2$. Study of the relative content in CuO and ZnO in the crystals from Seh-Changi leads to the conclusion that these crystals are, in reality, hemihedrite or iranite:

	iranite (theor.)	SC 1	SC 2	SC 3	SC 4	hemihedrite (theor.)
CuO	2.65	1.85	1.52	1.31	0.55	—
ZnO	—	0.58	0.85	1.27	1.35	2.66

These crystals are frequently twinned on $(12\bar{1})$ (Williams indexing). Williams, McLean and Anthony (1970) have shown the structural analogy between hemihedrite and a series of isostructural monoclinic minerals: tsumebite, brackebuschite and fornacite. It is concluded that the $(12\bar{1})$ plane of the triclinic cell is transformed to the (010) plane of the monoclinic lattice, which is a plane of pseudosymmetry and hence a twinning plane for hemihedrite and iranite.

Fornacite, $\text{Pb}_2\text{Cu}(\text{AsO}_4)(\text{CrO}_4)\text{OH}$, is also common at Seh-Changi, and forms small sprays of olive-green crystals sometimes arranged directly on cupriferous hemihedrite. The faces are corroded and do not permit measurement on the goniometer. The parameters that we have observed on the diffraction photos are identical to those obtained by previous authors on fornacite from other deposits. The structure is very close to that of hemihedrite, but is monoclinic and hence the twin (010) does not appear.

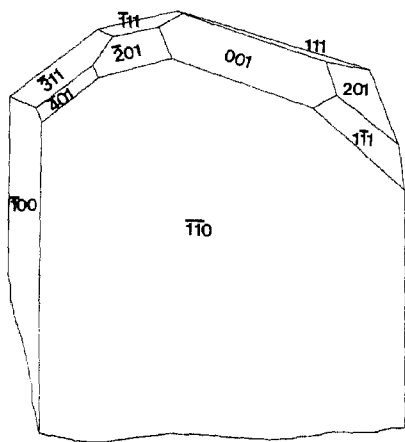


Figure 5. Morphology of phoenicochroite from the Seh-Changi mine.

Phoenicochroite, $\text{Pb}_2\text{O}(\text{CrO}_4)$, is the rarest chromate at the deposit. The crystals, isolated and very small, are of bright red color with the yellow streak characteristic of chromates. These are, in general, prisms elongated on $\{001\}$ and flattened on $\{110\}$. Electron microprobe analyses have shown that part of the chromium was replaced by sulfur. Phoenicochroite has therefore the same structure as lanarkite, $\text{Pb}_2\text{O}(\text{SO}_4)$, but the large difference of ionic radius between sulfur and chromium makes it difficult to fit the

sulfur into tetrahedral positions in the structure of phoenicochroite: there is only about 1 percent SO_3 in phoenicochroite from Seh-Changi.

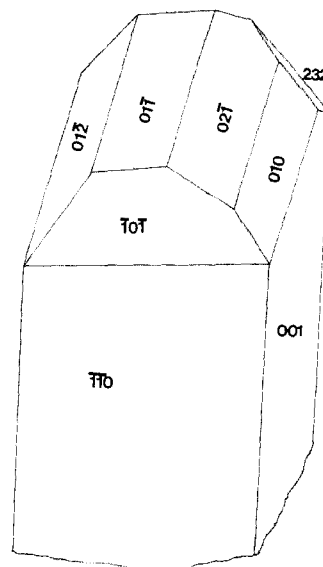


Figure 6. Morphology of cupriferous hemihedrite (X-ray oriented) from the Seh-Changi mine.

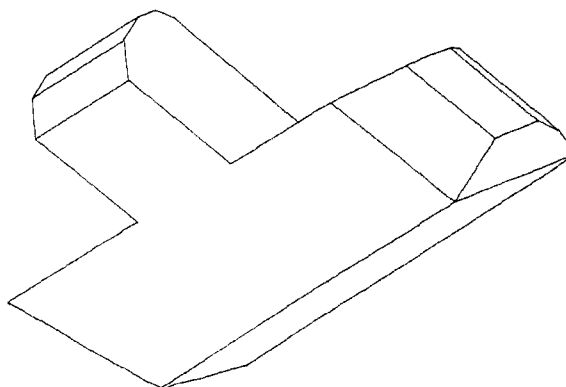


Figure 7. Morphology of a twinned crystal of cupriferous hemihedrite from the Seh-Changi mine.

GENESIS OF THE CHROMATES OF SEH-CHANGI

The succession of the chromates in time, deduced from observation of specimens, seems to be: phoenicochroite → cupriferous hemihedrite → fornacite. Phoenicochroite is practically never associated directly with the other two chromates. It is probable that the rather low Eh and the neutral to slightly basic pH have favored the precipitation of hemihedrite and fornacite, but the almost constant presence of wulfenite crystals with acute bipyramids $\{111\}$ next to the phoenicochroite suggests that the phoenicochroite had a very different environment of growth (following the reasoning of Williams, 1966). This chromate usually forms under basic pH, but its limits of stability, in relation to other chromates of the deposit, depend mainly on the concentration of copper and zinc with respect to lead in the solutions.

The morphology of wulfenite crystals depends more on the content of other substituted elements than on the physicochemical conditions. Thus, the first wulfenite that formed, before or contemporaneous with the chromates, is orange, with very flat form due to the extension of the $\{001\}$ faces, and contains very little chromium in substitution for molybdenum. With the increase in the content of

CrO₃ incorporated in the lattice, the {001} form tends to disappear and to be replaced with bipyramids. This phenomenon is also observed in synthetic wulfenite with increasing concentrations of chromium. The content of substituted chromium can exceed 10 percent CrO₃. It is interesting to note that the bipyramidal red wulfenite which is richer in chromium has crystallized after the chromates: these maximum values correspond without doubt to the time when the chromium was still abundant in the solutions, but not in quantities sufficient to favor the precipitation of independent chromates.

It is quite unusual to have free chromium during oxidation and also to find it in independent mineral phases (i.e. chromates) or in substitution in other minerals (e.g. wulfenite, mimetite), since the change of chromium from the trivalent to the hexavalent state happens only under well defined conditions. But it must also be present in the rock which is undergoing oxidation. This element can come either from small amounts in the hypogene sulfides or from the surrounding rock.

Williams and Anthony (1970) found 0.14 percent CrO₃, measured by X-ray fluorescence, in a specimen of altered diabase from the Florence mine. But no ultrabasic rocks were noted at Seh-Changi, and the primary sulfides don't have chromium. The origin of the element must then be sought in the volcanic breccias or in the interstratified sandstones. The presence of chromium in such sediments would not be surprising since deposition followed the Cretaceous which, in Iran, was a period when important chromium deposits were formed.

ACCESS

The mine, difficult of access, has been abandoned since 1973. The possibility of lodging there is nonexistent. Because of the chaotic political situation in Iran and Afghanistan it would prove a great optimism to hope to do collecting or research in these regions.

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