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CUPRIFEROUS MINERALIZATIONS IN THE SERRANIA DE PERIJA BETWEEN CODAZZI AND MOLINO (Colombia)

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ABSTRACT.—The "Serranía de Perijá" is a mountain chain situated in the north-eastern part of the Republic of Colombia (Departamento del Magdalena and Intendencia de la Guajira), at the Venezuelan border.

Cupriferous rocks outcrop in the part of this chain located between the latitudes of the villages Codazzi and Molino. These outcrops are dispersed in a wide area, but in some places they are concentrated in small extentions.

The present work deals with these manifestations of copper mineralization and their origin.

RESUMEN.—La "Serranía de Perijá" es una cordillera situada en la parte nororiental de Colombia (Departamento del Magdalena e Intendencia de la Guajira), en el límite con Venezuela.

En la parte de esta cadena incluída entre las latitudes de las poblaciones de Codazzi y Molino se encuentran en afloramiento unas rocas cupríferas dispersas en grandes extensiones, pero a veces concentradas en pequeñas áreas.

El presente trabajo se ocupa de estas manifestaciones cupríferas y de su origen.

RIASSUNTO.—La "Serranía de Perijá" è una catena montuosa situata nella parte nord-orientale della Colombia (Dipartamento del Magdalena e Intendenza della Guajira), al confine con il Venezuela.

Nella parte di questa catena inclusa tra le latitudini dei paesi Codazzi e Molino affiorano rocce cuprifere disperse su vaste aree, ma a volte concentrate in piccole estensioni.

Il presente lavoro tratta di queste manifestazioni cuprifere e della loro origine.

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RESUME.—La "Serranía de Perijá" est une chaîne de montagnes située dans la partie Nord-Est de la République Colombienne (Département du Magdalena et Intendance de la Guajira), à la frontière Vénézuélienne.

Dans la partie de cette chaîne comprise entre les latitudes des villages Codazzi et Molino affleurent des roches cuprifères dispersées sur des grandes surfaces mais quelque foi concentrées.

Le présent travail a pour objet l'étude de ces manifestations cuprifères et de ses origines.

PREVIOUS WORKS

Very few minerogenetic works exist on the coupriferons mineralizations of Serranía de Perijá. The only studies on this subject are those of R. WOKITTEL (Boletín geológico Vol. 5 Nº 3 - Servicio Geológico Nacional 1957) and of the Bundesanstalt für Bodenforchung (Investigaciones de yacimientos de minerales en Colombia, by W. FRICKE, W. H. GREBE and G. van den BOOM - 1960, not published).

A more complete literature exist on the regional geology. The "LEXICO ESTRATIGRAFICO" published by the Ministry of Mines and Hydrocarbours of Venezuela is a compilation of data of the stratigraphy of the oriental side of the Serranía. Moreover there is a geological and petropraphic study of the mineralized area, in the western side of the chain, by L. RADELLI, published in "Geología Colombiana" Nº 1, 1962. This work has been taken as the base of the present study, and detailed informations about the geology and petrography of the region are available in it.

THE COPPER BEARING OUTCROPS

1) *Ubication*

The most important copper bearing outcrops are situated in the lowest slope of the Serranía de Perijá, near the plain. The localities where the most important outcrops are concentrated are: San José-Quitafrío, El Seno and Zeppelin in the proximity of San Diego, and El Ovejo, on the southern edge of the Manaure Terrace. Other outcrops of minor importance are those of Gallinazo, to the east of Urumita, Botella, east of Villanueva and those situated to the east of Molino. These outcrops, which are of secondary importance, will be treated separately.

2) *Principal Mineralized Areas*

The region of San Diego, including the localities of San José, el Seno, Zeppelin and El Ovejo, si chiefly composed by the arenaceous red beds of the "La Quinta" formation of permo-jurassic age. These beds have been affected, during this period, by effusions and instrusions of volcanic and subvolcanic rocks along a line going through the mentioned places. These volcanic rocks may be interpreted as the result of the activity of a linear volcano. The copper mineralization took place in these rocks. A fossiliferous limestone of Cretaceous age lies upon the described formations.

The volcanic rocks are dacites, andesites and basaltic andesites and are often strongly mixed up with the sandstones to make a sort of conglomerate of sandstone blocks and volcanic cement. The subvolcanic rocks are microcrystalline quartz-diorites and gabbros.

In detail, quartziferous microgabbros recovered by andesites with basaltic tendences and sandstones are found in San José. Andesitic lavas more or less porous and vacuolar lie at El Seno. Olivine diabases covered by basaltic andesites, at Zeppelin, and chiefly andesitic lavas at El Ovejo (According to RADELLI, see loc. cit.).

The various cupriferous manifestations in these localities are very similar to one another. Some more or less extended areas of light coloured, slightly greenish, strongly altered and friable rocks may be seen within the complex of volcanics. The mineralization has chiefly developed in these areas, where small lenses of epidotized and silicified rock are present. The direction of the lenses is generally east-west. They always have neat gouges and are in relief on the host rock, because of their hardness. Inside these lenses are large quantities of oxidized minerals of copper (cuprite, hydrous carbonates and native copper), which have not been completely dissolved by the surficial waters because of the difficulty of circulation in the very compact rock of these lenses. Some chalcocite is present, beside the above mentioned minerals, at El Ovejo.

3) *The Hydrothermal Alteration of the Igneous Rocks*

The altered igneous rocks, in which, as I have said, took place the mineralization, are extremely variable in wideness. Colour and compactness are very different from those of the unaltered rocks. They are gray, greenish or whitish, and often very friable, in such a way to impede the elaboration of thin sections. Oxidized minerals of iron, as limonite and goethite are likely to be found in these rocks, while no copper minerals are present due to their strong solubility.

The presence of these altered areas shows an hydrothermal phenomenon much more important than that shown only by the cupriferous outcrops. It is noticeable that in the altered areas, not always epidotized and mineralized lenses are found, nor those lenses are always mineralized.

THE MINERALIZATION

1) *Type*

The copper minerals are present in the lenses in form of impregnation. Replacement of the rock minerals by the metallic minerals is very rare. On the contrary, replacement among the metallic minerals and among the gangues is very frequent.

The following is a general scheme of the mineralization:

Through numerous small fissures and joints caused by the relatively rapid cooling of the rock and by its strong alteration, hydrothermal solutions have circulated depositing their metallic salts. The result of this process is the filling of the small cavities of the rock and the replacement of some silicate minerals by primary sulfides of copper and iron. These have been transformated, in a second time, into the oxidized minerals that may be seen at present, by the action of surficial waters. The mineralization is similar to the type called "Disseminated Copper".

Such impregnation may have affected all the altered rock, which is friable and porous. The supergenic enrichment may have taken place afterwards, so that an enriched ore body may exist below the surface.

2) *The Gangue Minerals* (*)

The following sequence of gangue minerals is found together with the metallic minerals, that will be described afterwards.

Epidote is the principal component of the mineralized lenses. It is chiefly present in allotriomorphic crystals. It is less frequent in the host rock were it may be seen either in allotriomorphic crystals or in thin veins. Together with the epidote, some allotromorphic quartz has deposited (*Quartz I*).

The *Quartz II* is very aboundant. It is allotriomorphic and came after the epidote. In fact, it penetrates into the epidotized rock as thin veins, often including portions up to some millimeters in diametre.

Barite is present in large radiated structures.

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* This chapter has been written by L. RADELLI.

Afterwards took place some strongly coloured *chlorite* in well developed lamellae, *tourmaline*, in idiomorphic prisms, *quartz III*, idiomorphic and *calcite* in rounded masses.

3) *The Metallic Minerals*

The metallic minerals present in the outcrops of this region are all of secondary or supergenic origin. Copper and iron ores are found, which implies that the protores should have been probably iron-copper sulfides.

The *native copper* is present everywhere in crystals of different size. It is often idiomorphic. A more or less developed cupritic ring has been frequently observed around the copper crystals.

The *cuprite*, beside the described rings around the copper crystals is also present in thin veins, in the intergranular spaces or in the small fractures of the rock; it is also present as more or less idiomorphic crystals, disseminated in the gangue. This form is probably due to complete alteration of copper crystals.

The carbonates, *malachite* and *azurite* are found in veins or in crusts in the joints. They generally do not penetrate inside the rock.

Chalcocite is rather rare. It is frequent only at El Ovejo, while in the other localities it is absent, or represented only by few skeletons strongly replaced. The crystal shape is prismatic, with rombic section. It does not contain exsolutions of bornite, nor does it make mixed crystals with this mineral, which proves that this sulfide has formed at a temperature lower than 105°C., and therefore is of secondary origin.

Some small crystals of *tenorite* have been observed at San José. They are always associated with the cuprite, and have the same origin.

Among the iron minerals, hematite and goethite are present. The *hematite* is relatively frequent only at San José. It chiefly appears as small hydiomorphic, microgranular and microlamellar crystals. It often shows lamellar twinning in three orders of lamellae at angles of 60° from one another. The crystals are isodiametric in shape, so it is probable that this mineral belongs to the variety "Martite", hematite pseudomorphic on magnetite. Therefore, this iron oxide, or a least the martitic crystals, has a primary origin different from that of the other metallic minerals, being the magnetite part of the mafic fraction of the lava.

The *goethite* is much more frequent than the other iron oxide in all the localities. It belongs to the terrous variety, beeing intimately associated with limonite and lepidocrocite.

The primary metallic minerals (protores) are absent. Only few microscopic crystals of chalcopyrite have been observed at El Ovejo. Primary chalcocite, bornite and mainly chalcopyrite sould have been the primary minerals that have originated the described supergenic. The alteration of the primary minerals took place with gradual passages, from sulfides to secondary chalcocite, to native copper, to cuprite. These alterations are well visible because of the relicts they have left. In some cases it has been observed a chalcocite crystal, reduced to a peripheric ring, while the center is occupied by native copper, altered on its boundaries to cuprite. This structure shows the passage: chalcocite —native copper— cuprite.

PARAGENESIS

From the microscopic study of polished and thin sections of specimens coming from the region, the following paragenetic succession may be seen.

Some small faults with breccia have formed due to tectonic movements of little intensity, in the volcanic rocks. These faults are often concentrated in little extentions and have a general strike east-west. Afterwards, a large portion of the volcanics has been deeply altered by solutions of low temperature coming from a magmatic reservoir which need not coincide with that which originated the volcanic intrusions and effusions. The epithermal solutions must have raised through the fractures originated by the cooling and consolidation of the volcanics, and through the small faults described above, and have permeated the rock through the intergranular spaces. From the economic standpoint these solutions are barren, but from the mineralogical standpoint, much chlorite has formed. Epidote-rich solutions have afterwards invaded the rock, mainly where it had lost its compactness due to alteration. The epidote has chiefly concentrated into the small faults of east-west strike, where the breccia, for its strong porosity, was the favourable host. Little quartz accompanies, in some places, the epidote. After the epidotization, the metal-rich mesothermal solutions came. The minerals deposited by these solutions were copper and iron-copper sulfides, preceded by quartz and followed by barite. The whole altered rock might theoretically have been impregnated by these solutions. Here again, the small faults with breccia were the favourable host. To this mineralizing phase, followed another one, of higher temperature, which brought gangue minerals in this order: chlorite, tourmaline, quartz and calcite. The quartz caused a high silicification and, consequently, a high induration of the epidotized lenses. That is the cause of the relief of these lenses on the host rock which has not been affected by such silicification.

All the deposited minerals have been, at a later time, slightly broken by weak tectonic movements.

Circulation of surficial water, erosion and weathering have succesively caused the oxidation of the primary minerals, their dissolution and transport to deeper zones. Only few oxidized minerals remained in the surficial epidotized lenses, where the water circulated with difficulty due to their compactness.

It is worth to note that at San José, Seno and Zeppelin the oxidized zone outcrops, while at Ovejo a deeper zone is present at the surface. The presence of a good deal of supergenic chalcocite shows that the outcrop at Ovejo is the beginning of the enriched zone.

The mineralization of the studied region may be resumed in the following scheme:

1st. tectonic fase: faults strike East-West

1st mineralizing phase:
- I Alteration of volcanics (chlorite)
- II Epidote and quartz I
- III
  - Quartz II
  - Cu, Fe sulfides
  - Barite

2nd. mineralizing phase:
- Coloured Chlorite
- Tourmaline
- Quartz III
- Calcite

2nd. tectonic phase: weak breaking of minerals

Oxidation — Dissolution — Supergenic Enrichment

AGE AND CLASSIFICATION OF THE DEPOSIT

From the complex of the observations exposed above, the origin of the mineralization seems to be posterior to, and independent from the volcanic rocks.

This interpretation is based on the following:

(1) Paragenesis has no subvolcanic character

(2) Shape of ore-body is not vein-like, as would be normal in a subvolcanic deposit

(3) Presence of tourmaline. which is also found in granites of presumably tertiary age, in the near region of Alta Guajira, where they cross formations similar to those of Serranía de Perijá.

Moreover, this hypothesis is suggested by the normal scheme of the Andine mineralization (emeralds of Colombia; Cerro de Pasco, Perú; Pulacayo, Bolivia; Chuquicamata, Chile, to quote only the most important), depending on the tertiary magmatism. So the existence of a hidden batholite in the Serrania de Perijá must be supposed. On this batholite depends the mineralization of this zone.

SECONDARY MINERALIZED AREAS

Beside the mineralized areas described in the precedent chapters, tere are, in the Serrania de Perijá, many other manifestations of minor importance. Some of them have been exploited, but now they are all abandoned, due to the low grade and irregular mineralization.

Beside that described in the foregoing pages, there are two other types of cupriferous mineralization of secondary importance in the region: (1) impregnations in sandstones and (2) fissure veins.

(1) *Impregnation in sandstones*

A slight impregnation of copper carbonates is observed in the red sandstones where the granulometry and the porosity of the rock is higher than normal, Moreover, some malachite and azurite crusts of supergenic origin are visible in the joints. Due to circulation of silica-rich solutions, the rock has been strongly hardened, and forms small ranges up to ten foot high with a prevalent strike aproximately east-west. Little exploitation has been made of these outcrops, which are very visible for their bright green or blue-green colour.

Among these manifestations it is worth while to mention La Riga and Socorro, in the proximity of San Diego, and the Cerro de la Palangana, east of Molino. Malachite and azurite are the chief minerals present in these outrops, but at Palangana it is also present a large quantity of chalcocite and covellite, copper sulfides that, for their characteristics, may be considered of secondary origin. Moreover, at Palangana, there are also present some crystals of cubanite, an iron-copper sulfide of hypogenic origin, strongly altered and replaced by the supergenic chalcocite. Some native copper and cuprite have been found at Socorro.

(2) *Fissure Veins*

In the locality called Botella, aproximately ten miles east of Villanueva, near the bed of the rio Villanueva, there are some small veins up to two inches wide mineralized with chalcocite, bornite and neodigenite. These veins are in a volcanic body of little extension (100 by 150 feet aproximately) near the contact of this body with the sandstones of the La Quinta formation. The veins are more or less massive, as the quartz gangue is very scarse. The gouges are neat, but in some places the surrounding rock has been replaced by chalcocite, which forms massive bodies of small dimiensions. Crisocolla and malachite impregnate the rock in the proximity of the vein outcrops. It is noticeable that aproximatively hundred yards upslope from the vein outcrops, the sandstone has been strongly impregnated by malachite and crisocolla, in the same way described for the localities La Riga and Socorro. Specks of malachite are also found in the whole extension between the higher and the lower outcrops.

In the lower outcrops, near the bed of Río Villanueva, some mining works have been executed. A tunnel going inside the mountain for aproximately one hundred and fifty feet, following the direction of the mineralized veins has been dug, together with two other small galleries some yards downslope.

The origin of this ore-body is probably similar to that of the principal localities described in the foregoing pages. In fact, in the whole zone surrounding the Botella mine, small epidotized lenses, more or less barren are visible.

The difference between the zone of San Diego and this one is in the paleohydrostatic level. Here outcrops a deeper zone, just at the limit between the enriched and the primary zone, while in the region of San Diego, the surficial oxidized zone outcrops.

The microscopic study of polished sections of specimens coming from the Botella tunnels has shown the presence of both supergenic and hypogenic chalcocite, which means that the primary zone of unaltered sulfides is not far and that the enrichment zone is at its lower limit. About the neodigenite it is difficult to state whether it is of primary or secondary origin, but it seems to have originated by the metasomatic reactions between chalcocite and bornite. Bornite is probably hypogenic. It is chiefly present as exsolution in the chalcocite and neodigenite. Very little covellite is also present.

It is worth while to mention, among the cupriferous manifestations of secondary importance, that of Gallinazo which is situated about seven or eight miles sout-east of Uramita. It is very similar to the San Diego type. Volcanic rocks are intercalated with the red sandstones; but the epidotized rock has, beside the lenticular shape, also a "pocket" shape of larger size. The same minerals are found here, that were in San Diego, but in smaller quantities.

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