REGIONAL GEOLOGY OF THE CHANARCILLO SILVER MINING DISTRICT AND ADJACENT AREAS, CHILE

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ABSTRACT

Chañarcillo, renowned for its fabulous bonanzas, is in a long belt of silver-producing mining districts in northern Chile. Part of the belt, parallel to the Pacific Coast and the Andes mountains, has been mapped recently in some detail. New concepts of the regional stratigraphy and structure that resulted from this work aid in reappraising the Chañarcillo deposit and those of adjacent areas.

The belt, which corresponds roughly to the Andean geosyncline, is bordered to the west by basement rocks of Paleozoic and possibly Pre-cambrian age. The oldest geosynclinal strata are clastic rocks of Triassic age. These are succeeded by marine sedimentary beds of Early Jurassic age and volcanics of Jurassic (?) age. The succeeding Chañarcillo Group and Bandurrias Formation, of Early Cretaceous age, crop out extensively. These two stratigraphic units interfinger, and the rocks in the zone of facies change are the host of the Chañarcillo deposit and many other mineral deposits of the belt. The overlying Cerrillos and Hornitos Formations, comprising volcanic and sedimentary rocks of Late Cretaceous (?) age are the hosts of the rest of the silver deposits of the region. All of the formations are intruded by rocks of intermediate composition.

The chief structural features are folds, domes, and faults that follow the same NNE trend as that of the silver deposits, and which are cut by northwest-striking faults. Chañarcillo is on the south flank of an open dome with radial fractures and faults of the northwest-striking system.

The ore deposits of Chañarcillo occur as vein fillings of the radial fractures, and to a lesser extent of the northwest faults. The relation between ore deposition and doming here seems to be analogous to that described by Wisser (16) for the North American Cordillera. A well

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developed zone of oxidized and supergene sulfide enriched rock has yielded most of the ore that has been mined at all of the silver mining districts in the belt. With few exceptions, the unenriched hypogene zone has not yielded ore. There is little likelihood that Chañarcillo will produce much more ore, except from dumps. Nearby areas of doming, fracturing and deep oxidation, on the other hand, may well be the sites of new ore bodies.

**INTRODUCTION**

The Chañarcillo silver mining district is located at 27°48.6′ S. Lat. and 70°25.6′ W. Long. in northern Chile 50 km south of Copiapó and about 10 km east of the Pan-American highway. Altitudes in the district range from about 750 m to 1,500 m but the ground surface at most of the mines is between 900 and 1,200 m above sea level. The district is very arid and there is little or no vegetation. Chañarcillo is the chief one of about 20 silver mining districts (Fig. 1) that lie within a narrow belt roughly parallel to the coast and 30 km to 90 km inland from the sea, in Atacama and Coquimbo provinces.

The area is in the most southwesterly one of eight 15-minute quadrangles mapped by the author, aided in part by other geologists, during the period 1957–1962. Mapping of the region was greatly facilitated by the use of vertical airphotographs made by the HYCON Company in 1955 with an approximate scale of 1:60,000. Field work in the Chañarcillo quadrangle was accomplished with the aid of Aldo Moraga, of the Instituto de Investigaciones Geológicas, and the geology was plotted on a topographic base at 1:50,000 scale released by the Instituto Geográfico Militar in March 1962. A reconnaissance map of most of the region was made by Carlos Ruiz F. in 1946–53 at 1:500,000 scale, and the present author is greatly indebted to him not only for the use of his unpublished map, later incorporated in the Metallogenic Map of Chile (in press), but for critically reviewing the present manuscript and illustrations. Thanks are also due to W. D. Carter, of the U. S. Geological Survey, for review of the manuscript.

Of published reports on Chañarcillo by many authors, those of F. A. Moesta (3, 4), based on observations made about a century ago, and those of W. L. Whitehead (14, 15), based on observations made about 50 years ago, are the most complete. These publications supply valuable information on the now virtually inaccessible mines, but they were prepared, of course, without our present knowledge of the local and regional geology, leaving much to be said about the stratigraphic and structural setting of the ore deposits. The purpose of the present paper is to describe first the regional geology of the western part of Atacama and Coquimbo and then the geologic setting of the Chañarcillo district in some detail comparing it in a general way with that of other silver mining districts in these provinces.

Areas where similar conditions exist that may be favorable in the exploration for new deposits are suggested.

**SEDIMENTARY AND VOLCANIC ROCKS**

The oldest rocks in the area (Fig. 1) are regionally metamorphosed sedimentary rocks of probable Paleozoic age occurring along and near the coast.
Fig. 1. Geologic map of parts of Atacama and Coquimbo provinces, showing locations of silver-mining districts.Outlined area south of Copiapó is shown in more detail in Figure 3.
In the northern part, where they are of low metamorphic grade, the rocks consist of phyllites, quartzites and a little marble, but in the southern part, where the degree of metamorphism is higher, mica schists are present. At this time no name has been assigned to these rocks, but a tentative correlation with the El Toco Formation of Antofagasta province has been made for a sequence of phyllite and quartzite in the vicinity of Chañaral. The age of the El Toco Formation is believed to be late Paleozoic (6). The mica schists west and southwest of Vallenar and in the region of La Serena may possibly be as old as early Paleozoic or Precambrian.

Acidic volcanic rocks, subaerially deposited conglomerates with granite cobbles, and local coal beds unconformably overlie the rocks of Paleozoic (?) age at several localities. Coal beds northeast of Copiapó containing plant remains of Rhaetic (Late Triassic) age have been assigned to the La Ternera Formation (11).

Limestone and sandstone containing ammonites and other marine fauna of Early Jurassic (Liassic) age and overlying the continental, coal-bearing beds have been assigned to the Lautaro Formation (8). These rocks are in turn unconformably overlain by a predominantly volcanic series, chiefly of lavas which are probably correlative with the La Negra Formation, of Middle
(?) and/or Late (?) Jurassic age, the type locality of which is east of Antofagasta (6).

Marine limestone of Early Cretaceous (Neocomian) age, with interbeds of clastic rocks, forms the Chañarcillo Group. Clastic and volcanic rocks of the Bandurrias Formation are of equivalent age, for the most part. The Chañarcillo Group and the Bandurrias Formation crop out in a north-striking belt that extends lengthwise across the area of Figure 1 (shown with the symbol “KI”), and are the host rock of most of the silver deposits in the region.

The Chañarcillo Group is composed of 4 formations, of which the Abundancia, named for a copper mine 38 km northeast of Chañarcillo, is the oldest. In Quebrada Meléndez, 4 km north of the Abundancia mine, the Abundancia Formation consists of interbedded limestone and tuff (or tuffaceous sandstone) with a total thickness of 205 m (Corvalán, in preparation). At Chañarcillo the Segundo Tuff, about 70 m thick (14), and which appears only in the deepest mine workings, is probably equivalent in age to the upper part of the Abundancia Formation.

The Nantoco Formation is the second oldest of the group. Nantoco, a small village on the Copiapó river about 32 km northeast of Chañarcillo, is the type locality of the formation and of three members, Alpha, Beta, Gamma (1). At Chañarcillo a sedimentary series that is probably equivalent to the Alpha and Beta Members of the Nantoco Formation has been divided into seven members (14). There is no paleontological evidence to establish the correlation between beds at the two localities (Fig. 2), but the gypsiferous Nantoco Gamma Member, lithologically unique in the region, crops out not only in Quebrada Meléndez but also immediately north of Chañarcillo, where it overlies Whitehead’s Descubridora Limestone. The correlation indicates a facies change from limestone with argillaceous interbeds and very little tuff in Quebrada Meléndez to limestone with abundant tuff at Chañarcillo.

The Nantoco Formation is overlain by the Totoralillo and Pabellón Formations, named by Biese for towns upstream from Nantoco, on the Copiapó river (op. cit.) These formations consists of shaly limestone and cherty limestone with clastic interbeds, respectively, at their type localities. A thick lens of volcanic rocks is intercalated in the shaly limestone of the Totoralillo Formation immediately east of Chañarcillo.

The Bandurrias Formation, consisting of volcanic and clastic rocks, crops out west of Chañarcillo, at the same stratigraphic levels as those of the Chañarcillo Group. From its type locality in Sierra Bandurrias, 54 km northwest of Chañarcillo,2 to Cerro Negro, 20 km south, the formation interfingers with the Chañarcillo Group, thus producing a strong facies change from west to east (10). During preparation of the geologic map of the Chañarcillo region it was decided that mappable lenses of clastic and volcanic rocks cropping out well to the east of the main Bandurrias-Nantoco contact should be assigned to the Bandurrias Formation (Fig. 3). Other clastic and volcanic beds (Verde, Ahuesado, Constancia, and Segundo Tuffs) in the areas assigned to the Nantoco, Totoralillo or Pabellón Formations are not

2 Not to be confused with another Sierra Bandurrias immediately south of Chañarcillo.
shown on the map, either because of their small size, or because they are seen only in mines; these beds should probably be considered as interfingering members of the Bandurrias Formation.

Subaerially deposited conglomerates and sandstones of early Late Cretaceous age overlie the older rocks of the region with angular unconformity.

These rocks, together with intercalations of lava higher in the section comprise the Cerrillos Formation in the vicinity of Copiapó (12). This formation of continental rocks together with the overlying Hornitos Formation are the hosts of most of the silver-ore deposits that are not in rocks of Neocomian age. The Hornitos Formation, lithologically similar to the Cerrillos Formation, but also containing lenticular ash flows overlies the Cerrillos and older formations with angular discordance (8).
Alluvium, both in the form of valley fill deposits and high terrace deposits, is extensively distributed in the western part of the area of Figure 1.

INTRUSIVE AND CONTACT-METAMORPHIC ROCKS

Granite, generally coarse-grained and replete with crystals of pink orthoclase, intrudes the metamorphic rocks of Paleozoic (?) age. The radiometric age of this granite, as determined by the lead-alpha method on zircon, is late Paleozoic (6). Granite of similar appearance occurs abundantly as cobbles in the La Ternera Formation, of Late Triassic age. These circumstances indicate that the two granites may be equivalent.

![Diagram of geological section and map](image)

**Fig. 4.** Geologic map and section of the Chañarcillo dome and mining district. Outlined area in lower left-hand part of map is shown in more detail in Figure 5.

All of the rocks described above except the alluvium are intruded by rock of intermediate composition, chiefly granodiorite, which occurs as an extensive batholith in the western part of the region, and stocks or cupolas, in the eastern part. Innumerable dikes and several sills of considerable continuity are exposed in the central part. In the batholith and stocks, the granodiorite, with its gradations to tonalite, granite, diorite or rarely gabbro, is characteristically of equi-granular texture though finer-grained than the pre-Rhaetic granite. In the dikes and sills, on the other hand, the intrusive rock is characterized by a porphyritic texture. At Cerro de los Carros, in Chañarcillo, the intrusive rocks consist of a cupola of altered granodiorite with an outcrop area about 200 m wide, and many highly altered augite (?) porphyry dikes ranging in thickness from 1 to 5 m. It is probable that the dikes were originally diorite or tonalite (14, p. 17).
Garnetiferous contact rocks are exposed at the surface in the southwestern part of the Chañarcillo dome and mining district (Fig. 4, area with ‘Kmc’ symbol), as well as in mines of the entire district below the surface, suggesting that there is more intrusive rock at depth. In places even the upper limestones contain crystals of hornblende and scapolite, resulting from the contact effects.

The age of the granodiorite and related porphyries is about 100,000,000 years (early Late-Cretaceous) (6), at least in part, but some of the intrusive rocks of intermediate composition that are near the coast may be as old as Late Jurassic.

STRUCTURE

A strong northeasterly structural grain is noted in the Chañarcillo area (Fig. 3) and extends throughout the region of Figure 1. The elements that comprise this grain are: (1) the Tierra Amarilla anticlinorium, and other folds; (2) elongation of the principal outcrop areas of granodiorite and of roof pendants; (3) long zones of faulting of layered rocks and closely spaced shearing of granodiorite.

The complex Tierra Amarilla anticlinorium can be traced from about 27°S. Lat. (9, on p. 15) to 27°45', a distance of 85 to 90 km. A cluster of relatively small, doubly plunging anticlines or domes follows the same trend south of Lat. 27°45' (Fig. 3). On the gently dipping southeast limb of this structural high the Nantoco Gamma member and the successively younger Totoralillo, Pabellón, Cerrillos and Hornitos formations crop out in parallel, northeast striking belts (9). Repetition of this sequence on the northwest limb is interrupted by the intrusion of granodiorite.

Well marked and persistent elongation of batholithic bodies and stocks, as well as of roof pendants of the Bandurrias Formation, suggest that the emplacement of the granodiorite was influenced by the roughly parallel Tierra Amarilla anticlinorium and other folds antedating the batholith. Moreover, almost all the mapped intrusions southeast of the main batholith area (northwest corner of Fig. 3) are either sills or other concordant intrusive bodies of porphyry. It is possible that Sierra Bandurrias, immediately south of Chañarcillo, is a laccolith, and Cerro S. Dionisio, farther to the southeast, is a lopolith.

Shearing of granodiorite along a persistent N. 20°E. trend between the Pan-American highway and the coast, and between Copiapó and Vallenar has produced zones of schistose and gneissoid rock as much as 500 m wide (13). Paralleling the trend of these zones is a series of alluvial plains, or llanos traversed by the Pan-American highway.

A northeast-striking fault zone that can be followed for at least 50 km drops the southeastern part of the Chañarcillo quadrangle and adjacent areas (southeast corner of Fig. 3). Narrow outcrop belts of granodiorite and porphyry follow the edge of the upthrown block. Nearly vertical fault planes are exposed in the zone, but the amounts of displacement are unknown.

In addition to the northeasterly structural grain there is a well defined north to northwest-striking fracture system east of Copiapó (9), in the
Copiapó quadrangle (13), and farther south. In these areas, including that of Chañarcillo, the north-northwest system is later than the northeast system but it does not produce large displacements of the older system.

In the area of domes the general structural pattern of long northeast elements and shorter north to northwest elements is complicated by elements of diverse strike. In Sierra Fritis, Sierra de Chañarcillo and Sierra Bandurrias the orientation and arrangement of fractures indicate that at least some of them are radial or concentric to the domes (Fig. 3).

The dome in the Sierra de Chañarcillo (Fig. 4), hitherto undescribed in published reports of the area, has a diameter of 8 or 9 km. It is asymmetric, with a longer slope due to topography toward the southwest than toward the northeast. The Sierra de Chañarcillo comprises all of the dome, but the mining district from which most of the silver ore was produced is near the southwestern base. Except where it is interrupted by a small, open, southwest-plunging anticline and a syncline, and by faulting, the part of the dome that is in the district dips regularly from 8° to about 13° toward the southern quadrants. Nevertheless, dips from horizontal to 55° SW are seen in a disturbed zone near where the anticline is cut by a transverse fault (Fig. 5).

The fracture pattern in the Chañarcillo district comprises N and NE-striking fractures which are more-or-less radial to the dome, and N-to NW-striking fractures that cut the radial fractures. A horsetailing of the transverse northwest fractures is noted in the western part of the district (Fig. 5). The radial fractures (vein-filled), and the beds of limestone and tuff that they cut are displaced by the northwest fractures (generally dike-filled). Little or no displacement of beds by the radial fractures is evident. The Loreto fault, with a displacement of about 50 m down on the southwestern side “separates what have been called the northern and southern areas of the district” (14, p. 31). To the north and northeast of the district appear several curved fractures which are approximately concentric to the dome.

The doming of Sierra de Chañarcillo, as well as that of Sierra Fritis to the northwest and Sierra Bandurrias, to the south, resulted either from vertical uplift or from compressive folding due to the application of horizontal stresses. The presence of concurrent (?) radial and concentric (?) tension fractures favors the hypothesis of essentially vertical stresses. Inasmuch as metallized veins occupy these fractures, the relation described by Wisser (16) between ore deposition and doming in the North American Cordillera seems to apply as well to the part of the South American Cordillera that is described herewith.

On the other hand, according to Whitehead (14), the Corrida Colorada and Veta Descubridora, the principal ore-bearing veins, occupy tension fractures along the crests of anticlines that resulted from the application of lateral compressive forces (14, p. 18, 23). He states further that these are members of the same bifurcating fold and are separated by a shallow syncline. During detailed mapping of the surface of the district in 1962 it was found that the only mappable folds in the area of Figure 5 are the small local syncline and anticline described above. The anticline culminates about 100 m northwest of the Corrida Colorada. The syncline strikes at an angle of about 120° to...
FIG. 5. Geology of the central part of the Chañarcillo mining district, based on an unpublished map made in 1862 by F. A. Moesta. Explanation is the same as that of Figure 4, where applicable.
the crosscutting Veta Descubridora. Thus, there appears to be no direct
genetic relation between the small local folds and the two principal veins.
On the other hand, these veins are more-or-less radial to the dome—at least
as much so as those of Ophir, Utah, one of Wisser’s classic North American
localities (16, p. 20–21).

GEOLOGIC HISTORY

The Chañarcillo silver mining district and adjacent areas are in the
Andean geosyncline and in an area of basement rocks to the west. Geosynclinal sedimentation that commenced in Middle (?) Triassic time with the
deposition of clastic deposits was accompanied by extrusion of silicic rocks.
Submergence and marine transgression in Early Jurassic (Lias) time were
accompanied by extrusion of andesites. Following uplift, this extrusion con-
tinued until Early Cretaceous (Neocomian) time, when a narrow seaway
formed along the middle of the geosynclinal belt.

The area that is now the Chañarcillo mining district was at or near the
western shore of the Neocomian seaway and was subjected to 4 or 5 trans-
gressions and regressions of the sea. During the fluctuations of sea level,
volcanism took place on the landmass between the seaway and the Pacific
Ocean, so that in addition to sedimentation with rapid facies changes, an
interfingering of lavas and tuffs took place.

Renewed uplift was accompanied by late Neocomian or Aptian (?) fold-
ing, constituting the first strong orogeny that affected the Andean geosynclinal
deposits. With uplift and erosion the folds were truncated and coarse, clastic
beds were deposited subaerially producing an angular unconformity between
the marine and continental rocks. Extrusion of andesite was repeated and
more folding took place. Ash flows were deposited on the folded volcanic
rocks and terrestrial sediments. Fracturing followed, chiefly along north-
northeast-striking trends.

A long cycle of magmatic activity that began about 100,000,000 years
ago and probably lasted for millions of years, accompanied the folding and
faulting. The first effect of this activity was to produce the Andean batholith
and its apophyses: stocks, sills and dikes; possibly a laccolith and a lopolith
as well. Emplacement of the intrusive rocks was largely controlled by the
pre-existing faults, folds and bedding planes. Locally, however, the vertical
forces of intrusion and subsidence modified some of the earlier structures or
produced new ones. In some places, particularly where the bedding was flat,
domes (Chañarcillo, Fritis, Bandurrias) and basins (San Dionisio, Don
Beno) were formed. The intruded rocks were thermally metamorphosed
for considerable distances from their contacts with plutonic rocks, but the
dikes and sills had little or no thermal effect.

A late stage of the cycle of magmatic activity was the circulation of hydro-
thermal solutions. Metalliferous deposits were precipitated from these solu-
tions in the regional northeast fractures and in local fractures related to the
doming. In the Chañarcillo district there was little or no hydrothermal
alteration of the wall rock. At a still later stage, north-to northwest faulting
took place, and the last of the dikes were intruded along the fault planes a little before metallization ceased.

Epeirogenic uplift, and processes resulting from the uplift are the principal events of the Cenozoic Era in the Chañarcillo district and adjacent areas. Valley cutting, alluvial fill, and trenching of the fill are consequences of the changes in sea level that have taken place, chiefly during the Quaternary Period. Oxidation, leaching, and supergene sulfide enrichment of the metaliferous deposits are processes that have accompanied the erosion. Movements along the fault planes have continued until the present time. The latest displacements have been lateral at many places, as shown by horizontal slickensides along fault planes and in veins.

ORE DEPOSITS

Copper, gold, silver and iron deposits abound in the area of Figure 1. Twenty-three of the 34 silver mining districts shown on the new metallogenic map of Chile (7, in press) are in this area. From 1860 to 1885 a dozen mines on 3 veins in the Chañarcillo district, the Corrida Colorada, Descubridora, and Candelaria, produced 2,500,000 kg of silver (15, p. 216). During its entire period of activity of 90-100 years the now-abandoned Chañarcillo district produced at least U. S. $100,000,000 in silver. Almost all of the production came from 15 or 20 mines crowded within an area of about a third of a square mile.

Because of flooding, the mines are now inaccessible at depth; even the upper levels were difficult of access in 1962. Much of the surface is covered by dumps, and where bedrock is exposed, finely disseminated pyrite is the only product of metallization that is seen megascopically. The veins that have not been stoped out are narrow and apparently without ore minerals at the surface. Even the dumps have been so thoroughly picked over that only rarely can even a small sample of high-grade ore be found, although large volumes of the dump materials contain as much as 300 g of silver per metric ton (Carlos Ruiz Fuller, oral communication). Because of these circumstances very little can be added to Whitehead’s descriptions of the size and shape of the ore deposits of Chañarcillo, their minerals and paragenesis.

The known ore bodies of Chañarcillo were pods along nearly vertical veins, most of them of the north-to-northeast-striking radial fracture system, which cut the interbedded limestones and tuffs. A notable feature of the ore deposits of the district is their close lithologic control. During exploitation of the mines it was found that ore bodies in limestone as much as several meters wide and 100 to 200 m long were reduced to as little as a few centimeters wide and several meters long where the same vein passed through tuff. This feature is well illustrated in the Constancia mine (14, Fig. 2).

The veins are strongly zoned vertically. The most productive parts occur in the zone where supergene sulfide enrichment has taken place. Progressive erosion has permitted deeper and deeper oxidation and leaching, leaving oxidized ores above the water table, and producing supergene sulfide enrichment of primary ore below the water table. Because of the absence, locally,
of a major drainage system, erosion in the Chañarcillo district did not strip the supergene zone faster than it could form, as it did along the Copiapó river, farther to the northeast, where primary sulfide ores are exposed at the surface (13).

The zone of oxidized rock at Chañarcillo extends to a depth of 190 m east of the Loreto fault and 100 m west of the fault (14, p. 36). Most of the ore minerals of this zone have been found in the Descubridora limestone east of the fault and in the Negro limestone west of the fault. These minerals include the following halides of silver that have replaced earlier silver minerals and calcite: cerargyrite, iodobromite, bromyrite, embolite, and iodyrite. Locally in the zone, the oxidation reactions have been reversed and halides have been replaced by native silver and argentite (14, p. 38).

The zone of supergene sulfide enriched rock is in the Negro limestone (Fig. 2) in the eastern part and in the Delirio limestone in the western part of the district. In this zone the primary ore, containing pearceite, proustite, tetrahedrite, polybasite, and pyrargyrite (14, p. 31), has been replaced first by stephanite and argentite, and then through oxidation of the sulfides, by dyscrasite and native silver (14, p. 35).

Characteristics shared by Chañarcillo with the other silver mining districts shown in Figure 1 are: (1) The ores of highest grade are in the upper parts of the deposits. (2) Limestone and andesite or rocks of similar composition are the most favorable host rocks. Calcareous sedimentary rocks are the most favorable and andesitic rocks the least favorable hosts for ore deposition at Chañarcillo. For no apparent reason, the reverse is true at Tres Puntas, Arqueros and some other districts (5, p. 1153–1154). (3) Barite is an abundant gangue mineral.

The favorability of limestone as a host rock at Chañarcillo can be explained by its susceptibility to replacement, but even in that district the limestone is richest in silver near its contacts with the tuffs (5). A similar relationship is noted in the Gran Bonetón copper mining district, 9 km north of Chañarcillo, where interfingering of the Bandurrias and Nantoco formations is also evident. Ore bodies of the manto type at the Gran Bonetón are either in limestone very near a sedimentary contact with andesite or in andesite very near a sedimentary contact with limestone.

POTENTIAL SILVER RESOURCES

Since the cessation of virtually all silver-mining activity in Chile at the beginning of the 1930's, important production (about 50,000 kg in 1960) has continued only because silver is a by-product recovered from most ores mined for their copper and gold content. Removal of pillars in the mines and hand-sorting of dump material have resulted in a minuscule recovery of silver ores from the Chañarcillo district during the past 30 years. With recent improvement of the position of silver in the commodities market and the promise of higher prices in the near future, it is possible that the many thousands of tons of dump material containing 300 g or more of silver per metric ton may be utilized.
The possibility of finding new ore bodies along known veins in the Chañarcillo district is not great, because exploration has been very thorough, especially during the period 1900–1920, when practically every stringer was followed in the enriched zone and when workings were extended 500 m and even 600 m or more below the surface. With rare exceptions the grades of mineralized rock at depth, in the unenriched hypogene zone, seem to be uncommercial.

Only in the supergene zone do good possibilities for discovery of new ore bodies exist in the region. Exploration should be limited, therefore, to localities where the zones are well developed. Keeping this in mind, old erosion surfaces that have formed on bedrock having favorable lithologic and structural characteristics should provide attractive ground for exploration. Where these surfaces are veneered with gravel deposits, or even where they are deeply buried, silver ore bodies that have escaped detection so far may possibly yield to discovery by geochemical or geophysical methods.

Judging from ore occurrence at Chañarcillo and in many of the other silver-mining districts in Atacama and Coquimbo provinces, favorable lithologic conditions are presented in the Bandurrias formation and other stratigraphic units of equivalent age, preferably where there is interfingering of calcareous strata and andesitic rocks, and near where the strata are cut by small intrusive bodies. A favorable structural environment would be where strata have gentle dips, especially on the flank of an open dome or doubly plunging anticline, or near the crest. Presence of a fracture system is required, but the fractures need not be long, wide or continuous, and if there has been fault movement the displacements need not be great.

The ridge that is 3 to 5 km north of the Chañarcillo district, as well as the least inclined of its slopes, appears to have a geomorphic and geologic environment favorable to the localization of silver ores. The only factor lacking seems to be a well defined fracture system. More or less the same is true of the ridge that extends in a northeasterly direction from the district, except that mappable fractures are present, as well. The two ridges are on the same broad domal structure as the Chañarcillo mining districts. Much of the crestal area of the Tierra Amarilla anticlinorium (Fig. 3), which extends from these ridges northeastward to the Ladrillos district (Fig. 1, no. 6), and beyond, is favorable geomorphologically, stratigraphically and structurally for the deposition of oxidized silver minerals.

In other domes or doubly plunging anticlines south of Chañarcillo and on the sides of the structural basin southeast and east of these small uplifts (Fig. 3) there are numerous mineral deposits that have been mined on a small scale for silver, gold, copper, and iron. Further prospecting, particularly near contacts between rocks of different lithology, may reveal new silver deposits or extensions of the old ones. The prospecting should yield better results on hilltops or gentle slopes, even where there is a veneer of Quaternary clastic deposits, than near water-courses or on the steep sides of valleys. Geochemical prospecting, so far untried in the Chañarcillo district and adjacent areas, may be useful in detecting silver halides, for example, in mantle rock.
An old erosion surface that extends southward from a line of broad, north-striking valleys or *pampas* is the locale of the Cabeza de Vaca and Lomas Bayas deposits (Fig. 1, nos. 9, 11 and 12). North of 27° S Lat. this surface is immediately east of the 70th Meridian, and between 27° and 28° (where it finally dies out), the surface is to the west of the same Meridian. The southern extension of the surface is represented by terrace remnants developed in deeply weathered sedimentary rocks and andesite of the Cerrillos and Hornitos Formation, and partly covered with Quaternary clastic deposits. Parts of the terrain are known to be argentiferous. Hitherto-unknown silver deposits may exist in other sectors of this old erosion surface, particularly where it is covered by stream gravels or by the products of mass wasting.

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