# Base-Metal Deposits of the Cordillera Negra Departamento de Ancash, Peru

GEOLOGICAL SURVEY BULLETIN 1040

*Prepared in cooperation with the Ministerio de Fomento, Instituto Geológico del Perú, under the auspices of the Interdepartmental Committee on Scientific and Cultural Cooperation with the American Republics Department of State*

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*By* ALFRED J BODENLOS *and* JOHN A. STRACZEK

GEOLOGIC INVESTIGATIONS IN THE AMERICAN REPUBLICS

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# GEOLOGIC INVESTIGATIONS IN THE AMERICAN REPUBLICS

## BASE-METAL DEPOSITS OF THE CORDILLERA NEGRA, DEPARTAMENTO DE ANCASH, PERU

By ALFRED J BODENLOS and JOHN A STRACZEK

### ABSTRACT

The Cordillera Negra, the westernmost range in the Departamento de Ancash, is just north of the central mineral province of Peru Within several kilometers of its crest and along a length of 140 kilometers are more than 60 base-metal deposits that total several hundred veins These deposits were studied in 1947 by the United States Geological Survey in cooperation with the Instituto Geológico del Perú

Ores in the deposits contain principally the sulfides of lead and zinc and, in some places, copper, one mine produces antimony ore and another, silver Base-metal production is wholly dependent on silver content of ore, hence only argentiferous sulfides of lead or copper are sought and sphalerite, which contains little or no silver, is discarded At the time of our examination, three mines were operated on a comparatively large scale, but one of these subsequently closed, in 1947 the three produced about 37,000 tons of ore, which was concentrated in flotation plants In the same year fifteen small mines produced probably less than 1,000 tons of ore, which was concentrated by hand cobbing or hand jigging The deposits in the Cordillera Negra have been worked for many years, so the majority of both large and small active mines now contain small reserves The reserves of most of the abandoned mines could not be estimated, owing to inaccessibility of their workings

The oldest rocks that can be dated in the Cordillera are Cretaceous in age An estimated 2,200-meter-thick sequence of sedimentary rocks of Early Cretaceous age consists predominantly of nonmarine sandstone and shale but includes several coal beds, a thin unit of limestone, and, toward the top of the sequence, a unit of tuff These rocks are overlain by Albian to Turonian limestone, estimated to be from 200 to 400 meters thick This sedimentary sequence is overlain by a sequence of layered volcanic rocks, possibly in part of Late Cretaceous age but mostly of Tertiary age The volcanic rocks are estimated to be at least 1,000 meters thick, lava and agglomerate are the most common rocks, but some tuff and a few beds of nonvolcanic sediments are included in the sequence Most of the lava and the agglomerate is porphyritic andesite and most of the tuff is rhyolite The volcanic sequence can be divided into two groups a lower group includes layers that are moderately closely folded, an upper group includes those that are only slightly folded The sedimentary and volcanic rocks are intruded by granodioritic and granitic batholiths and stocks, by porphyritic andesite and rhyolite stocks and plugs, and by sills and dikes ranging from pegmatite to andesite in composition Some sedimentary rock has been converted to andalusite schist near contacts with the batholiths or the larger granitic stocks.

The layered rocks have been deformed during two periods of major orogeny, the first of possible Late Cretaceous or very early Tertiary age, and the second of possible early Tertiary age Each is marked by a conspicuous unconformity. The lower unconformity is between the sedimentary sequence and the folded lower volcanic group, and the upper is between the folded lower volcanic group and the slightly folded upper volcanic group Plutonic intrusion of granodiorite and granite and shallow-seated intrusion of porphyry seems to have occurred in the Tertiary

Strata of the sedimentary sequence are closely folded and those of the lower volcanic group are moderately closely folded, and strata of both are broken by thrust and reverse faults Axial planes of folds dip steeply and strike generally N 30° W , parallel to the structural trend of the Andean Cordillera in this part of Peru Open folds and warps characterize deformation in the upper volcanic group, and are accompanied by steeply dipping normal and reverse faults of small displacement Only limited regional metamorphism of the older rocks resulted during orogenesis, slaty cleavage is found in some shale

Most deposits are mineralized fractures containing pyrite, galena, and sphalerite in a gangue of quartz and carbonate, other minerals that may be present are arsenopyrite, chalcopyrite, enargite, or tetrahedrite Other deposits are quartz-pyrite veins, and in some the sulfides commonly are marmatite, pyrrhotite, and pyrite One vein contains stibnite and pyrite in quartz Either primary or secondary silver minerals occur in all deposits, in some in sufficient quantities to repay fairly high mining costs, gold also is present in many deposits but generally in insignificant amounts Nearly all minerals were deposited as fissure-fillings, but some replaced wall-rock on a small scale in several veins Alteration in most deposits was slight and altered zones are confined to adjacent wall-rock Several deposits, however, occur in widespread altered zones

Textures and the prevalence of low-temperature minerals suggest that the deposits were formed at shallow depths, and that the vertical range of ore deposition was small Mining discloses the maximum range was almost 600 meters At several mines zoning is well developed in both vertical and horizontal dimensions, in distances as small as 200 meters The type of minerals, degree of crystallinity, and vein structures indicate that the veins formed at shallow depths under conditions of moderate to low temperature and pressure, and thus can be classed as ranging from mesothermal to epithermal

Although 600 meters is about the maximum vertical range of strongly mineralized deposits, most veins do not reach this depth Veins range in length from several meters to 2 5 kilometers, and range in width from several centimeters to many meters Lenticular ore shoots of irregular sizes and shapes occupy only small parts of most veins, this precludes any great increase in the rate at which ore is mined

## INTRODUCTION

This report describes the base-metal mineral deposits in the Cordillera Negra, the westernmost range of the Andes in the Departamento de Ancash Most deposits contain sulfides of lead and zinc, but some contain copper minerals, and several contain antimony Silver occurs with galena and, in places, with copper minerals; in one deposit silver sulfides form the principal ore minerals. Gold is present in many deposits but in such insignificant quantities that its value is negligible

The field investigation of the deposits in the Cordillera Negra, made from June to November in 1947, was part of a cooperative geologic program between the Instituto Geológico del Perú, Ministerio de Fomento y Obras Públicas, and the Geological Survey, United States Department of the Interior. The work of the Geological Survey in Peru at that time was sponsored by the Interdepartmental Committee on Scientific and Cultural Cooperation with the American Republics, of the United States Department of State

During our field investigation, more than 60 deposits totalling several hundred veins were examined Most of these deposits were unworked or abandoned A total of fifteen small deposits and relatively large mines with small reserves were being mined or prospected on a small scale and were producing shipping-grade concentrates by hand-cobbing or hand-jigging methods Only three deposits were being mined on a comparatively large scale the Huancapetí and Collaracra deposits of the Anglo-French Ticapampa Silver Mining Co , and the Santa Elena deposit of the Cía Minera Santa Elena, a subsidiary of Mauricio Hochschild y Cía. Production of ore in 1946 was on the order of 10,000 tons by the Anglo-French company and 27,000 tons by the Hochschild company Both companies concentrated ore in flotation plants, but the Hochschild company's mine and mill were closed at the end of 1948, owing to depletion of ore

Like past operations, present operations are conducted so as to recover galena or copper sulfides having a high tenor of silver. Sphalerite, which contains little or no silver, is left unmined or is discarded, even during 1947 and 1948, when zinc prices were relatively high, no attempt was made to ship zinc ores from the Cordillera Negra For a brief period in 1950 and 1951, the Cía. Minera Santa Elena shipped zinc ore during exploration work on one deposit

It is doubtful that much or any increase of the small annual production can be expected. Minor quantities of ore will continue to come from small deposits as new ore shoots are found, but reserves, even in the larger deposits, are small. It should be emphasized, however, that many parts of old mines are inaccessible, and more thorough and elaborate exploration may discover mineable veins or vein segments Access roads to several areas would stimulate in greater production from some smaller deposits that now mine only the ores containing the greatest quantity of silver

## GEOGRAPHY

The Departamento de Ancash lies along the Pacific Ocean north of the Departamento de Lima and south of the Departamento de La Libertad (fig 1) The Cordillera Negra is the westernmost range in the Departamento, extending from the Río Pativilca on the south to the west-flowing lower part of the Río Santa on the north, a distance of about 230 kilometers The upper part of the Río Santa, which flows parallel to the coast for about 170 kilometers before turning to-

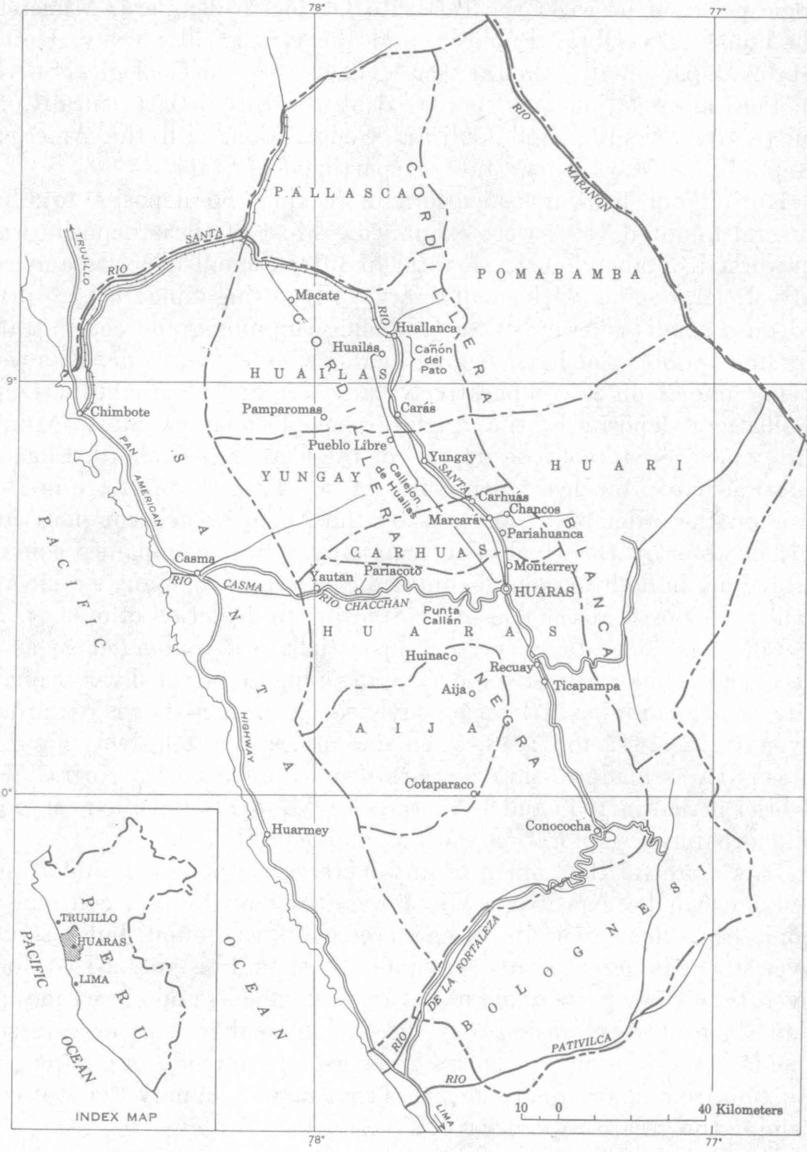


FIGURE 1.—Index map of the Departamento de Ancash.

ward the Pacific, borders the range on the east. The Cordillera Negra connects with the main ranges of the Andean Cordillera only at its southeast end, between the headwaters of the Río Santa and the Río Pativilca. Short tributaries of the Río Santa drain the east slope of the Cordillera Negra; the west slope is drained by longer rivers, of which one or two carry enough water to reach the Pacific. From south to north, the western rivers are the Fortaleza, Huarmey, Culebras, Casma, Nepeña, and Lacramarca

The crest of the Cordillera Negra, from 70 to 80 kilometers from the Pacific, is only from 5 to 15 kilometers from the Río Santa. The crestline is comparatively uniform, having a maximum range in altitude from about 4, 200 meters in the bottoms of several passes to nearly 5,200 meters on the summits of several peaks. Peaks are comparatively unimpressive, rising only a few hundred meters above the surrounding areas The highest are near the north end of the range where at least 8 surveyed points are higher than 5,000 meters, elsewhere in the range only 1 peak reaches 5,000 meters.

The terrain in the Cordillera Negra in places is comparatively open and gentle but elsewhere is extremely rugged. The west slope is characterized by long, deeply incised valleys separated by steep ridges and has little difference in aspect wherever seen. The east slope, on the other hand, becomes progressively steeper and more rugged from south to north Total relief from the Río Santa to the crest of the range is only a few hundred meters at Lake Conacocha, the head of the river at the south end of the range lying at an altitude of 4,020 meters; but is as much as 3,800 meters between the peaks and Huallanca, a town on the river at an altitude of 1,380 meters The crest of the range has comparatively open terrain in its southern and central parts, but from the latitude of Carás north, the crest is very rugged

Peaks throughout the range were glaciated during the Pleistocene period Many cirques are found along the crest, some of them occupied by lakes Other basins were formed by morainal dams and contain lakes and swamps Several are used as reservoirs for towns and farms in valleys below

A noteworthy topographic feature of the area is the tremendous gorge cut by the Río Santa through a ridge of granodiorite a short distance south of the point where the river turns westward toward the Pacific. This feature, known as the Cañón del Pato, is one of the deepest gorges in the western part of the Peruvian Andes. Its descent of several hundred meters in less than 10 kilometers makes it an ideal hydroelectric-power site, for which purpose it has been under development by the Corporación Peruana del Santa, an agency of the Peruvian Government

Although the region is near the Equator, the climate changes from that of a tropical desert to an alpine one as altitude increases. Above 4,000 meters, temperatures near the freezing point are common at night, but many days are warm Precipitation is small in the months from June to September, but rain, snow, or sleet are apt to fall during the remainder of the year on the area above 4,000 meters on the west slope and on nearly any part of the east slope. Total annual precipitation is not great, the Cordillera Negra has much less than the neighboring Cordillera Blanca to the east Owing to the smaller precipitation and the lower altitudes, the Cordillera Negra does not carry the perennial snow and glaciers that are common in many peaks in the Cordillera Blanca (Bodenlos and Ericksen, 1955, p. 40–45)

Vegetation similarly changes from tropical desert flora to an alpine flora with increase in altitude. As the west slope is ascended, varieties of cactus and mesquite are replaced by bunch grass and some wild flowers. Natural timber does not grow in the area. By means of irrigation various crops are cultivated in the valleys to a maximum altitude of about 3,700 meters, and planted eucalyptus trees also survive nearly to this altitude In a zone between 2,500 and 3,700 meters in the valleys on the west slope, and in the Santa Valley, several temperate crops, such as grains and potatoes, are raised. Another irrigated zone in lower parts of valleys on the west slope, from the coast to about 1,000 meters altitude, produces such crops as sugar cane and tropical fruits.

Eucalyptus groves in the Santa Valley and in several valleys on the west slope furnish the bulk of timber needed for mining operations, but some imported pine is used in several of the larger mines Water supply for mine operations varies with season and location, depending on whether deposits are near small streams or the many lakes near the crest of the range.

The largest concentration of population in the Departamento de Ancash is found in the valley of the Río Santa, in a zone including several towns that extends from the railhead at Huallanca, below the Cañón del Pato, to Recuay and Ticapampa, a distance of about 115 kilometers The heart of the zone, dependent on agriculture and known as the Callejón de Huailas, extends from Huailas, in a tributary valley west of the Río Santa, to Huarás, capital of the Departamento de Ancash, a distance of about 85 kilometers Towns in the Cordillera Negra itself are small agricultural centers in the valleys of major streams flowing westward to the Pacific or in tributary valleys of the Río Santa from about the latitude of Huarás northward Along the coast, agricultural areas are associated with the towns of Paramonga, Huarmey, Casma, Nepeña, and Santa Just south of Santa is Chimbote, terminus of the railroad leading to Huallanca. Chimbote has developed rapidly, owing to improvements in its port installations and to anticipated industrial development based on power from the Cañón del Pato Another town that grew during the 1940's is Hidroelectra, headquarters for the Cañón del Pato project, just above the railhead at Huallanca

Within the Cordillera Negra and above the irrigated valleys, the only settlements are mining camps, the sizes of which are dependent on the scale of mining operations Scattered huts of sheepherders and prospectors are found throughout the high country.

## TRANSPORTATION ROUTES

The principal artery of traffic in the area is the Panamerican Highway, the major coastal road of Peru, which connects the region to all cities of importance in the country. Branching from it, three routes lead to the interior of Ancash. The southermost is a road that leaves the highway at Paramonga, ascends the valley of the Río Fortaleza and thence descends the valley of the Río Santa to Huallanca. The central route is a road that branches from the highway at Casma and extends to the Santa Valley at Huarás. The northern route is the railroad between Chimbote and Huallanca, following the valley of the lower Río Santa (fig. 1).

The principal depots for ores mined from the Cordillera Negra are Ticapampa, site of the Anglo-French Ticapampa Silver Mining Co. flotation plant; Huarás, where Mauricio Hochschild y Cía. maintains offices and a depot, and Carás. Here dealers buy from small miners or transship the ores from their own mines, and from these points, ores are moved by truck either north to the railhead at Huallanca for shipment to the port of Chimbote, or south, via the Fortaleza Valley to the coast. Products moving south are loaded on ships either at Supe, 16 kilometers south of Paramonga, or at Callao, the port of Lima, 190 kilometers south of Paramonga. Distances between the ore depots in the Santa Valley and the ports are shown on the accompanying tabulation.

*Distances, in kilometers, from shipping points in the Santa Valley to junctions and ports*

| Shipping point | Route | | | | | |
|---|---|---|---|---|---|---|
| | Río Santa—Río Fortaleza road | | | | Río Santa road—railroad | |
| | Junction or port | | | | | |
| | Paramonga | Supe | Lima (Callao) | Chimbote | Huallanca | Chimbote |
| Ticapampa | 179 | 196 | 369 | 411 | 139 | 272 |
| Huarás | 210 | 226 | 400 | 442 | 110 | 243 |
| Carás | 290 | 306 | 480 | 522 | 30 | 163 |

Only the two large mining companies maintain connections with the arterial routes. The Anglo-French Ticapampa Silver Mining Co. has an aerial tram running from its Huancapetí mine, past the Collaracra mine, to Ticapampa. A road between the two mines provides private transport but does not connect to the highway. The Cía. Minera Santa Elena built a road from Punta Callán, the pass on the

Casma-Huarás road, to its mine and flotation plant at Huinac. In 1950 this company also built a road from a point near Punta Callán to the Jecanca mine. The only other spur road in the Cordillera is that joining the Santa Valley road to the town of Huailas, but this road serves no active mines. Operators of mines, other than those near these routes or the arterial roads, must ship supplies and concentrates on pack animals over trails.

## LOCATION OF MINERAL DEPOSITS

Nearly all mines described in this report are within a few kilometers of the crest of the Cordillera Negra. The east slope of the range, comparatively near transportation routes and towns, has been rather thoroughly explored, and most of the known deposits in the area extending to just west of the crest of the range also have been explored or worked Less is known of the region father down the west slope, but in all likelihood it was explored in the past and apparently was found to lack the concentration of mineralized areas such as occur near the crest. The region near the coast is underlain by the Coastal Batholith, a body of granodiorite extending nearly the length of Peru, and known to be comparatively barren in base-metal deposits throughout most of its extent.

Some difficulty is met in attempting to define true mineral districts in the Cordillera Negra, because mineralization on a small scale was comparatively widespread. Where groups of mineral deposits do resemble mineral districts they will be identified as such, but where mineralized areas are sporadic, groups of deposits are not given district names

Deposits visited in this study occur in a north-south mineralized belt about 140 kilometers long, from a point about 5 kilometers north of Huallanca to a point about 20 kilometers south of Ticapampa (pl 1). The mineralized belt in most places is narrow but in several parts of the range is about 15 kilometers wide. To facilitate description, the belt is divided into three parts that will be termed the southern, central, and northern areas. Arbitrary boundaries are the Casma-Huarás road and a line running west from the town of Carás, at a latitude of about 9°03′ S.

The southern area includes three large deposits and many smaller ones The Santa Elena deposit at Huinac is the northernmost within the higher part of the range, but several small deposits near the Río Santa are only from 5 to 10 kilometers south of Huarás. The largest number of deposits form a group concentrated along the crest of the range for a length of 12 kilometers opposite Ticapampa This group includes Huancapetí and Collaracra, the two large deposits of the Anglo-French company. Scattered deposits are found as far south as Cerro Murpa, a peak northeast of the town of Cotaparaco, and others on the west slope of the range occur between this town and Aija.

The terrain in the southern area is comparatively open and trails are many, so that most deposits can be reached without undue difficulty, although here and there circuitous routes must be used. The principal trails extend from Ticapampa and Recuay to Aija, and from Ticapampa or other points in the upper Santa Valley to Cotaparaco. A network of trails connects Aija to Cotaparaco and to other small agricultural centers on the west slope of the range Trails from Aija also extend northeast toward the Santa Valley and northwest to the roadhead at Huinac.

The central area, roughly between the latitudes of Huarás and Carás, includes several moderate-sized deposits and many small ones, but most larger ones have been worked out. The more important groups of deposits are. at Jecanca (pl 1, loc 21), on the east slope of the range just northwest of Huarás; a belt opposite Carhuás and extending from Cerro Rocotuyuc on the southeast to Lake Cashma on the northwest; on the west slope between Quebrada Pishac on the southeast and the Colquipocro mine on the northwest, opposite Yungay and Carás; and on the east slope of the range above Pueblo Libre, an agricultural center several kilometers south of Carás. These, as well as other scattered occurrences, are comparatively easily accessible by principal trails extending from towns in the Santa Valley to towns on the west slope of the range, and by sheepherders' secondary trails branching from the main routes. Several important trails lead from the town of Carhuás to towns on the Casma-Huarás road, and others go from Carás to the Colquipocro area. Additional trails from Carás and also from Yungay connect to Pueblo Libre and to the other routes along the crest of the range.

Comparatively few deposits are found in the northern area Several small deposits are near the crest of the range northwest of Villa Sucre and southwest of Huailas, and a group occurs in the hills just south and west of Huailas. The only deposit of moderate size, Patara, is just west of the crest of the range between Huailas and Macate, an agricultural town on the north slope of the Cordillera. Several kilometers north of Patara is a group of copper prospects in the Cerro Callhuash area. Trails from the roadhead at Huailas extend to most of these deposits, but several of the more southerly are more easily reached by trail from Villa Sucre The copper prospects can be reached by a trail from Patara or by trails extending from the railroad which follows the Río Santa. A road was being built in 1947 by the Corporación Peruana del Santa to facilitate construction of a power line westward across the range from Huailas, and this may possibly improve access in the Patara area.

## PREVIOUS GEOLOGIC WORK

No systematic geologic studies have been made in the Cordillera Negra. Brief accounts of the geology along trails crossing the range may be found in Raimondi (1873, 1874, and 1913), Dueñas (1904), Sievers (1914), and Boit (1926). A little more detail is found in the broader work of Steinmann (1930), who mapped small parts of the range. Mineral deposits have not been described in detail, although geology of deposits are outlined and summaries of production are given by Velarde (1908), Miller and Singewald (1919), and Steinmann (1930). An early work, that of Raimondi (1873), lists mineral descriptions of some mines and gives notes on early mining in the area It is rather difficult to trace the locations of many mines listed in these reports, either because names have been changed or because mines have been abandoned and forgotten in the intervening years

The Huarás, Recuay, Casma, and Huarmey topographic quadrangles and parts of the Corongo and Santiago de Chuco quadrangles (scale 1·200,000) cover the Cordillera Negra, they were mapped by the Servicio Geográfico del Ejército (Peruvian Army Geographic Service) Topographic maps of the adjacent Cordillera Blanca, compiled on a scale of 1:100,000 by privately financed German geographic expeditions, include the east slope and parts of the crest of the Cordillera Negra The northern section of the range appears on the map by Borchers (1935), and the southern, on the map by Kinzl (1939)

## FIELD WORK AND ACKNOWLEDGMENTS

Field work in the Cordillera Negra in 1947 was conducted by the authors of this paper, ably assisted by Sr J E. Bellido, Geologist of the Instituto Geológico del Perú Sr. Bellido not only was of great help in the geologic studies but also provided valuable assistance in the assembling and maintenance of our pack train and equipment. The chief of the camp crew, Sr. Policarpo Caballero, also is deserving of thanks for his expert packing and for his work as survey assistant Acknowledgment also is made to G E Ericksen, of the United States Geological Survey, for assistance over a period of several weeks in 1948 in mapping several deposits and for studying part of the volcanic-rock sequence just west of Huarás

The 1947 field work was done in two stages, the first, a reconnaissance examination of the many deposits, and the second, a detailed mapping of three of the larger deposits. The reconnaissance examination was done in the course of two pack trips, the first, starting at Ticapampa and ending at Huinac, covered the southern area, and the second, starting at Huarás and ending at Huailas, covered the central and northern areas During this work deposits were mapped only by means of sketches or with brunton and tape. Regional geology was mapped on aerial photographs or topographic maps, generally only along the route of the reconnaissance. The regional map therefore is far from exact but serves to give the general geologic environment of the deposits.

The three deposits studied in detail were Huancapetí, Santa Elena, and Jecanca. The surface was mapped with plane-table and alidade on a scale of 1:5,000; underground workings were mapped with brunton and tape on a scale of 1:500. Officials of the Anglo-French and Hochschild companies provided surveys of their workings for use in our underground mapping.

In 1948, the senior author and Ericksen studied two small deposits in the Santa Valley south of Huarás and the El Carmen stibnite mine near the Casma-Huarás road.

Bearings listed in this report are given as true north, based on an assumed magnetic declination of 6°30′ east of north. Altitudes were obtained from base maps or by means of airplane-type altimeters; owing to lack of accuracy of the instruments, altimeter readings are rounded to the nearest 100 meters.

Many people helped to make this investigation possible; among these is Ing. Jorge A. Broggi, then Director of the Instituto Geológico del Perú, through whose efforts it was possible to begin and complete the program carried out in 1947. Mr. Carrel B. Larson, at that time Minerals Attaché of the United States Embassy in Lima, also gave us information and assistance in beginning this study. Mr. Victor E. Benavides provided unpublished stratigraphic information about the Cretaceous rocks of Ancash, based on his field work in 1951 and 1952.

In addition, we received assistance from the various officials of the Ministerio de Fomento y Obras Públicas and also complete cooperation from the officials of the Departamento de Ancash while in the field. The officials of the Anglo-French Ticapampa Silver Mining Company, and the Cía. Minera Santa Elena, subsidiary of Mauricio Hochschild y Cía, offered us splendid hospitality and quarters as well as technical information while studying their deposits; we especially thank Ing. Rocha, superintendant of mines of the Anglo-French company, and Ing. Susenaga, superintendant of the Santa Elena mine. In addition to these favors, the Hochschild organization permitted us to use its staff house at Pariac as field headquarters. Thanks are also due to many other operators and miners who gave us information on mineral deposits of the area.

## GEOLOGY

Three main rock groups are found in the Cordillera Negra: a sequence consisting dominantly of sedimentary rocks; an overlying sequence consisting dominantly of layered volcanic rocks, and a group of igneous masses intruded into both layered groups. The sedimentary sequence consists principally of continental or fluviatile

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sandstone, shale, and related clastic rocks, but includes some marine limestone and also minor amounts of tuff. The few fossils collected from the sequence in the Cordillera indicate that most or all strata are of Early and Middle Cretaceous age. The volcanic sequence consists principally of lava, tuff, and agglomerate, but includes some volcanic breccia, pillow lava, and minor amounts of sedimentary rock The volcanic rocks unconformably overlie the sequence of Cretaceous rocks and are thought to be of Late Cretaceous and Tertiary age, fossils have been found in them at only one locality, so the age of the group is not well established. The intrusive masses occur as batholiths, small stocks, plugs, sills, and dikes; compositions of these masses range from granite and rhyolite to gabbro. The stage during which they were intruded is not fixed with certainty but probably is in the Tertiary. Unconsolidated glacial deposits of Pleistocene age are found along the crest of the Cordillera Travertine of Recent age occurs at one locality, deposited by hot springs that were still active in 1947.

The sedimentary sequence is closely folded and apparently is faulted to some extent. The overlying sequence of volcanic rocks is less intensely folded and faulted. Neither sequence has been extensively metamorphosed, although some low-grade slate and quartzite are found, probably the result of deformation in the area, and contact metamorphism has affected rocks to a minor degree near some intrusive masses. The lithology, structure, and mutual relationships of these rock groups is in part comparable to units of corresponding ages in central Peru that have been described by McLaughlin (1924), Harrison (1943), and Steinmann (1930).

The sedimentary sequence crops out largely on the east flank of the Cordillera north of Huarás, but extends across the crest of the range west of Carás. Rocks presumably of Cretaceous age also crop out in valleys on the west slope of the range where overlying volcanic rocks have been removed. (See pl. 1). The sequence crops out extensively in the lower part of the Santa Valley, northwest of the mapped area. The volcanic sequence caps the Cordillera, extending down both flanks various distances. Its northern limit is in the high peaks overlooking the Santa Valley several kilometers northwest of the northernmost deposit mapped in this study. To the south, the volcanic sequence extends at least beyond the headwaters of the Río Fortaleza. The main mass of igneous intrusive rock is the Coastal Batholith, part of the large body extending the length of Peru; it lies west of the mapped area The largest mass within the mapped area is an apophysis of the Cordillera Blanca Batholith which crosses the Río Santa at the Cañón del Pato. Smaller igneous bodies occur on both flanks of the range, intruding both sedimentary and volcanic rocks.

It may be noted that our map differs from the Geologic Map of South America (Stose and others, 1950), which was based on previous and relatively incomplete studies (p 10). It was previously thought that exposures of the Coastal Batholith and the apophysis of the Cordillera Blanca Batholith covered larger areas than they actually do. Comparison of the two maps also indicates that the volcanic sequence extends farther north than previously thought. Furthermore, we consider it questionable that sedimentary rocks of Devonian age are present in the southern part of the range

As stated in the introduction, mapping of regional geology was of reconnaissance type only, so contacts shown on the regional map are generalized. We were able to determine their locations with any degree of refinement only where our reconnaissance route crossed or followed major contacts In intervening areas, contacts were interpolated from the study of aerial photographs Similarly, no systematic traverses were made across the range nor were sections of layered rocks measured The map and statements on stratigraphy should therefore be considered as tentative and subject to revision by future students of the area.

## ROCK UNITS

### THE SEDIMENTARY SEQUENCE

Steinmann, in his "Geología del Perú" (1930), which contains a compilation of most of what was known of the geology of the Cordillera Negra, lists the sedimentary rocks of the region as belonging to the lower Neocomian division and the Barremian, Aptian, and Albian stages of the Cretaceous Certain nonfossiliferous rocks, metamorphosed to some extent and generally occurring as isolated outcrops, have been considered by various geologists to be older than the Cretaceous Inasmuch as the nomenclature of Cretaceous rocks in Peru is that used in Europe, the accompanying chart, with equivalents used in the United States, is given for reference

Most units described by Steinmann were studied by him in the Callejón de Huailas (fig. 1), but they can be traced westward into the Cordillera Negra His lower Neocomian sequence consists of quartzite, sandstone, and shale, and several coal beds One section measured by Yáñez León is 760 meters thick (Steinmann, 1930, p. 98). Overlying it is his Barremian sequence, consisting of three units a lower limestone unit, a middle heterogeneous unit, as much as 300 meters thick of sandstone, shale, limestone, marl, and tuff; and an upper *Caprotina*-bearing limestone unit about 100 meters thick (p. 111–116 and 121). Steinmann (p. 112–113 and 120–121) found limestone of Aptian and Albian ages overlying the Barremian sequence. The Aptian limestone, only 15 meters thick, is predominantly marl; the Albian limestone, considerably thicker, is bituminous and contains interbedded black shale. Several parts of this Cretaceous section

*Divisions of the Cretaceous period*

| In Peru[1] | | | | In the United States[2]: Western interior | | | In the United States[2]: Gulf coast | | |
|---|---|---|---|---|---|---|---|---|---|
| Upper Cretaceous | Senonian | | Danian[3] | | | | | | |
| Upper Cretaceous | Senonian | | Maestrichtian | Upper Cretaceous | Montana gp | Fox Hills ss | Gulf series | | Navarro group |
| Upper Cretaceous | Senonian | | Campanian | Upper Cretaceous | Montana gp | Pierre shale | Gulf series | | Taylor group |
| Upper Cretaceous | Senonian | | Santonian | Upper Cretaceous | Colorado group | Niobrara chalk | Gulf series | | Taylor group |
| Upper Cretaceous | Senonian | | Coniacian | Upper Cretaceous | Colorado group | Niobrara chalk | Gulf series | | Austin chalk |
| Middle Cretaceous | | | Turonian | Upper Cretaceous | Colorado group | Benton shale | Gulf series | | Eagle Ford shale |
| Middle Cretaceous | | | Cenomanian | Upper Cretaceous | Dakota ss | | Gulf series | | Woodbine formation |
| Middle Cretaceous | | | Albian | Lower Cretaceous | Purgatoire fm. | | Comanche series | | Washita group |
| | | | | | | | Comanche series | | Fredericksburg group |
| Lower Cretaceous | Neocomian | Upper | Aptian | Lower Cretaceous | No deposits | | Comanche series | | Trinity group |
| Lower Cretaceous | Neocomian | Upper | Barremian | Lower Cretaceous | No deposits | | (base concealed) | | |
| Lower Cretaceous | Neocomian | Lower | Hauterivian | Lower Cretaceous | No deposits | | | | |
| Lower Cretaceous | Neocomian | Lower | Valanginian | Lower Cretaceous | No deposits | | | | |
| | | | Berriasian[4] | Lower Cretaceous | No deposits | | | | |

[1] After Steinmann, (1930)
[2] Simplified from C O Dunbar and others (1942)
[3] The Danian is not included in the Cretaceous by Dunbar
[4] The Berriasian is not included in the Cretaceous by Steinmann

have been found in the central Cordillera Blanca and the northern Cordillera Huayhuash (Bodenlos and Ericksen, 1955, p 23–26).

More recently V E Benavides (Ph D. thesis, manuscript in preparation, Columbia University, New York) studied the stratigraphy in the Callejón de Huailas and revised age determinations as well as correlation of units in this area with those in central Peru Benavides (oral communication) found that the lower Neocomian sequence of Steinmann is restricted to the lower Valanginian. The lower limestone unit of Steinmann's Barremian sequence is of upper Valanginian age The middle heterogeneous unit of the Barremian sequence has a wider range, extending from the lower Hauterivian through the Aptian, and the upper *Caprotina*-bearing limestone unit is considered by Benavides as of lower Albian age The Aptian and Albian limestone of Steinmann are assigned by Benavides to the middle Albian

Cretaceous units in central Peru are the Goyllarisquisga formation, the Machay limestone, and the Jumasha limestone (McLaughlin, 1924, p 605-609; Jenks, 1951, p 211) Steinmann correlated his lower Neocomian sequence with the Goyllarisquisga, and the limestone and shale of Aptian and Albian ages with the Machay, placing his Barremian sequence between them Benavides, however, determined that the Goyllarisquisga formation is equivalent to the middle heterogeneous unit of Steinmann's Barremian sequence Steinmann's lower Neocomian sequence, and the lower and upper limestone units of his Barremian sequence do not occur in central Peru According to Benavides, Steinmann correctly correlated units he considered as Aptian and Albian in age to the Machay limestone Steinmann did not find the Jumasha limestone in Ancash, but Benavides traced it into the northern Cordillera Huayhuash, it is considered to range in age from upper Albian through the Turonian.

### PUEBLO LIBRE-COLQUIPOCRO AREA

The most extensive section of rocks of Cretaceous age in the Cordillera Negra occurs in the north-central part of the range, in the area between the Río Santa and the Colquipocro mine (pl 1, loc. 45) The oldest rocks crop out in a generally anticlinal area on the east slope, in the vicinity of Pueblo Libre (pl. 1, loc 40), and the youngest in a generally synclinal area on the west slope, several kilometers east of Colquipocro

In the vicinity of Pueblo Libre, the lower part of the lower Neocomian sequence of Steinmann consists of interbedded quartzite, sandstone, and shale, and several coal beds The upper part of the lower Neocomian sequence consists of thick-bedded quartzite forming a unit that is several hundred meters thick The shale of the lower part of the sequence is drab to dark gray and black, and in places is metamorphosed to carbonaceous slaty rock The interbedded sandstone is thin bedded and has drab and somber colors, in places it contains considerable impurities and approaches graywacke in composition The quartzite in the lower part of the sequence is lighter in color than the sandstone The beds of quartzite in the upper part of the sequence are light colored and form extensive and prominent outcrops The thickness of Steinmann's lower Neocomian sequence is estimated to be at least 1,000 meters In the Pueblo Libre area, the sequence crops out in an area extending from the Río Santa to just below the crest of the range.

Overlying the upper quartzite unit of the Lower Neocomian is a sequence of limestone and shale that includes some sandstone. It is equivalent to the lower limestone unit of Steinmann's Barremian sequence Although the sequence consists predominantly of moderately dark shale, it contains three groups of gray to dark gray limestone beds, each about 20 meters thick. The two lower limestone groups are thin bedded and the upper group is thick bedded Several zones contain turriteloid gastropods, none of which were sufficiently well-preserved to permit identification The limestone groups are more resistant to erosion than the shale and sandstone beds and hence form narrow but prominent outcrops The sequence is estimated to be 250 meters thick The thick-bedded limestone is at the top of the sequence, and the lowest group of thin-bedded limestone is about 150 meters below the top of the sequence

Overlying the limestone and shale sequence is a thick sequence of thin-bedded shale and sandstone, which contains some calcareous beds and tuff. Near the base, sandstone predominates. Above it, thin-bedded shale, sandstone, limestone, and marl are interbedded, and near the top is a unit of tuff. The basal sandstone is darker than the quartzite in the upper part of the lower Neocomian sequence, the interbedded heterogeneous part of the sequence is mainly drab, and the tuff beds are reddish and green The sequence is equivalent to the middle heterogeneous unit of Steinmann's Barremian sequence We estimate that it is more than 1,000 meters thick, a considerably greater thickness than the section of 250–300 meters measured for the unit by Steinmann in the Santa Valley. Along the Pueblo Libre-Colquipocro trail, the sequence crops out from a point several hundred meters east of Cerro Chacay, the crest of the Cordillera Negra in this area, to Hacienda Cajabamba, 4 kilometers east of the Colquipocro mine. Close folding has caused repetition of parts of the sequence throughout the upper Quebrada Cajabamba (pl. 2, *A*) The tuff was seen only in a belt 1 kilometer east of the Hacienda Cajabamba, and also along the Cajabamba-Huata trail, in the saddle west of Cerro Pucarangra

The uppermost sequence of Cretaceous rocks is predominantly limestone. Most of the limestone beds are comparatively thin, gray to dark gray, and have interbedded sandy and shaly layers Some are strongly bituminous and contain interbedded black shale We estimate the thickness of the sequence to be between 200 and 400 meters The limestone crops out in the vicinity of Hacienda Cajabamba, extending southward along the Cerro Aquilpampa-Cerro Ananpunta ridge, and also below the volcanic rocks on the southeast flanks of Cerros Putaca and Rico.

Two collections of ammonite fossils from the vicinity of the Santa Rosa mine (pl. 1, loc. 49), on the south flank of Cerro Ananpunta, were identified by R. W. Imlay of the Geological Survey. One contains *Oxytropidoceras* sp, *Brancoceras*? sp, *Inoceramus* cf. *I. concentricus* Parkinson, and *Oxytropidoceras carbonarium* (Gabb), considered as representing the middle Albian stage. The other contained *Prionotropis* and *Mammites*?, which are of middle or upper Turonian age The limestone sequence in part therefore corresponds to Steinmann's Aptian and Albian limestones. The underlying upper limestone unit of Steinmann's Barremian was not seen but undoubtedly is present. More significant is the presence of limestone of Turonian age, heretofore found only in northern Peru (Kummel, 1948, fig. 7, p. 1251), although the Jumasha limestone, dated by Benavides (oral communication) as upper Albian to Turonian, crops out 80 kilometers to the east in the San Marcos and Huari area (Bodenlos and Ericksen, 1955, p 26–27).

In summary, the section of Cretaceous rocks includes an estimated 1,000 meters of quartzite, shale, sandstone, and several coal beds, 250 meters of limestone and shale; 1,000 meters of thin-bedded clastic rocks containing some calcareous and tuffaceous beds; and from 200 to 400 meters of limestone and shale According to revisions made by Benavides, the lower clastic rocks and limestone are Valanginian in age, the upper clastic rocks range from lower Hauterivian through the Aptian in age, and the upper limestone is Albian in age. The identification of Turonian fossils by Imlay raises the upper limit of limestone deposition by several stages over that in the Santa Valley

Our estimates of the thicknesses of the two clastic sequences are greater than those given by Steinmann. It is evident that the section of the lower Neocomian of Steinmann, as measured by Yáñez León, is not complete, because its base is a coal bed which obviously is not the base of the sequence The upper clastic sequence similarly seems to be substantially thicker than reported by Steinmann. As his sections show both the base and the top, it is not known why the discrepancy occurs. In this reconnaissance investigation, we did not differentiate the subdivisions of the upper limestone sequence, including Steinmann's upper limestone unit of the Barremian and his Aptian and Albian limestones. The bituminous limestone and interbedded black shale correspond in lithology to Steinmann's Albian limestone.

#### OTHER LOCALITIES

The sedimentary section described above crops out along the east flank of the Cordillera Negra from the Pueblo Libre area southward toward Huarás. The most conspicuous beds are those of the unit of thick-bedded quartzite at the top of the Lower Neocomian sequence and limestones of the overlying unit of Steinmann's Barremian sequence In addition to the lithologic types in the section passing through Pueblo Libre, some conglomerate occurs above Pariahuanca.

The upper limestone sequence was not seen along the east flank of the range south of Pueblo Libre.

In the northern part of the range, from Huailas northwest to Patara and Quebrada Manto Alto (pl. 1, locs. 62, 63), we skirted the edge of the sedimentary section. As in the south, lower Neocomian clastic rocks with included coal beds are present. In the Quebrada Rumicruz southwest of Huailas, just below the contact with unconformably overlying volcanic rocks, we collected fossils that were identified by R. W. Imlay as *Brancoceras* sp. and *Inoceramus* cf. *I. concentricus* Parkinson, of middle Albian age. From this we assume that most of the Cretaceous column occurs in this part of the range. Boit (1926, p. 55) noted some gypsum occurring with the limestone in the Huailas area, Benavides (oral communication) states that gypsum is characteristic of the middle heterogeneous unit of Steinmann's Barremian sequence. Fossils collected by Lisson (1930, 1937) from rocks lower in the section were first considered as Aptian, but these occur with *Valanginites broggii* (Lisson) and *Trigonia gerthi*, which Srta. Rosalvina Rivera, paleontologist of the Instituto Geológico del Perú, considers to be of Valanginian-Hauterivian age (written communication).

Sedimentary rocks in the Cañón del Pato are contact metamorphosed both south and north of the apophysis of the Cordillera Blanca Batholith. Boit (1926, pp. 55, 66, and 71) and Broggi (1945, pp. 69–79) indicate that the metamorphosed rocks may be of upper Jurassic age, Tithonian (Portlandian) stage. Our work in the adjacent Cordillera Blanca led us to conclude that dating of such metamorphosed rocks before detailed stratigraphic studies is doubtful because Tithonian and lower Neocomian rocks in this area are lithologically similar (Bodenlos and Ericksen, 1955, p. 20).

Elsewhere than in the upper Quebrada Cajabamba, all sedimentary rocks on the west slope of the range crop out in isolated areas and only where the overlying volcanic sequence has been removed by erosion. Such areas are more extensive than shown on the regional map. In addition to the areas around Aija and Cotaparaco, we saw rocks of sedimentary origin in the valleys of the Río Fortaleza and the Río Casma. Raimondi (1873, p. 284) reported the presence of sedimentary rock in the valleys of the Río Culebra and the Río Nepeña, and Boit (1926, p. 68) noted similar rocks along the coast at Casma and at Chimbote. The areas in the river valleys extend to the contact with the Coastal Batholith.

According to previous accounts, the sedimentary rocks in most of these valleys are substantially metamorphosed, and this fact and the lack of fossils has led to the conclusion that they are older than Cretaceous. Sievers (1914, p. 57) opined that such rocks near Pariacoto, in the valley of the Río Casma, might be as old as pre-Cambrian. As with the case of the contact-metamorphic rocks in the Cañón del

Pato, however, we feel that considerably more study would be necessary before such rocks could be dated with any degree of reliability.

In the Aija area, we traversed closely folded sedimentary rocks from Cerro Condorpunta on the south, through Aija and La Merced, to Huinac on the north. Raimondi reported they extend to Coris, about 14 kilometers southwest of Aija, and Pflucker (1906, p. 15) stated they extend 7 kilometers northeast of Aija.

Most beds in the Aija area are of dark shale or its slightly metamorphosed equivalent. Southwest of Aija is an anticline in thick-bedded quartzite, which may be equivalent to the thick-bedded quartzite at the top of the lower Neocomian on the east slope of the range. In addition, some sandstone, thinner-bedded quartzite, conglomerate, limestone, and coal beds were seen in the area. The rocks definitely resemble the rocks of the lower Neocomian and the middle unit of Steinmann's Barremian sequence. Lisson and Boit (1942) found *Berriasella* cf. *cornifera* Gabb, of Valanginian-Hauterivian age, in this area, and Srta. Rivera identified *Holcostephanus* sp. of Hauterivian age, collected near the Santa Elena mine (written communication).

In the vicinity of Cotaparaco, closely folded and complexly faulted shale, quartzite, red shale and conglomerate, and limestone comprise the sedimentary rocks. A thick bedded quartzite in the sequence may be equivalent to the quartzite southwest of Aija, but the red shale and conglomerate were not seen elsewhere

Only a narrow width of rocks of sedimentary origin was seen in the valley of the Río Fortaleza They are slightly metamorphosed sandstone and shale, occurring just east of the Coastal Batholith, some 60 kilometers by road from the Panamerican Highway

In the valley of the Río Casma, sedimentary rocks extend several kilometers east of Hacienda Chacchán, where they are in contact with overlying volcanic rocks The western limit is said to be near Pariacoto, according to Dueñas (1904, p. 23–24) and Boit (1926, p 49), but both writers also noted isolated masses of metamorphic rocks in the Coastal Batholith near Yaután

### SEDIMENTARY OUTCROPS IN VOLCANIC TERRANE

Small outcrops of sedimentary rock are found in several parts of the range in which the volcanic sequence predominates. We did not find fossils in any such areas

In the southern part of the range quartzite crops out between Lake Conococha and the head of the valley of the Río Fortaleza A second locality is just southwest of the San Ildefonso mine (pl 1, loc. 12). Here conglomerate, black shale, cherty and tuffaceous limestone, and chert crop out in an area about one-half kilometer in diameter. At the west end of the Collaracra vein (loc. 1), shale and argillite are exposed west of the intrusive.

It may be noted that rocks of Devonian age are shown on the Geologic Map of South America (1950) in the Collaracra-Aija area. No reference to this dating has been found. A possibility exists that it results from a misinterpretation of the geologic map of Peru accompanying Steinmann's text, because almost identical colors are used for Devonian sedimentary rocks and for Tertiary intrusive rocks. Redbeds of unknown age are said to crop out at the north end of the zone shown as Devonian (V. E Benavides, oral communication).

North of the Casma-Huarás road, quartzite crops out below the Cerro Maco deposit (loc 25); north of the pass at Punta Callán, in the vicinity of the San Juan deposit (loc 23), and east of the crest of Cerro Pacusin, the summit of the range above locality 26 In addition, examination of aerial photographs suggests that quartzite may crop out between the San Juan deposit and Punta Callán, crossing Cerros Torococha and Uchunka All outcrops may be isolated ridges of the massive quartzite of the lower Neocomian of Steinmann, which crops out near the crest of the range in the large embayment of the sedimentary sequence.

To the northwest, quartzite and quartz conglomerate are upfaulted and upfolded at the Pucajirca deposit (loc 30) and between Pucajirca and Cerro Plumisa (loc 34) These rocks also may be of lower Neocomian age, but quartzite is interbedded with volcanic rocks in the vicinity of Lake Shaullán, just north of Cerro Plumisa, so it is possible that the sedimentary rocks of this area may be younger than Cretaceous in age

## THE VOLCANIC SEQUENCE

### GENERAL DESCRIPTION AND PETROLOGY

Geologic studies in central Peru indicate that toward the end of the Cretaceous period, an orogeny produced some folding and marked the end of deposition of marine sediments in the Andean area. This disturbance, named the Peruvian orogeny by Steinmann (1930, p. 296), also marked the beginning of volcanism that continued in various parts of Peru through the Tertiary and in places even into the Pleistocene. During this interval, volcanism was interrupted by at least one major orogeny succeeded by extensive erosion; this disturbance, thought to have taken place in the early Tertiary, is named the Incaic orogeny by Steinmann (p 297) Diagnostic fossils are scarce in the continental clastic rocks and fresh-water sedimentary rocks interbedded in the volcanic sequence, so precise dating of the orogenies and of the volcanic rocks has not been possible.

Little can be found in the literature concerning the volcanic sequence in the Cordillera Negra. All geologists who crossed the range, including Raimondi, Dueñas, Pflucker, Sievers, and Boit, noted its presence, but their published information consists largely of brief lithologic descriptions. Steinmann (1930, p. 153–154, 187, 191, 216, and fig.

267, p. 230) made additional observations, summarized as follows Most volcanic rocks are of Late Cretaceous or Early Tertiary age, corresponding to the volcanic phase of the Rimac formation of central Peru (the Río Blanco volcanics of the Casapalca formation, McLaughlin, 1924). In one locality on the east slope of the range, between Huarás and Punta Callán, a limestone interbedded with volcanic rocks contains fossils identified by Steinmann as Senonian in age. On the map accompanying Steinmann's text, younger volcanic rocks of Tertiary age are shown in several parts of the range.

Types of volcanic material in the Cordillera Negra include lava, flow breccia, pillow lava, agglomerate, and tuff, among which lava and agglomerate predominate. Volcanic breccia is interbedded with some lava but is not conspicuous in most places Pillow lava was seen in only a few localities. Tuff is not uncommon but its beds are thinner than those of lava and agglomerate. Flows of very fine-grained rhyolite, comparatively thick in the northern part of the range, possibly may be welded tuff. Interbedded sedimentary rocks, generally thin and inconspicuous, have sporadic distribution Most are sandstone or shale associated with tuff. The only limestone we saw occurs just west of the Jecanca area, and although near the locality where Steinmann collected fossils said to be of Senonian age, it appeared to be nonfossiliferous Angular or rounded quartzite and sandstone fragments form conglomeratic material in some flows. In the Lake Shaullán area, beds of quartzite interbedded with volcanic rocks are comparatively thick.

Thin-section study shows the volcanic rocks to consist of rhyolite, rhyodacite, dacite, trachyte, trachyandesite, andesite, and basalt. Petrographic determination by microscope was not wholly satisfactory, inasmuch as the fine grain size and alteration obscured identification and relative proportions of minerals; less than half the rocks collected throughout the range could be classified with any degree of assurance. Within these limitations, however, it is possible to assert that andesite predominates in lava and agglomerate, and rhyolite predominates in tuff. With increasing potash content, andesite grades toward trachyte, and with increasing quartz content andesite and trachyte grade toward dacite and rhyodacite Dark minerals tend to be subordinate to feldspars and quartz, so basic rock types, such as basalt, are uncommon With increasing calcium content, tuff grades from rhyolite toward dacite, quartz-free varieties among the fine-grained pyroclastic rocks were not recognized Only one glassy flow rock was seen in thin-section.

Hand specimens from lava and agglomerate beds of the andesite-trachyte-dacite-rhyodacite group are quite similar in appearance, tending to be gray to green fine-grained porphyritic rocks. Phenocrysts, principally of plagioclase feldspars and to a lesser extent of orthoclase, quartz, pyroxene, amphibole, and biotite, are from 1 to 3 millimeters in length or diameter, although exceptionally they may reach 5 millimeters These are set in fine-grained groundmasses that consist mainly of feldspars but contain quartz in the more silicic varieties Generally the grain size in the groundmass is just large enough to enable the grains to be seen under high magnification and is too fine to permit ready identification of the minerals

In andesite, plagioclase phenocrysts are zoned and may be complexly twinned In 16 of 20 specimens classed as andesite the cores of plagioclase phenocrysts were in the andesine range ($An_{30-50}$), and in the other 4 they were in the labradorite range ($An_{55-65}$); the mantles generally were calcic oligoclase In a few specimens, some orthoclase occurred as phenocrysts but was more common associated with fine-grained plagioclase in the groundmass Dark minerals included augite, pigeonite, hornblende, and biotite Lesser constituents, seen in one or several slides, included orthopyroxene, anorthoclase, perthite, and microperthite Some specimens included small amounts of quartz occurring either as small phenocrysts or mixed in the groundmass; these were considered to be intermediate between andesite and dacite.

In trachyandesite, plagioclase is either sodic andesine or oligoclase; orthoclase as phenocrysts also is present Hornblende is the chief dark mineral In trachyte, orthoclase predominates, occurring both as phenocrysts and in the groundmass The plagioclase is never more calcic than $An_{30}$ All dark minerals seen in thin section show alteration In rhyodacite, quartz and orthoclase are common, plagioclase ranges from albite to oligoclase, and microperthite may be present. Biotite was the only unaltered dark mineral seen in slides of rocks classed as rhyodacite Some hand specimens of rhyodacite are comparatively light in color as compared with specimens of other rock types, and it is possible that the darker colors in the others are due in large part to alteration products

In basalt, the plagioclase labradorite ($An_{54-62}$) predominates, zoned toward sodic andesine or calcic oligoclase. Either pigeonite or augite forms the principal dark mineral, one slide also contained hypersthene and in another biotite partly replaced ortho- and clinopyroxenes. Both in hand specimens and in thin sections, basalt is darker than other volcanic rocks, in part owing to magnetite dust scattered through the finer-grained material forming the bulk of the rock In contrast to the rocks described above, basalt is less prominently porphyritic, consisting of smaller phenocrysts and coarser groundmasses

Rhyolite is lighter in color than the less silicic rocks, generally ranging from creamy white to light gray Quartz always can be seen in hand specimens, together with some orthoclase Quartz grains range in shape from subhedral to rounded and may be embayed, orthoclase not only forms phenocrysts but is mixed with fine-grained quartz in the groundmass. The plagioclase ranges from albite to oligoclase and muscovite also is common The groundmass tends to be finer grained than in less silicic rocks, and in many thin sections actually is cryptocrystalline

It was stated that some comparatively thick flows classed as rhyolite may be beds of welded tuff Evidence is insufficient to confirm this possibility, but this rock tends to have comparatively angular and poorly sorted phenocrysts embedded in a cryptocrystalline groundmass Muscovite flakes may be complexly bent and flow lines seen in outcrops may be complexly contorted The megascopic appearance of this rhyolite is that of a dense light-colored rock containing a few small quartz phenocrysts

Tuff in the Cordillera Negra ranges in color from creamy white through light grays and greens to reds, it forms outcrops distinguished by their colors and by their tendency to weather and erode more readily than flows and agglomerates Mineral fragments include quartz, orthoclase, anorthoclase, plagioclase, muscovite, biotite, and hornblende One thin section contained stony fragments of fine-grained feldspar aggregates Plagioclase ranges from andesine ($An_{33-46}$), through oligoclase, to albite, the more calcic grains are zoned to oligoclase Glass shards, devitrified to different degrees, are common All specimens are classed as rhyolite and rhyodacite crystal tuff Some contain nonvolcanic material, generally silt but also sand and small pebbles, and one, probably water-laid, includes considerable lime

All thin sections show that volcanic rocks are altered Alteration ranges from slight kaolinization of feldspars, either the result of weathering or hydrothermal alteration, to complete conversion to quartz-sericite rock where rock was strongly attacked by hydrothermal solutions near mineral deposits Chlorite, epidote, calcite, sericite, and accompanying quartz and either magnetite or hematite are the chief products. Most alteration may have been done by hydrothermal mineralizing solutions, yet rock similarly although less intensely altered is widespread and is found in areas some distance removed from known mineral deposits Alteration will be described in greater detail in discussion of ore deposits (See p 51 )

The total thickness of the volcanic sequence in the Cordillera is great but as yet is unmeasured In areas where the rocks are comparatively flat-lying, such as in the vicinity of Cerro Uchunga on the crest of the range southwest of Yungay, a difference in altitude between the peak and the base of the volcanic rocks is 800 meters on the east and 1,000 meters on the west Similar thicknesses seem to prevail among the slightly folded volcanic rocks in the southern part of the range. Where part or all of the volcanic sequence is more closely folded, the difference in altitude between the base of exposures and the crest of the range is greater. South of Huarás the vertical extent of exposures is from 1,200 to 1,500 meters, and west of Huata and Huailas it is 2,500 meters It would appear that the minimum thickness of the sequence is 1,000 meters, the maximum cannot be estimated

Sections of volcanic rocks are apt to differ substantially from place to place, owing to lensing and wedging of beds and groups of beds (pl 2,*B*) Local unconformities, especially in lava and agglomerate, are also common Tuff beds, although relatively thin, are more extensive than lava flows or agglomerate beds, and can be traced for distances of from 10 to 15 kilometers in parts of the range

### DIVISION OF THE VOLCANIC SEQUENCE

A division can be made of the volcanic sequence that is based on the extent of deformation in the rocks a lower volcanic group consists of moderately closely folded older volcanic rocks, and an upper volcanic group consists of only slightly folded, warped, or tilted younger volcanic rocks. An unconformity is seen at some contacts between the sedimentary rocks of Cretaceous age and overlying folded volcanic rocks, and is most evident southeast of Cerros Rico and Putaca (pl 2,*A*). Within the volcanic sequence another unconformity, quite conspicuous in places, occurs between the closely folded lower group and the slightly folded upper group. Where the less deformed upper group lies directly on Cretaceous sedimentary rocks, such as around Aija, between Cerros Mangan and San Antonio (pl. 3), and south and west of Huailas, the unconformity is always a major one The structures are considered to reflect the mountain-making disturbances named the Peruvian and Incaic orogenies.

Our reconnaissance route did not follow contacts for sufficient distances to warrant showing the areal distribution of the lower and upper volcanic groups on the regional map A description of the approximate areas underlain by the folded lower group and by the less deformed upper group of volcanic rocks follows.

In the central and southern parts of the Cordillera, the major belt of the closely folded volcanic rocks of the lower group lies on the east flank of the range, extending from the bulge 10 kilometers north of Huarás to the south edge of the mapped area, a distance of at least 60 kilometers The unconformable contact with less-folded volcanic rocks of the upper group is visible in the ridge south of the Tuctu deposit (pl 1, loc 9), and can be traced southward just east of the crest of the range The unconformity is not as conspicuous from Tuctu northward, but it seems to run east of the Huancapetí deposit, probably near the west contact of the Collaracra intrusive mass. A small block of folded volcanic rocks also crops out just west of the Huancapetí intrusive mass.

At Huarás, folded lava flows are overlain with apparent unconformity by low-dipping lava flows and beds of pyroclastic material that extend to within half a kilometer of the Río Santa. Farther west along the Huarás-Casma road, more steeply dipping volcanic rocks again are exposed, extending about halfway to the pass Apparently the upper volcanic group was removed irregularly by erosion in this valley, accounting for the patchy distribution of the lower volcanic group. Between Huarás and the Jecanca deposit (pl 1, loc 21), younger volcanic rocks with a low east dip lie on the lower flanks of the range, but west and north of the veins at Jecanca, only steeply dipping volcanic rocks are seen.

Farther north in the central part of the range are two areas underlain by folded volcanic rocks. The first is in the upper parts of Quebradas Quirhuac and Jacayurac, west of the town of Parihuanca, where nearly vertical layers of volcanic rocks are overlain in sharp unconformity by flat-lying volcanic rocks The second area extends from just west of Cerro Mangan southeast to the Lake Shaullán area, and patches also are seen farther southeast around the Huallpac deposit (pl 1, locs 32, 35, 38). The northwestern belt is several kilometers wide and is at the crest of the range. Contacts with flat-lying volcanic rocks are lower on slopes and concealed by alluvium Part of the contact in the Huallpac area is faulted.

Our reconnaissance extended into only small areas of volcanic rocks in the northern part of the range, in none of which were contacts seen between the folded lower group and the less-deformed upper group Around Cerros Rico and Putaca the volcanic rocks are moderately closely folded. The contact with underlying Cretaceous sedimentary rocks is unconformable and dips west at moderate angles on the south flank of Cerro Putaca (pl 2,A). Due south of Cerro Rico, folded volcanic rocks override sedimentary rocks along a thrust fault striking N 70° E South and southwest of Huailas, from the lower part of the Quebrada Rumicruz to the crest of the range, rocks dip at low angles and seem to be little deformed (pl. 1, locs. 56–61) Moderately folded volcanic rocks about 6 kilometers northwest of Huailas lie west of slightly folded rocks, the more closely folded rocks extend to the crest of the range in the Patara area (pl 1, loc 62)

The youngest volcanic rocks seen in the range are south of the mapped area, in the headwaters of the Río Fortaleza. They seem to be undeformed and apparently were deposited much later than either of the two groups described above. Parts of this third group have pinnacled erosion remnants somewhat similar to the "rock forest" volcanic badlands near Cerro de Pasco.

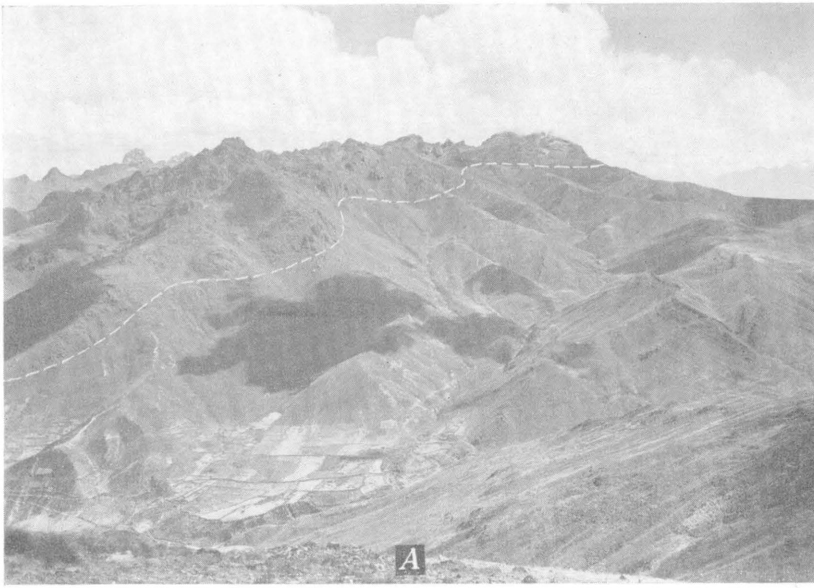
In given localities, dips of the slightly folded volcanic group are as much as 30°, probably caused by slight folding increasing the angle of original dip Where such beds are traced out, the dips tend to decrease, in contrast to dips of the closely folded rocks of the lower group which are more likely to be greater than 30°. In addition to folds, typical structures in the upper group are local and minor unconformities (pl 2,*B*), structures which probably are also present in the lower group but not as conspicuous in its folded rocks The best examples of minor unconformities are seen in the rocks exposed between the Tuctu deposit and the south edge of the mapped area Successively younger layers of slightly warped volcanic rocks are crossed as one goes south, each slightly unconformable on the underlying layer and all markedly unconformable on the folded volcanic rocks east of the crest of the range The structures indicate deformation and erosion occurred intermittently during this stage of volcanic activity.

Within the scope of our reconnaissance studies, we did not find appreciable differences in lithology between the lower and upper volcanic groups One volcanic-rock type, the dense rhyolite, which may be welded tuff, does seem to be more common in the lower group Near Lake Shaullán, both fine- and coarse-grained nonvolcanic clastic material is abundant in the lower group, but such material is not common in this group elsewhere in the range Metamorphism does not seem to have been appreciably more intense in the closely folded volcanic rocks. From the standpoint of a petrologist, our conclusions are different from those of Steinmann (1930, p 190–191 and 215–216), who stated that in Peru the pre-Incaic volcanic rocks are predominantly of submarine origin and of diabasic and basaltic composition (formacíon andina de diabasas-meláfidos), and that the post-Incaic volcanic rocks are dominantly pyroclastics of rhyolitic to andesitic composition (rioandesitas).

If the unconformity is used as the boundary between the lower and the upper group of volcanic rocks, it is apparent that the lower group has a smaller outcrop area than the upper group. Steinmann's geologic map of Peru and his generalized section across the Cordillera Negra (fig 267, p 320), show that he considered the bulk of volcanic rocks in this range to belong to the lower, or older, group No statement can be found in Steinmann's text to indicate what boundary was used to divide the two groups in this region.

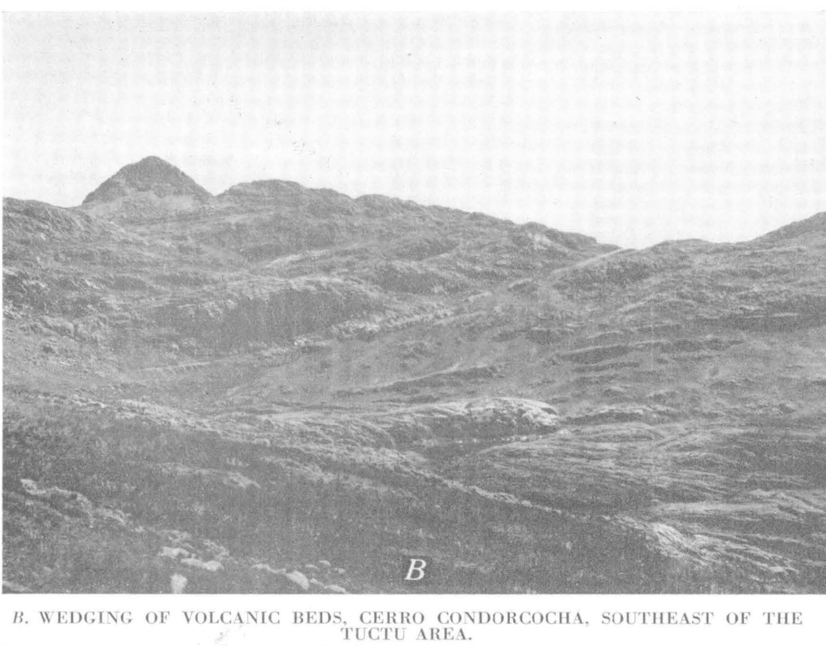
Folded lava flows and agglomerate beds, cropping out in the Santa Valley between Huarás and Recuay, are said by Steinmann to have been deposited during the disturbance occurring from the end of the Cretaceous to early in the Tertiary (Peruvian orogeny). They possibly are equivalent to similar folded volcanic rocks found in the valley of the Río Rimac east of Lima (Steinmann, 1930, p. 191, and McLaughlin, 1924, p 622).

We have little doubt that the two angular unconformities, one at the top of the sedimentary sequence and one between the closely folded



*A.* ROCKS OF CRETACEOUS AGE OVERLAIN BY ROCKS OF THE VOLCANIC SEQUENCE

View from Cerro Aquilpampa, looking north to Cerro Putaca on the left and Cerro Rico on the right. Hacienda Cajabamba is in the lower left. Several close folds in the Cretaceous rocks are visible on the right.



*B.* WEDGING OF VOLCANIC BEDS, CERRO CONDORCOCHA, SOUTHEAST OF THE TUCTU AREA.

The beds on the right thin toward the left. Several minor unconformities are present in the section. A small cirque at the base of the peak contains a tarn lake, concealed behind the low outcrops in the middle foreground.

MAJOR UNCONFORMITY, SHOWN BY DASHED LINE, BETWEEN CLOSELY FOLDED SEDIMENTARY ROCKS OF CRETACEOUS AGE AND OVERLYING SLIGHTLY FOLDED VOLCANIC ROCKS OF PROBABLE TERTIARY AGE EXPOSED ALONG RIDGE CREST

Upper east flank of Cordillera Negra, southwest of Yungay.

group and the slightly folded group of volcanic rocks, represent intervals of erosion following strong orogenies that produced the major structural features of the Andean Cordillera in Peru Each unconformity is marked by a difference in magnitude of folding between older and younger rocks and by extensive erosion of older rocks. Isoclinal folds are common in the sedimentary sequence, but folds are only moderately closed at most places in the lower volcanic group The upper group of volcanic rocks, although having moderate dips in places, nowhere form more than open folds and commonly are only slightly warped However, correlations with rocks having similar structures in central Peru and determination of their ages is handicapped by lack of fossil evidence If the one paleontologic determination made by Steinmann (1930, p 191) is correct, then the folded lower group, at least in part, is Cretaceous in age, and the Peruvian orogeny and the beginning of volcanism occurred in the Senonian The time of the second disturbance, the Incaic, cannot be fixed as the result of our work, and therefore in conformance with geologic thought elsewhere in Peru, is considered to be in the early Tertiary

The minor unconformities and deformation of the upper group of volcanic rocks similarly cannot be dated in the Cordillera Negra. A stage of minor compression, the Quichuan orogeny (Steinmann, p 298), is thought to have occurred early in the Pliocene in Peru, and uplift of the Andean block is considered as having begun late in the Pliocene Each may have played some part in the depositional and structural history of the younger group, but any conclusions on the subject would be extremely tenuous

## INTRUSIVE ROCKS

### GENERAL CLASSIFICATION AND DISTRIBUTION

Intrusive igneous rocks in the Cordillera Negra occur as batholiths, stocks, plugs, sills, and dikes, and are emplaced in all types of layered rocks described in the preceding sections Some massive bodies of intrusive rocks are well crystallized, but most are fine grained and porphyritic. As the accompanying chart shows, the acid or quartz-bearing intrusive rocks are chiefly granodiorite and less commonly granite and tonalite among well-crystallized varieties, and are mainly rhyolite grading to rhyodacite and trachyte among porphyritic varieties Intermediate and basic igneous rocks, or rocks without visible quartz, are diorite and gabbro among well-crystallized varieties, and chiefly andesite among porphyritic types Some trachyte and trachyandesite also are found in intermediate varieties of porphyritic rocks Where quartz is present in parts of such masses, the intermediate varieites grade toward rhyodacite; other andesitic masses grade toward more basic types such as basalt or anorthosite Tabular intrusives, the dikes and sills, include both quartz-bearing and quartz-free types

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Very coarse-grained pegmatites are associated with one granodioritic mass.

The size of massive intrusions ranges from major batholiths to plugs as little as one hundred meters in diameter. The Coastal Batholith, the major intrusive mass of Peru which extends nearly the length of the country, follows the west flank of the Cordillera Negra where it averages about 50 kilometers in width. An apophysis of the Cordillera Blanca Batholith, which projects into the northeast corner of the Cordillera Negra, is about 20 kilometers long and as much as 3 kilometers wide. Five stocks in the mapped area are more than 2 kilometers long; the remaining eighteen stocks and plugs are from 100 meters to nearly 2 kilometers in diameter or in length. Dikes and sills have considerable range in size, the maximum length being about 1 kilometer.

Figure 2 shows size, composition, and texture of intrusives, and it can be seen that most of the larger masses are granodiorite and granite. One large body is rhyolite, one is trachyandesite, and another is andesite; parts of the two intermediate composition grade into quartz-bearing varieties. Among the smaller intrusives, 2 kilometers or less in maximum dimension, porphyritic andesite and trachyandesite predominate, followed in frequency by porphyritic rhyolite.

| GRANITE TEXTURED OR EUCRYSTALLINE | | | | | |
|---|---|---|---|---|---|
| Granite | Granodiorite | Tonalite | Syenite | Diorite | Gabbro |
| Chaquicocha-L 43,50 → | → | Portachón-S 58 | | El Carmen-?S 24 | Cotaparaco-S |
| Pueblo Libre-S# 42 | Apophysis Cordillera Blanca Batholith-LL 55 | | | ← | ← Patara-S 62 |
| | | | | Uchunga-S# | |
| | Cashacarana-L | | | Aija-S# 16 | |
| | Coastal Batholith LL# | | | | |
| **PORPHYRITIC** | | | | | |
| Rhyolite | Rhyodacite | Dacite | Trachyte | Andesite | |
| Collaracra-L 1 | | | Ananpunta-S 48 | Santa Elena-S 18 | |
| Huancapetí-S 2 → | → | → | → | Cerro Plumisa-S 34 | → basalt |
| Cerro Maco-?S 25 → | → | | | La Shaullan-?S 35 | |
| Quebrada Manto Alto-S 63 | ← | ← | ← | ← Cashma-L 39 → | → anorthosite |
| | | | | Rumichaca-S 52 | |
| Aquilpampa-S 47 | ← | ← | ← | ← Colquipocro-?S 45 | |
| | | | Trachyandesite | | |
| | ← | ← | ← Jecanca-L 21 22 → | → | |
| | ← | ← | ← Huinchos-?S 29 | | |

S Maximum dimension less than 2 kilometers
L Maximum dimension more than 2 kilometers
LL Maximum dimension more than 20 kilometers
? Not positively known to be intrusive
# No thin sections, classified on basis of field determination
Arrows indicate subvarieties
Numbers refer to localities on plate 1

FIGURE 2 —Size, composition, and texture of massive intrusive rocks, Cordillera Negra, Peru

The regional map (pl. 1) shows that intrusive masses are widespread throughout the mapped area. In addition to those shown on the map, small intrusive masses also occur at the El Carmen, Cerro Maco, Huinchos, Laguna Shaullán, Rumichaca, Portachón, and Patara deposits (locs 24, 25, 29, 35, 52, 58, and 62) Areas underlain by intrusive masses are small in the mapped area, but if the area between the west limit of the mapped area and the Pacific Ocean is included, at least 50 percent of the Cordillera Negra consists of intrusive rock

Two difficulties arise in the description of intrusive masses in the Cordillera Negra The first is comparable to the problem of classification met in the study of the volcanic rocks—the intrusive rocks are altered to various degress, some to such an extent that only minor amounts of original consitutents remain. Most alteration resulted from action by hydrothermal solutions; a part is attributed to weathering The second difficulty arises from the similarity in aspect of porphyritic masses and the porphyritic lavas they intrude In such areas, indentification and mapping of intrusive bodies was uncertain, especially in reconnaissance examinations Where such similar rock types are altered, even detailed work did not always differentiate them. It is possible, therefore, that some porphyritic masses described below are not intrusive bodies but thick extrusions, and conversely, it is also possible that other small porphyritic intrusions were not recognized as such in the field

In the following petrographic descriptions, the rocks of the intrusive bodies are divided into two broad groups: acid, those having considerable visible quartz; and intermediate and basic, those having little or no visible quartz In each group, the granitic-textured (eucrystalline) rocks are described first, porphyritic types last Owing to the small number of specimens collected and sectioned, we were not above to establish compositions and gradations in detail, and the simplest nomenclature is used to avoid emphasizing unusual petrographic types.

### ACID, OR QUARTZ-BEARING, INTRUSIONS

Figure 2 indicates that most of the larger masses of intrusive rocks in the Cordillera Negra, the batholiths and several of the larger stocks, are oversaturated with respect to silica and carry considerable visible quartz The granitic-textured rocks are volumetrically greater than the porphyritic quartz-bearing rocks

Although we did not study the area underlain by the Coastal Batholith, herewith is a summary of its known limits. In the valley of the Río Fortaleza, it reaches a point about 60 kilometers by road from the highway junction at Paramonga It has been reported as far east as these localities Coris, 14 kilometers southwest of Aija, in the valley of the Río Huarmey, about 5 kilometers west of Huanchay, in the valley of the Río Culebras; Pariacoto in the valley of the Río Casma, just above Hornillos in the valley of the Río Nepeña; and near Lacramarca, a hamlet 40 kilometers northwest of Chimbote (Raimondi, 1873, p. 284, Dueñas, 1904, p. 23). Boit (1926, p. 49) reported that the limits of the batholith are east of Pariacoto in the upper tributaries of the Río Casma and extend nearly to the pass Punta Callán, and that isolated cupolas of it occur between Punta Callán and Huarás. This eastward extension of its limits, which apparently was used in the compilation of the Geologic Map of South America (1950), seems far too great. Westward, the batholith extends to the Pacific except for comparatively local blocks of metamorphosed rocks, such as those noted by Boit (1926, p. 68) near Casma and Chimbote.

Megascopically the rock of the Coastal Batholith is moderately coarse grained, light gray, and granitic in texture; its composition seems to be that of granodiorite. Blocky outcrops are rounded and disintegrated at the surface, probably due to mechanical weathering in the rigorous desert climate prevailing in western Ancash. Ramified dike systems of darker rocks are common in several parts of the mass.

The next largest mass in the Cordillera Negra is the apophysis of the Cordillera Blanca Batholith which extends into the Cordillera Negra at the Cañón del Pato. Outcrops were seen along the road Villa Sucre to Huailas and in the vicinity of the hamlet of Ancoracra west of Villa Sucre. The limits of the apophysis, other than its southwest end, as shown on pl. 1, loc. 55, are largely inferred. This configuration differs from that on Steinmann's map of Peru, on which the apophysis is shown as a chain of cupolas in roughly the same area where we consider it to be a continuous mass, and from that on the Geologic Map of South America, where the apophysis is shown to extend nearly as far south as Carhuás. That town evidently is well beyond the actual area of outcrop. In the Cañón del Pato area the apophysis intrudes sedimentary rocks of probable Cretaceous age. In Cerro Paltac, at its south end, it intrudes both groups of volcanic rocks, but it seems to be overlain by the upper volcanic group in Cerro Culebrilla.

The only specimens of this mass that were examined under the microscope were collected south of Ancoracra (loc. 55). In this area the rock is medium grained, light gray, and of granitic texture. It consists principally of plagioclase feldspar (35 percent), together with orthoclase (15 percent), quartz (30 percent), and biotite and lesser hornblende (20 percent). Accessory minerals are titanite, apatite, and magnetite. The plagioclase is oligoclase, zoned from $An_{31}$ in cores to $An_{22}$ in mantles. Orthoclase and quartz corrode plagioclase to some extent. The rock is classed as granodiorite.

At the south edge of the apophysis near the prospects in Cerro Paltac, a darker border facies, gray in color, is slightly porphyritic.

It contains the same minerals as the main mass, but the plagioclase is more calcic ($An_{38}$), zoned to oligoclase, biotite and hornblende are more abundant, and there is less quartz A small cupola just beyond the margin of the main mass contains still more hornblende and less quartz than the border facies The dominant granodiorite seems to be grading locally toward quartz diorite

One of the largest stocks in the range, several kilometers south of Patara in Cerro Cashacarena, is at least 2 kilometers wide and probably 4 kilometers or more long The mass apparently is intrusive into sedimentary rocks and folded volcanic rocks It consists of medium-grained light-gray granodiorite, containing plagioclase, quartz orthoclase, biotite, and hornblende, with accessory apatite The predominant plagioclase is zoned from $An_{30}$ to at least $An_{20}$ and is mantled with orthoclase

Another large stock, about 4 kilometers long and slightly more than 1 kilometer wide, is at Cerro Chaquicocha, extending southwest to Cerro del Hueco (pl 1, locs 43, 50) It consists of fine- to medium-grained light gray rock ranging in composition from potash granite to granodiorite, of which the potash granite facies seems to predominate A specimen of granite, collected near the northeast end of the intrusive, consists of quartz, perthitic orthoclase, plagioclase ($An_{16-20}$), biotite, and minor hornblende; orthoclase is more abundant than plagioclase In specimens of granodiorite from the southwest end of the mass, plagioclase is the most abundant mineral and consists of zoned crystals ($An_{54-20}$); it is accompanied by orthoclase, microcline, augite, hornblende, and quartz Hornblende is deuteric after augite

The stock intrudes sedimentary rocks and in part is overlapped by flat-lying volcanic rocks In Cerro Chaquichocha itself, part of its contact with flat-lying volcanic rocks locally is steep, but it was not determined if this is an original feature or is due to faults

No thin-sections were made of specimens from the small stock northeast of Cerro Chaquicocha and near Pueblo Libre (pl 1, loc. 42), a mass about 1 5 kilometers in diameter which intrudes sedimentary rocks of Lower Cretaceous age It resembles megascopically the potash-granite facies of the Chaquicocha body.

The only other granitic-textured quartz-bearing intrusive crops out southeast of Lake Colquicocha, in the Portachón area (loc 58). It seems to be a plug only a few hundred meters in diameter It is a tonalite, consisting principally of zoned plagioclase (cores $An_{30}$), lesser quartz with orthoclase intergrowths, and biotite The mass intrudes flat-lying volcanic rocks

Of the porphyritic quartz-bearing intrusive bodies, only the stock at Collaracra is large It is 2 kilometers wide and possibly 5 kilometers long, and intrudes folded volcanic rocks just west of Ticapampa (pl. 1, loc. 1). In the vicinity of the Collaracra vein system, the rock is light green and fine grained. Phenocrysts, as much as 2 millimeters in maximum dimension, make up more than 50 percent of the rock Resorbed quartz and anorthoclase, subhedral orthoclase and albite, and ragged scraps of muscovite are present The rock is classed as rhyolite, having nearly equal proportions of potassic and sodic feldspars.

A smaller rhyolite intrusive body lies several kilometers west of Collaracra in the Huancapetí-deposit area (pls 1 (loc. 2) and 4). It is elongate, at least 1,200 meters long and from 100 to 300 meters wide, and was intruded between folded volcanic rocks to the west and flat-lying volcanic rocks to the east The fine-grained groundmass contains phenocrysts of quartz, orthoclase, anorthoclase, albite ($An_{10-3}$), and muscovite; dark minerals may have been present but, if so, were altered beyond recognition Orthoclase always predominates, so most of the body is rhyolite The quartz content is not uniform, however, so the rock locally grades to quartz trachyte and to trachyte

Just southwest of the veins at Cerro Maco (pl 1, loc 25), two small massive blocks of highly altered porphyry possibly are intrusive into flat-lying volcanic rocks; their contacts are in part faulted Only quartz, orthoclase, and plagioclase ($An_{5-14}$) can be recognized, on the basis of which the blocks are classed as rhyolite, or possibly rhyodacite, porphyry In places the masses contain dragged-out clastic inclusions which impart a gneissic appearance

A plug several hundred meters in diameter intrudes middle Cretaceous sedimentary rocks in Cerro Aquilpampa, on the west flank of the range opposite Yungay (loc 47). The rock is a light-gray quartz-bearing porphyry having small phenocrysts, and is tentatively classed as rhyolite.

Just north of the Quebrada Manto Alto deposits, at the very north edge of the mapped area (loc. 63), a mass of indeterminate size intruded into Cretaceous sedimentary rocks is a fine-grained porphyry having phenocrysts no more than 3 millimeters in maximum dimension. Plagioclase ($An_{8-16}$) and biotite are the most prominent minerals, with lesser amounts of quartz and orthoclase. The rock is considered to be a soda-rhyolite.

#### INTERMEDIATE AND BASIC INTRUSIONS

The intermediate and basic rocks, those with little or no visible quartz, are most common in the smaller intrusive masses Only two bodies in this group are more than 2 kilometers in maximum dimension and most others are only small plugs. Although the textures of some intermediate and basic intrusive rocks are eucrystalline (granitic-textured), most are porphyritic.

At the south edge of the mapped area, a small mass having dimensions about 0 5 by 1 kilometer is exposed on both sides of the steep-walled valley of the Río de Cotaparaco, several kilometers northwest of the town of the same name The mass intrudes complexly folded and faulted sedimentary rocks Constituent minerals are labradorite zoned to oligoclase, hypersthene, augite, and minor biotite and orthoclase, the texture of the rock is eucrystalline The rock is classed as hypersthene gabbro

Another mass in the southern part of the range, 4 kilometers south of Aija, is a eucrystalline gray-green rock intruding both sedimentary and flat-lying volcanic rocks This rock was classed in the field as diorite

At the El Carmen stibnite deposit (loc 24), a small mass of eucrystalline, fine-grained, dark-gray rock is probably a plug intruded into volcanic rocks Although considerably altered, it seems to be composed dominantly of andesine with lesser orthoclase, biotite, and amphibole, and therefore is classed as diorite.

A small plug intruding flat-lying volcanic rocks on the northeast flank of Cerro Uchunga, about 5 kilometers south of the granite stock in Cerro Chaquicocha, has similar appearance to the mass at El Carmen It was therefore classed in the field as diorite.

In the vicinity of the Patara veins, a small plug and associated dikes intruded folded volcanic rocks (fig 3) The rock is dark gray-green, medium-grained and eucrystalline, grading to porphyry at all contacts The eucrystalline facies consists principally of zoned plagioclase ($An_{44-28}$) and irregular aggregates of fine-grained hornblende, some interstial orthoclase also is present. The porphyritic facies consists of unzoned plagioclase ($An_{62}$) phenocrysts as much as 2 millimeters long and pyroxene phenocrysts, set in a fine-grained dark groundmass that seems to be almost entirely plagioclase and pyroxene The rock is classed as gabbro, possibly grading toward diorite

The southernmost porphyritic intrusive body of intermediate to basic composition is in the vicinity of the Santa Elena mine at Huinac (pl 1, loc 18) The mass intruded both Cretaceous sedimentary rocks and overlying volcanic rocks In overall dimensions it is just less than 2 kilometers long and as much as 900 meters wide The mass is the most complex in the range, because of its shape and because it consists of material emplaced by two different processes The map of the area (pl 5), shows the irregular outcrop pattern of the main intrusive mass and its associated apophyses, cupolas, sills, and dikes, the southeast lobes of the body coalesce just beyond the mapped area to form a satelite pluglike mass This main intrusive mass apparently was emplaced by normal intrusion of magma and consists of fine-grained porphyry with some fine-grained non-porphyritic rock at con-

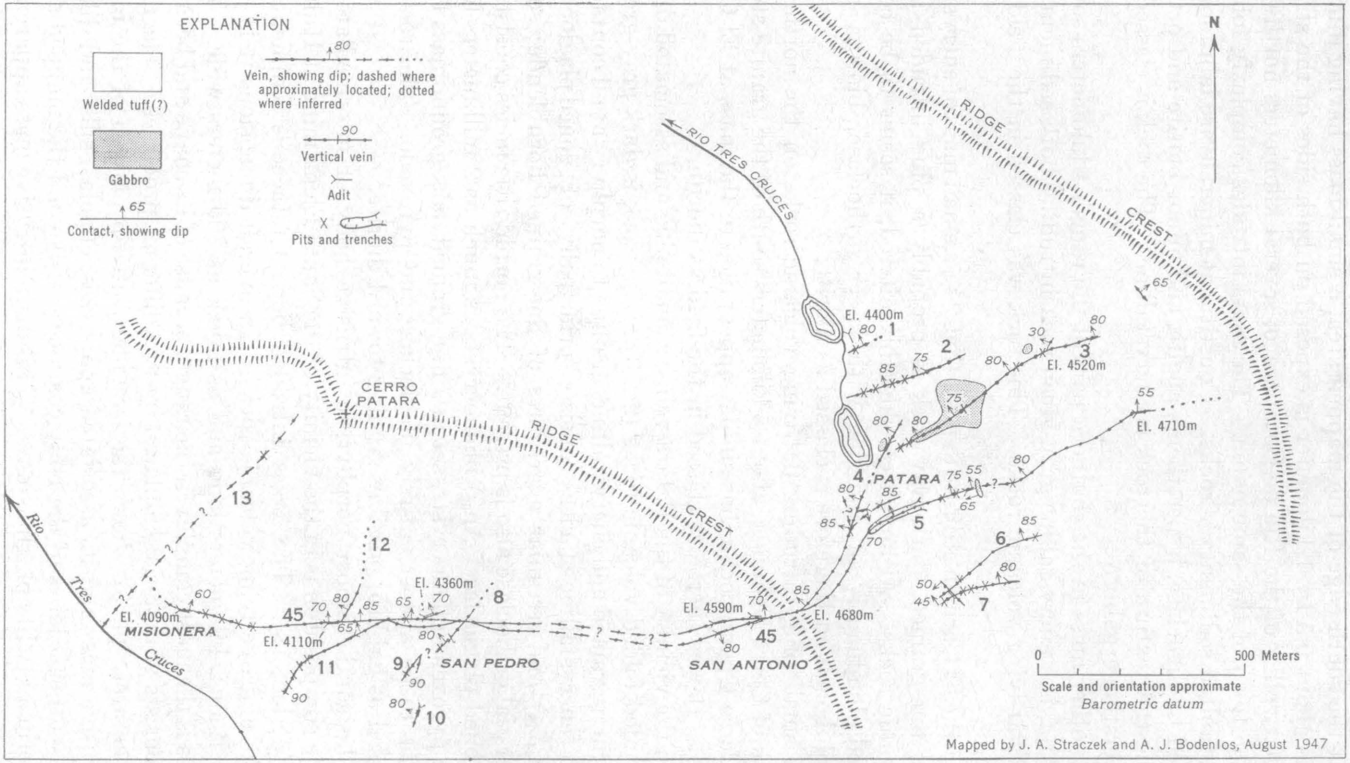



FIGURE 3.—Geologic sketch map, Cerro Patara area.

tacts and in dikes. The second stage of intrusion evidently was explosive in nature, and its products consist of agglomerate and breccia of mixed sedimentary and pyroclastic material. The distribution of the agglomerate and breccia in the porphyry and in sedimentary rocks is highly irregular. To the southeast, explosive action evidently moved the material along fissures; to the northwest, the material burst through multiple odd-shaped vents.

Except at its southeast end, the entire mass is strongly altered, in part owing to mineralizing solutions, but possibly also to action of gases accompanying the explosive stage. Moderately fresh specimens show the porphyry to consist of a fine-grained groundmass of plagioclase, orthoclase, and minor quartz, in which phenocrysts from 1 to 4 millimeters long are moderately abundant. The phenocrysts consist of plagioclase ($An_{55}$, zoned) and hornblende. Therefore the rock is classed as andesite. No fresh specimens were obtained of agglomerate or of pyroclastic fragments in breccia.

Several kilometers northwest of Huarás, a porphyritic intermediate intrusive mass, which may be one of the largest in the range, crops out in the vicinity of the Jecanca and Condorhuaín deposits (pl. 1, locs. 21, 22). Strong alteration of the rocks in the area makes location of contacts uncertain. If the entire mass is an intrusion, its dimensions are 1.5 by 5 kilometers. Folded volcanic rocks lie to the west and flat-lying volcanic rocks to the east (pl. 6).

North of the main vein system of the deposits, where the mass most probably is an intrusion, the rock is a fine-grained gray-green porphyry containing phenocrysts as much as 6 millimeters in length. Phenocrysts are of sodic andesine, orthoclase, some anorthoclase, quartz in variable amounts, and dark minerals that are completely altered. The rock is classed as trachyandesite, grading in its quartz-rich portions toward rhyodacite. South of the main vein system, where the block possibly is an intrusion, the porphyry is slightly darker in color and phenocrysts are only 2 millimeters in length. The only fresh mineral is plagioclase, the cores of which are calcic andesine. Outlines of dark minerals seem to be those of hornblende. The rock is probably an andesite.

Near the Huinchos mine (loc. 29), a small iron-stained mass of light-colored fine-grained rock possibly is intrusive. It is several hundred meters in diameter and extends from the ridgecrest to the Mediza prospect. The major part of the mass is a porphyry that contains phenocrysts of plagioclase ($An_{33}$) partly replaced by orthoclase, and hornblende, in a groundmass of orthoclase laths; this rock is trachyandesite. Part of the mass has pyroclastic texture and contains phenocrysts and angular fragments of plagioclase ($An_{46}$ and $An_{28}$), orthoclase, and quartz. The pyroclastic facies is rhyodacitic.

A small plug at the Cerro Plumisa deposit (loc. 34), rather strongly altered, contains phenocrysts of plagioclase ($An_{60}$, zoned) and hornblende pseudomorphic after pyroxene The rock is either andesite or basalt, but is so altered that mineral proportions cannot be determined Just to the east, at the south Lake Shaullán deposit (loc 35), a small mass which may be intrusive contains plagioclase ($An_{50}$) and much biotite as phenocrysts. Considerable quartz is in the altered groundmass, but most of it may be secondary. The rock possibly is andesite

The intrusive body in the Lake Cashma area, larger than most intrusive masses in the range, is at least 3 kilometers long and 1 kilometer wide; its south end lies in the Mangan deposit area (locs 38, 39) The mass intrudes sedimentary rocks to the north and flat-lying volcanic rocks to the south; the southwest part of the mass is in contact with folded volcanic rocks Several specimens show zoned plagioclase to range from $An_{39}$ and $An_{54}$ toward more sodic material in mantles. Dark minerals are altered, but crystal outlines suggest that hornblende was present. Embayed phenocrysts of quartz and anorthoclase occur in parts of the mass The largest part of the intrusive body is considered to be andesite, grading toward anorthosite where plagioclase phenocrysts are closely packed, and grading toward rhyodacite where quartz and anorthoclase are present in more than average percentages

A small plug intruding sedimentary rocks at the Rumicacha deposit (loc 52) consists of fine-grained phenocrysts of plagioclase ($An_{48}$, zoned) and clinopyroxene in a partly devitrified groundmass, and accordingly is classed as andesite Another small mass in similar rocks several kilometers to the north on the flank of Cerro Ananpunta (loc 48), is strongly altered However, at places this rock contains orthoclase phenocrysts and may be a trachyte

The northernmost mass of porphyritic rock of intermediate composition, possibly an intrusion of massive rock in an area of layered volcanic rock, occurs at the Colquipocro deposit (loc 45) The two thin sections cut from specimens from the mass indicate the rock is strongly altered One section contains phenocrysts of plagioclase ($An_{46}$), complexly twinned and zoned, and a few remnants of hornblende and augite, so the rock tentatively is classed as andesite. Another contains oligoclase and orthoclase as well as quartz If the quartz in part is primary, this specimen is rhyodacite; if not, it is trachyandesite

### DIKES AND SILLS

Igneous rocks of all types occur in the dikes and sills, their textures generally are fine grained and porphyritic, but some nonporphyritic types and some pegmatites were seen. Some tabular masses definitely are associated with larger massive intrusive bodies; others have no obvious relation to them. In sedimentary rocks, dikes and sills crop out relatively conspicuously, but in volcanic rocks or intrusive masses, pegmatites are the only tabular intrusive bodies that are easily seen.

A few dikes and sills are quartz-bearing. Several were seen near the deposits south of Pueblo Libre and east of the intrusive at Santa Elena. Pegmatite bodies were noted near the south end of the apophysis of the Cordillera Blanca Batholith in Cerro Paltac, and bodies of pegmatite and aplite cut this mass in the Cañón del Pato.

Tabular bodies consisting of quartz-free rock types are more common. Many were seen in sedimentary rocks between Pueblo Libre and Colquipocro Long sills in folded limestone beds are abundant in the Cerro Aquilpampa ridge, and east of this area in upper Quebrada Cajabamba, conjugate joint systems are occupied by dikes. To show the range in composition, four representative specimens are described The rock of a sill on the west flank of Cerro Aquilpampa contains hornblende, augite, and orthoclase phenocrysts, inasmuch as dark minerals predominate, the rock is shonkinite porphyry. The rock of the sill at the deposit on the north flank of this ridge (loc. 46) contains phenocrysts of augite, plagioclase ($An_{38}$), and orthoclase, and is classed as trachyandesite porphyry. Rock of a dike southwest of the Piedra Imán deposit (loc 50) contains phenocrysts of plagioclase ($An_{38-54}$), amphibole, and biotite, and is classed as an andesite porphyry. Just east of the Honca deposit, a nonporphyritic rock from a dike consists of orthoclase laths and minor interstitial quartz; dark minerals are altered Evidently the rock is trachyte.

### GENETIC RELATIONSHIPS AND AGE OF INTRUSIONS

The geographic distribution and ages of host rocks of the four major types of intrusive rocks (fig 2) suggest that certain intrusive masses may have been derived from a common magma or may have been emplaced during the same period of intrusive activity. The first type, which includes eucrystalline (granitic-textured) acid rocks of the granite-granodiorite type, is confined to an area between Cerro Chaquicocha and Huallanca, or about to the north of the latitude of Yungay The second type, the eucrystalline basic rocks such as gabbro and diorite, occurs along the length of the range The third type, porphyritic rhyolite, occurs in an area that extends from the latitude of Ticapampa to Cerro Aquilpampa Only one intrusion of quartz-bearing porphyritic rock occurs in the north end of the range—in Quebrada Manto Alto—and because only the contact zone of this body was seen, we cannot be certain that the entire mass is porphyritic The fourth type, porphyritic quartz-free rock—mainly andesite—occurs in about the same area as the rhyolite Some masses of all types intrude rocks as young as the upper slightly folded volcanic group. Whereas most porphyritic intrusive masses occur in rocks this young, only parts of several of the eucrystalline masses intruded the upper volcanic group.

It would appear, therefore, that intrusions of granite and granodiorite occur in an area extending from about the latitude of Yungay northward, and that intrusions of both quartz-bearing and quartz-free porphyritic rocks occur in an area extending from about this latitude southward. These two areas overlap and have a zone in common only a few kilometers wide. We provisionally conclude that at least two main periods of intrusive activity occurred in the Cordillera Negra. During the first, activity was plutonic, and batholiths of granitic rock and their cupolas were emplaced. After an extensive erosional interval, intrusive activity took place during the second at shallower depths, and stocks and plugs of porphyritic rock were emplaced

## STRUCTURE AND METAMORPHISM

The Peruvian and the Incaic orogenies formed the more important structures in the Andean Cordillera, and are thought to have occurred toward the close of the Cretaceous and early in the Tertiary A later deformation of lesser magnitude in parts of the Andes is the Quichuan, said to be of early Pliocene age The uplift of the Andes is considered as having begun in the late Pliocene and continued through the Pleistocene to the Recent (Steinmann, 1930, p 296–298, and 303–304). As a general statement it might be said that in the Cordillera Negra, the major structures formed during the Peruvian and Incaic orogenies were of the compressive type, and the major effect of the more recent uplift was formation of structures of the tensional type It is not known what type of structures are representative of deformation during the Quichuan disturbance, nor is it known whether it occurred in this part of Peru

Major angular unconformities considered as representing intervals of erosion after the Peruvian and Incaic orogenies separate the sedimentary sequence from the closely folded lower volcanic group, and the closely folded lower volcanic group from the slightly folded upper volcanic group. Minor unconformities in the slightly folded volcanic group may have resulted possibly from the Quichuan disturbance or from the beginning of the period of uplift of the Andean block. Deformation is relatively more intense in rocks below an unconformity than in those above, so the sedimentary sequence generally is very closely folded, the lower volcanic group for the most part is moderately closely folded, and the upper volcanic group with few exceptions is only slightly folded or warped

Within the sedimentary sequence, folds are generally alined about parallel to the coast, or N 30° W , the dominant structural trend in this part of Peru. Many but not all folds are isoclinal and axial planes of folds are steep, so most sedimentary rocks dip at high angles.

Crests and troughs of folds may be rounded, V-shaped, or boxlike Between Pueblo Libre and Colquipocro, where a comparatively well exposed cross section of the fold system in sedimentary rocks may be seen, most axial planes of folds are slightly overturned to the east

Although moderate dips prevail in the fold system of the lower group of volcanic rocks, generally between 30° and 60°, they locally may be nearly vertical, as in the vicinity of the Tuctu, Huancapetí, Jecanca, and Quebrada Quirhuac deposits. The major folds also seem to parallel the regional trend of folds in sedimentary rocks, but in places strikes of steeply dipping volcanic rocks do not conform to it At the Jecanca deposit, for example, steeply dipping volcanic rocks and interbedded sedimentary strata strike nearly east in parts of the mapped area (pl 6). The warps and flexures in the upper volcanic group may diverge considerably from the dominant trend in the older rocks, northeast and east strikes being not uncommon.

Thrust or reverse faults associated with close folds are clearly visible in only a few places and seem to be confined to the sedimentary sequence and to the lower volcanic group. Northeast of Cotaparaco in the southwest corner of the mapped area, thrust and reverse faults in an intricate pattern cut sedimentary rocks, and on the south flank of Cerro Rico, folded volcanic rocks are thrust south-southeast over sedimentary rocks, here fault breccias are as much as 15 meters thick. Other faults of compressive origin were judged to be the cause of irregular outcrop patterns of conspicuous beds of quartzite and limestone west and southwest of Pueblo Libre. In the vicinity of the deposits just southwest of this village, highly complex fault systems and associated crush zones are common. Owing to lack of detailed studies, the displacements along thrust and reverse faults produced during strong folding cannot be estimated.

Normal and reverse faults with steep dip and small displacement are numerous in all layered rocks and in the intrusive masses. Most can be traced only short distances, as much as a few hundred meters, but others, several of which contain the larger veins in the Cordillera, are from 1 to 2 5 kilometers long. Displacements generally are 50 meters or less and may be either in a horizontal or a vertical direction. Most of these faults seem to have been produced by tension. Fault systems locally may be alined transverse to the axis of the Cordillera, as at Huancapetí (pl 4), but many others do not conform to this orientation Most small faults and even some of the longer faults are comparatively straight Others, notably in the Patara deposit (fig. 3), curve strongly in strike Cross faults, which are found in the vicinity of a few deposits, such as those in Quebrada Carhuascansia (fig. 4) and at Jecanca (pl. 6), generally are small Details of minor structures in faults or in the wider shear zones can be seen on the large-scale maps of mine workings accompanying this report.

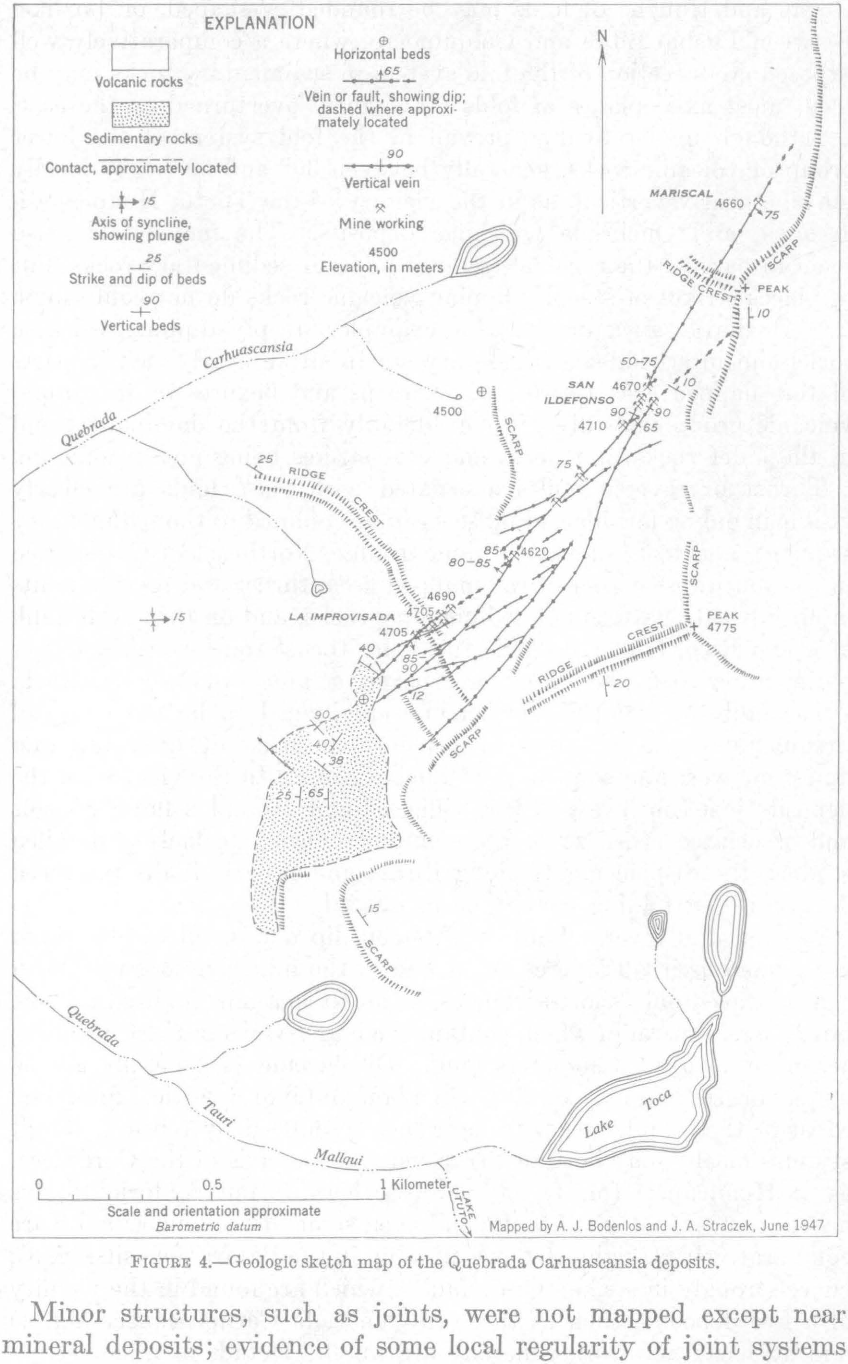



FIGURE 4.—Geologic sketch map of the Quebrada Carhuascansia deposits.

Minor structures, such as joints, were not mapped except near mineral deposits; evidence of some local regularity of joint systems was seen at Huancapetí and Jecanca. Mention has been made of the prominent conjugate joint set occupied by dikes in the sedimentary rocks of the upper Quebrada Cajabamba. The acute angle between these joints is transverse to the axis of the Cordillera

It is generally thought that the Andean Cordillera was beveled by erosion after initial folding during the Peruvian orogeny, so present configuration of the unconformity between the sedimentary sequence and the lower volcanic group should indicate in a rough way the type and magnitude of deformation since that time. The regional map (pl 1) shows that the major type of deformation has been an arching of the Cordillera Negra parallel to its axis This arching is illustrated, for example, in the area between Ticapampa and Aija, where sedimentary rocks in Quebrada Carhuascansia are several hundred meters higher than either at Collaracra or in the Aija area It is most strikingly shown west of Caras, where the unconformity rises some 2,000 meters between Huata and Cerro Rico and then declines westward on the other flank of the range (pl 2,A). A similar inclination of the unconformity on the east side of the range may be noted between Huailas and Patara Some modifications, such as a downwarped area of folded volcanic rocks north of Huaras and an upwarped area of sedimentary rocks between Cerro Chaquicocha and Colquipocro, are also evident.

In addition to the arching, possible warping along the axis also is discernable but its magnitude is small and it could be due to irregularities of relief on a peneplaned surface.

Orogenesis was not accompanied by intensive or widespread dynamic metamorphism. Some sandstone beds seem to have been metamorphosed to quartzite, shale locally has slaty cleavage, and siltstone at the Santa Elena mine shows some pencil cleavage. Limestone is not recrystallized, but in places may be locally dolomitized. Folded volcanic rocks are generally propylitized. Statements in the literature indicate stronger metamorphism occurred in sedimentary rocks west of the mapped area, these rocks, however, are near the contact of the Coastal Batholith and the cited effects seem to be those of contact metamorphism.

Within the mapped area, changes by contact metamorphism are considerably greater than those by dynamic metamorphism but are found only near the larger granitic masses. Both north and south of the apophysis of the granodiorite crossing the Cañón del Pato, contact effects in the sedimentary rocks are appreciable At Huallanca, andalusite schists have developed, as was noted by Boit (1926, p 55, 66, and 71) and by Broggi (1945, p. 69–79). Beyond the south margin of this intrusive in the Cañón del Pato, contact metamorphism and metasomatism of clastic sedimentary rocks produced garnet, biotite, magnetite, sillimanite, andalusite, some epidote, and much pyrite and quartz (Broggi, p. 78–79).

Another small area in which sedimentary rocks have been metamorphosed along intrusive contacts is on the west side of the Chaquicocha stock in the vicinity of the Piedra Imán deposit (pl 1, loc. 50). There limestone is recrystallized, partly dolomitized, and contains much coarse-grained actinolite and smaller amounts of finer grained garnet.

## GLACIATION

In common with other high ranges in Peru, the Cordillera Negra was glaciated during the Pleistocene Effects of ice action are comparatively small when compared to those in ranges reaching higher altitudes Glaciation has been less severe in the Cordillera Negra than in the adjacent Cordillera Blanca because it is lower and receives less precipitation The highest peaks in the Cordillera Negra, at most 5,200 meters in altitude, are from 1,300 to 1,500 meters lower than the more prominent peaks in the Cordillera Blanca Today, other than in a few small sheltered spots, perennial ice and snow are lacking in the Cordillera Negra, whereas all areas in the Cordillera Blanca above 5,100 meters still are mantled with ice. Precipitation is less in the Cordillera Negra, partly because of its lower altitude and partly because of climatic conditions which have produced an arid desert in the adjacent coastal region

The erosional effects of glaciation in the Cordillera Negra are confined to the summit of the range, generally above the altitude of 4,000 meters All common features of alpine glaciation may be seen. cirques, horns, aretes, and U-shaped valleys In the northern part of the range, the blockier erosional forms predominate, even in peaks (pl 2,*A*), and valleys have been quarried into an almost impassable series of benches and steep, high steps

Depositional features of alpine glaciation also are common and include ground, lateral, and end moraines, as well as outwash fans and sheets below former ice fronts Postglacial fluvial erosion has destroyed large parts of outwash deposits, but higher in the range most morainal deposits are nearly intact

Blocking of drainage by moraines and to a lesser extent by erosional features of glaciation has produced many lakes and swamps in the upper part of the Cordillera These may be scattered and abundant in open valleys, for example, at least seven lakes dot the valley north of Cerro Huarancayoc (pl 1, loc. 28) In the narrower U-shaped valleys they occur one above the other, as many as three have been seen in one valley in the northern part of the range

The cirque line in the Cordillera Negra is comparatively near the crest of the range, generally about 400 or 500 meters below summits of adjacent peaks Cirques are between 4,300 and 4,400 meters altitude in the southern part and slightly higher in the northern part of the range. With such a comparatively small area to supply snow and ice, it is thought that valley glaciers extending downslope from cirques probably were short and weak In no part of the Cordillera Negra are glaciated valleys incised as deeply nor are they as long as the huge U-shaped valleys on the west flank of the Cordillera Blanca The volume of outwash material from the Cordillera Negra also is much smaller than that in the tremendous fans and aprons bordering the front of the Cordillera Blanca.

## PHYSIOGRAPHIC DEVELOPMENT

The best description of the physiographic development of the Andes and its relation to uplift is that of McLaughlin (1924, p 624–626). He postulated that erosion produced a surface of small relief toward the end of the Tertiary (the Puna surface). During subsequent uplift the Puna surface was warped, dominantly seaward in areas adjacent to the Pacific. Two breaks in uplift are marked by succeeding erosion stages, the Junín, during which moderately wide flat-bottomed valleys were cut, and the Canyon, during which sharp canyons were incised in these wider valleys.

The upland surface of the Cordillera Negra corresponds closely to McLaughlin's description of the Puna surface Altitudes along the crest of the Cordillera range from 4,200 to 5,200 meters, a maximum relief of 1,000 meters, but only locally is relief along the crest more than half this amount Remnants of the Puna surface sloping toward the Pacific also are seen on ridges between the long deep valleys on the west flank of the range.

McLaughlin (p. 626) also described the origin of the upper Río Santa, the only stream on the west slope of the Andes that is not of consequent origin. He considered the upper course to be subsequent and to have developed during the Puna stage by successive capture of the heads of transverse consequent streams flowing from the Cordillera Blanca to the Pacific Owing to low precipitation in the arid coastal zone, the beheaded transverse streams have been unable to reduce the Cordillera Negra block nor have they obliterated the old Puna surface

Glaciation modified the topography inherited from the Puna stage In addition to sharpening the peaks, it produced additional effects in stream gradients on both sides of the range On the west slope, preglacial stream profiles, increasingly concave upward toward stream sources, were accentuated in this respect as glaciers gouged out the upper courses, and fluvio-glacial debris was deposited in the lower courses of valleys Stream gradients of the east slope are steep throughout their courses Glacial erosion probably was the effective process near the crest of the range, but the steepening below is considered to have resulted from the crowding of the Río Santa against the base of the range by the great fans and aprons of fluvio-glacial debris emanating from the Cordillera Blanca

The last physiographic feature to be mentioned is the Cañón del Pato, the tremendous gorge at the north end of the Callejón de Huailas This gorge has been cut by the Río Santa through the east side of a ridge which nearly closes the upper valley of the river Steinmann (1930, p 276) apparently assumed that the Cañón developed only after glaciation because he considered that the north end of the Callejón de Huailas was occupied by a lake during the close of the main glacial stage We wish to note, however, that partly eroded high-level terraces of glacial outwash debris occur within the upper end of the Cañón itself, so it is more likely that the passage existed before glaciation of the region

The most recent geological event in the Cordillera Negra is the deposition of travertine from hot springs These occur just west of Ticapampa, where wide benches are underlain by this material An unusual formation of this material is a travertine wall, about 100 meters long, 8 meters high, and 3 meters thick (Steinmann, p 284–285, and plate IV, figure 2). The feature, first described by Raimondi (1873, p 58–59; 1913, p 149–150), is thought to have been formed by a spring issuing from a long fissure and depositing material uniformly along its length Because the profile is smoothly convex upward, the fissure evidently was sealed from the ends toward the center at a uniform rate Springs depositing material in the benches still flow but those in the travertine wall were nearly dormant in 1947.

## GEOLOGIC HISTORY

Our work has given no information about pre-Cretaceous history and relatively little information of Cretaceous and later history of the Cordillera Negra During the lower Valanginian stage of the Cretaceous, the region was emergent but low lying and probably near the coastline Most sediments were nonmarine and fluviatile, and formed a comparatively thick sequence of clastic beds At intervals, vegetation accumulated in swamps to form beds of coal, and during the upper Valanginian, the region was submerged and limestone was deposited During the Hauterivian, Barremian, and Aptian, the area emerged again Tuffs overlying the clastic sequence indicates volcanism toward the end of this interval. Thereafter most Cretaceous deposits were marine; the region was submerged during the Albian and Turonian stages Dark bituminous limestone formed an appreciable part of the middle Cretaceous marine deposits The Albian sea was large, extending into both central and northern Peru, but the Turonian sea apparently did not extend south of western Ancash.

Events subsequent to those in the middle Cretaceous are not well dated, owing to lack of fossils. Folding and subsequent planation seem to have occurred during the Upper Cretaceous or at the very beginning of the Tertiary Planation was followed by extensive volcanic activity, which continued through much of the remainder of the Tertiary Possibly early in the Tertiary, volcanism was interrupted by folding and by deep-seated intrusion of batholithic rocks, and by subsequent erosion of sufficient magnitude to have reached the plutonic masses Postorogenic volcanism was interrupted only by mild warping and accompanying minor erosion, and at some time during this interval, shallow-seated intrusive activity took place The region was reduced to one of low relief by erosion toward the end of the Tertiary.

The two major orogenic events described above seem to correspond to the principal mountain-making disturbances known in other parts of Peru, the Peruvian and Incaic orogenies The mild warping during the later stages of volcanism may correspond to the Quichuan disturbance

Uplift of the beveled Andean block, considered to have started at the end of the Tertiary, continued through the Pleistocene The Río Santa, said to have captured the heads of transverse consequent streams before uplift, continued to deepen its valley and separated the Cordillera Negra from the Cordillera Blanca The beheaded transverse streams were unable to reduce the range, whose upland topography largely remains inherited from the pre-uplift surface Comparatively weak alpine glaciation in the Pleistocene modified the inherited topography to a small extent.

The most recent geologic events are dissection of glacial outwash deposits and deposition of travertine from hot springs still active just west of the town of Ticapampa.

## MINERAL DEPOSITS

With two exceptions, the deposits in the Cordillera Negra are fissure veins Metallic sulfide and associated gangue minerals largely were deposited in fissures, forming veins having wide ranges in size and in grade Wall rock is replaced by sulfide minerals but only on a small scale

### ENVIRONMENT OF MINERALIZATION

As may be seen on plate 1, mineral deposits in the Cordillera Negra occur in sedimentary and volcanic rocks of ages ranging from early Neocomian to the Tertiary, as well as in igneous masses intruded into these bedded rocks Despite the wide range of lithologic environment, deposits tend to be small in sedimentary rocks and in granitic masses, and tend to be larger in volcanic rocks Of 12 large veins in the Cordillera, only 1, the Buena Cashma, is in shale of Cretaceous age, and none is in granitic rock.

The veins are in faults or shear zones, most of which seem to have small displacement Some veins with low pitching slickensides may have been formed by nearly horizontal movement; others occupy bedding-plane faults. Individual shear planes along the faults are relatively short. Shear planes link and branch, comparatively simply in small veins and complexly in large veins. Along shear planes are gouge and in places brecciated wall rock. Details may be seen on the surface and underground geologic maps accompanying this report.

Commonly, several fault or shear zones are mineralized at a given deposit. Vein systems at the larger deposits generally form patterns. In the Collaracra, Huancapetí, Jecanca, Colquipocro, and Uchco deposits, most large veins are roughly parallel. In the Santa Elena deposit, the principal veins have irregular strikes and, at one level or another, link to each other. Cross veins are not common, but were seen in the Santa Elena, Jecanca, San Ildefonso, and Patara areas. Major veins and most minor veins dip steeply. Movement continued into the time of mineralization, and in most places was in the plane of the veins. Cross faults are uncommon and have small displacements; most are of premineral age.

The accompanying frequency diagram was compiled to test the possibility of relationships between regional structures and orientation of veins (fig. 5). The major peaks on the diagram occur at N. 75°

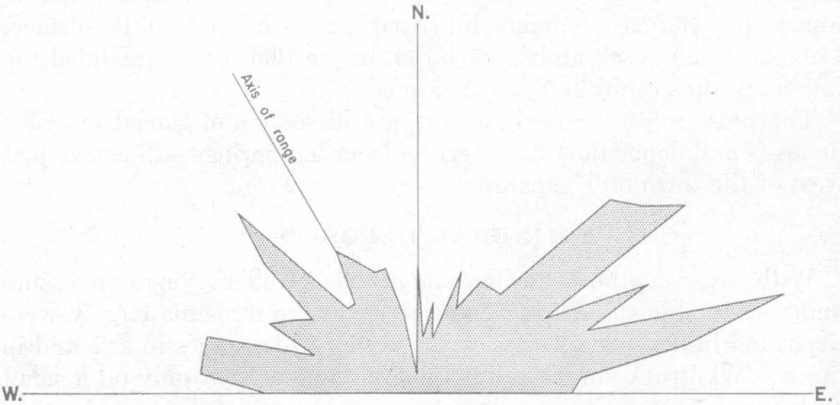



FIGURE 5.—Frequency diagram of strikes of about 300 veins and splits, Cordillera Negra.

E., N. 55° E., N. 45° W. and N. 80° W. The axis of the range and strike of Cretaceous sedimentary rocks is about N. 30° W. The peak at N. 80° W. may correspond to one direction of conjugate shear, and the peak at N. 55° E. is approximately transverse to the axis of the range. The peak at N. 45° W. results from bedding-plane veins in sedimentary rocks that locally deviate from the regional trend. Many veins, however, do not have a systematic relationship to major structures.

The veins can be traced for distances ranging from a few meters to 3 kilometers. Only 12 veins in the 63 deposits are more than 500 meters long, and of the other veins, less than half can be traced for distances of more than 100 meters  Vein widths range from fractions of a meter to about 5 meters  Shear zones and silicified zones may be considerably wider, but sulfide-bearing lenses occupy relatively narrow bands in such zones  In the larger deposits, the vertical extent of sulfide minerals ranges from about 300 to 600 meters; in prospects on small veins the known vertical extent may be only several meters  Mineral deposits are found from 2,800 to 4,800 meters in altitude, but only small deposits occur in the lowest 1,000 meters of this interval

Neither of the replacement deposits is large  One is in a contact zone near the Cerro Chaquicocha granite stock, and the other is several kilometers south of the same mass  In each, sulfide minerals occur in ramified fissures but may be found for a distance of several meters out in the wall rock

Attention is directed to the spatial relations between the deposits and the intrusive masses  Eight of the larger and 15 of the smaller deposits are in or near plugs or stocks  It is probable that the mineralizing solutions ascended from the deeper parts of such masses

## MINERALOGY

The following minerals were seen in the deposits in the Cordillera Negra·

| *Mineral* | *Chemical formula* |
|---|---|
| Stibnite | $Sb_2S_3$ |
| Galena | $PbS$ |
| Argentite | $Ag_2S$ |
| Chalcocite | $Cu_2S$ |
| Sphalerite | $ZnS$, or $(Zn, Fe)S$ |
| Alabandite | $MnS$ |
| Pyrrhotite | $Fe_{1-x}S$ (where $x=0$–$0.2$) |
| Covellite | $CuS$ |
| Bornite | $Cu_5FeS_4$ |
| Chalcopyrite | $CuFeS_2$ |
| Pyrite | $FeS_2$ |
| Marcasite | $FeS_2$ |
| Arsenopyrite | $FeAsS$ |
| Pyrargyrite | $Ag_3SbS_3$ |
| Proustite | $Ag_3AsS_3$ |
| Tetrahedrite series | $(Cu, Fe, Zn, Ag)_{12}(SbAs)_4S_{13}$ |
| Enargite | $Cu_3(As,Sb)S_4$ |
| Cuprite | $Cu_2O$ |
| Limonite and hematite | Iron oxides |
| Specular hematite | $Fe_2O_3$ |
| Manganese oxides | Gamma $MnO_2$ and unknown mineral |
| Rhodonite | $MnSiO_3$ |
| Chrysocolla | $CuSiO_3 \, 2H_2O$ |
| Gold | $Au$ |
| Quartz | $SiO_2$ |
| Chalcedony | Cryptocrystalline quartz |
| Calcite | $CaCO_3$ |

| *Mineral* | *Chemical formula* |
|---|---|
| Rhodochrosite | $MnCO_3$ |
| Ferruginous and manganiferous carbonates. | $(Ca, Fe, Mn)CO_3$ |
| Malachite | $CuCO_3 Cu(OH)_2$ |
| Azurite | $2CuCO_3 Cu(OH)_2$ |
| Gypsum | $CaSO_4 2H_2O$ |
| Celestite | $SrSO_4$ |
| Alunite | $K_2Al_6(OH)_{12}(SO_4)_4$ |
| Graphite | C |

Raimondi (1873, p 305–317) lists most of these minerals and adds jamesonite, boulangerite, bournonite, and malinowskite as sulfo-salts, and also lists native silver, silver oxides, magnetite, cerussite, and anglesite

*Lead minerals* —The only abundant lead mineral is galena, which generally is fine to coarsely granular but also shows crystal faces where it lines vugs In a few deposits it is plumose or bladed It contains silver, for which it is widely sought by miners The mineral was seen in at least three-fourths of the deposits, and probably was present in most of the inaccessible deposits Anglesite and cerussite reported by Raimondi to occur as secondary minerals in oxidized zones, evidently were removed during early mining activities

*Sphalerite* —Sphalerite, the only zinc mineral seen in the deposits, occurs as granular masses except in vug linings, where it shows crystal faces. It contains iron in various percentages, and is known as marmatite if iron content exceeds 10 percent. Its color ranges from honey to deep-brown, the darker colors being due to larger amounts of iron Like galena, it was seen in about three-fourths of the deposits Its silver content is low and it is not recovered or is discarded in most mining operations.

*Copper minerals* —The primary copper minerals, in order of frequency of occurrence, are chalcopyrite, enargite, tetrahedrite, and bornite Chalcopyrite was seen in one-third of the deposits, enargite and tetrahedrite in about 5 percent of the deposits, and bornite only at one locality. All contain some silver, and where deposits are rich enough these minerals are recovered even if galena is absent.

Chalcopyrite occurs as small granular aggregates, generally mixed with galena, sphalerite, and pyrite Enargite and tetrahedrite also occur with these minerals in several small deposits; but in the large veins of the Collaracra and Santa Elena deposits, these copper minerals are found in comparatively large bodies in association only with pyrite, quartz, and some arsenopyrite A few grains of bornite were seen with sphalerite and galena in a small vein at the Jecanca deposit

Of the secondary copper minerals, only malachite and azurite are fairly common, occurring as stain in and near veins Covellite is associated with the few grains of bornite at Jecanca. The low-grade copper occurrences at the north end of the Cordillera contain malachite, azurite, chrysocolla, and cuprite in small, scattered deposits

Malinowskite, reported by Raimondi from the Collaracra mine, is a variety of tetrahedrite containing lead That the variety occurs is questioned, because the lead ion theoretically does not fit into the tetrahedrite lattice (Palache and others, 1944, p 379).

*Silver minerals and gold* —The only silver minerals seen were argentite, pyrargyrite, and proustite, all primary Small amounts of argentite occur as thin streaks in some veins containing base-metal sulfides.[1] Proustite and pyrargyrite occur only at the Colquipocro mine, where they are sufficiently abundant to provide silver ore. The mode of occurrence of silver in galena and copper minerals is unknown Secondary silver minerals and native silver were reported by Raimondi to occur in the oxidized parts of nearly all veins he saw, but these parts of the veins have since been mined.

Assays of samples collected during this investigation indicate that ores contain traces of gold, but it is not known with which minerals the gold occurs Raimondi stated that it is contained in quartz-pyrite veins in various parts of the Cordillera.

*Iron sulfides* —Iron sulfide minerals are pyrite, marcasite, and pyrrhotite. Pyrite, the most common sulfide mineral in the Cordillera Negra, was seen at all but three deposits, all small In veins, it occurs chiefly as massive granular material, either pure or mixed with other vein minerals, and it also is common as disseminated grains in wall rock Marcasite, generally bladed, occurs in small amounts at several deposits Pyrrhotite, equally scarce, forms massive granular material which in places is vuggy and contains sphalerite

*Arsenic and antimony sulfides* —Arsenopyrite, occurring as grains or aggregates of grains, was seen in about 20 percent of the deposits. At depth in the Collaracra vein, arsenopyrite grains are oriented at right angles to vein walls Individual grains there are as much as 1 5 centimeters long and as much as 1 0 centimeter in diameter Stibnite, the sulfide of antimony, is present in about 10 percent of the deposits Generally it occurs as scattered blades or prisms, but in the El Carmen mine, lenses large enough to be mined consist of massive aggregates of stibnite grains.

*Manganese minerals.*—Small amounts of the carbonate rhodochrosite, the silicate rhodonite, and the sulfide alabandite are the manganese minerals seen in eight deposits. Manganiferous carbonate is a little more common.

*Iron and manganese oxides.*—Small amounts of specular hematite (specularite) of primary origin were seen in several deposits as scat-

[1] G E Ericksen, in a written communication, reports that laboratory study of base-metal ores from northern Peru showed that most material identified as "argentite" in the field proved to be very fine-grained tetrahedrite.

tered grains or small veins Much more common are the secondary oxides, limonite and hematite, found at every deposit. They occur in gossans capping the larger veins, and limonite also is abundant in veins to various depths

At all deposits containing primary manganese minerals, secondary oxides occur with limonite near or at the surface Several veins in the southeast corner of the Jecanca area contain only such oxides but are too small to be mined Several samples of secondary manganese oxides from the southwest end of the Huancapetí vein were analyzed by X-ray by J M Axelrod, of the Geological Survey As indicated in table 1, gamma $MnO_2$ forms the bulk of the material and with it is an oxide of unknown variety and some quartz

TABLE 1 —*Supergene manganese oxide minerals, Huancapetí mine*

[Sample 225, collected by J A Straczek from zone of supergene alteration near west end of Huancapetí vein J M Axelrod, U S Geological Survey analyst No X-315, reported June 28, 1948 ]

| Film no | Description | Minerals |
|---|---|---|
| 4201 | Soft, colloform, brownish-black | Gamma $MnO_2$ |
| 4202<br>4203<br>4208<br>4210 | Scoriaceous, sooty to silvery | Gamma $MnO_2$ and little quartz |
| 4204 | Hard, massive, black | Gamma $MnO_2$ and a little quartz |
| 4209 | Gray-lavender, soft | Unknown mineral Like oxidized museum specimen labeled pyrochroite |
| 4215 | Scoriaceous, reddish | Gamma $MnO_2$, a little quartz and a little of the unknown mineral |

*Quartz.*—Massive quartz occurs in all but six deposits In addition to its occurrence as fissure-filling material, it also is common as a fine-grained replacement of wall rock Silicified zones may contain small amounts of chlorite, epidote, actinolite, garnet, or tourmaline. In parts of the Huancapetí and Jecanca deposits such zones are as much as 70 meters wide Chalcedony is not common Some pellets of flinty material mixed with pyrite were seen in the Jecanca vein.

*Carbonate minerals*—Calcite is the most abundant carbonate mineral in the Cordillera Negra, forming compact granular aggregates in veinlets and veins. Some deposits contain manganiferous carbonate, light pink in color, which grades into rhodochrosite. Manganiferous carbonates tend to be fine grained and form laminated crusts. Several veins include small amounts of ferruginous carbonate, and one deposit is in dolomitized limestone About one-half the deposits contain one or more of the above carbonates

*Other minerals.*—Various sulfates of primary and secondary origin are seen in a few deposits. Gypsum fills vugs and breccia voids in the deposits near the Río Santa south of Huarás, and one vein in the same area contains small amounts of celestite Alunite was seen in small quantities in the underground workings of the Santa Elena mine

Graphite forms small pockets in carbonaceous shales near the west contact of the intrusive stock several kilometers south of Pueblo Libre. The occurrence is not related to sulfide-bearing veins.

## ALTERED WALL ROCK

The amount and type of altered wall rock differs at deposits, in part owing to the composition of the rock, in part owing to the nature of the mineralizing solutions The anhydrous silicate minerals of igneous rocks are altered to hydrous minerals mixed with minerals derived from elements released during the process; siliceous and argillaceous rocks may be slightly pyritized and sericitized, limestone may be dolomitized; and all rock types are silicified to some extent. At small deposits, alteration occurred in the veins and in immediately adjacent wall rock, forming zones that may be only 1 or 2 meters wide Along larger veins alteration increased in intensity to form zones many meters wide, and at several of the largest deposits has affected areas 1 or more square kilometers in extent.

Alteration of igneous rocks may be divided into four processes: propylitization, sericitization, argillitization, and silicification. Propylitization may have in part preceded mineralization (p 23). Pyroxenes, amphiboles, and related dark minerals are replaced by chlorite, feldspars by chlorite and epidote, and all these minerals are replaced by calcite. Small quantities of magnetite or hematite, evidently released by chloritization, replace dark minerals Porphyritic textures remain sharply defined and altered rock is greenish gray

Sericitization followed and possibly overlapped propylitization. In this process sericite replaces feldspars and, with increasing intensity, replaces chlorite, epidote, calcite, and remnants of primary dark minerals Quartz and pyrite commonly are deposited during sericitization, and the process seemingly is related to base-metal-sulfide deposition On a megascopic scale, sericitization produces two notable effects: 1, bleaching of rock as the darker feldspars and the products of propylitization were replaced, and 2, destruction of rock texture The end product of sericitization is a rock that is an ill-defined mesh of sericite and quartz grains. The texture of such altered rock is nearly or completely destroyed on a megascopic scale, and the original minerals are either completely destroyed or their remnants are so small as to preclude identification under the microscope

Argillization commonly accompanies sericitization but may in part be later Kaolin minerals and small amounts of hydromica replace earlier products of alteration Kaolinization may be related to surface oxidation, as kaolinized rocks are most common near the present surface, but slightly kaolinized rock is also present at some distance beneath the surface In surface zones, pyrite is oxidized to limonite, producing strongly stained rock, or where leached, light-buff or yellow rock.

Silicification of wall rock is either contemporaneous or follows sericitization, producing zones that may be many meters in width Quartz in such zones is fine grained and generally contains small amounts of pyrite, it may contain calcite, sericite, chlorite, epidote, clinozoisite, and tourmaline, either as scattered grains, rosettes, or veinlets Chalcedony and coarser grained quartz deposited as fissure filling in veins may contain the same accessory minerals.

To ascertain the chemical changes associated with these processes, four specimens of andesite from the Jecanca deposit were analyzed The results are shown in table 2 The first specimen is from the zone of limited hydrothermal alteration and is only propylitized and slightly sericitized; the second and third are from the vicinity of the Santo Toribio vein and are sericitized and pyritized; the fourth is from the oxidized zone of this vein

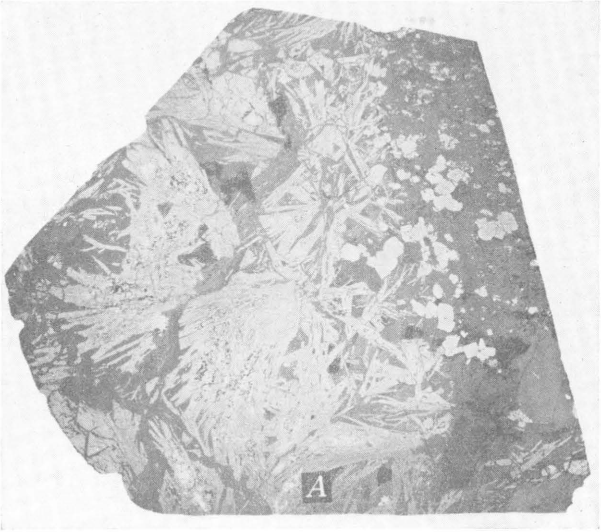
As indicated by the table, sericitization and pyritization result in a slight relative increase in silica and iron, a considerable increase in potash and sulfur, and a sharp decrease in magnesium, calcium, sodium, and carbon dioxide These changes are associated with the replacement of feldspars and propylitic minerals Comparisons of the analyses of sericitized and of argillitized oxidized rock shows that argillitization results in an increase in silica, alumina, potash, and sodium, and a decrease in iron, magnesia, calcium, and sulfur The comparison of specific gravity in bulk and in powder indicates porosity increases as alteration progresses

TABLE 2 —*Analyses of rocks from Santo Toribio adit, Jecanca mine*

[A C Vlisidis, U S Geological Survey, analyst No IWC-75, reported Sept 29, 1949]

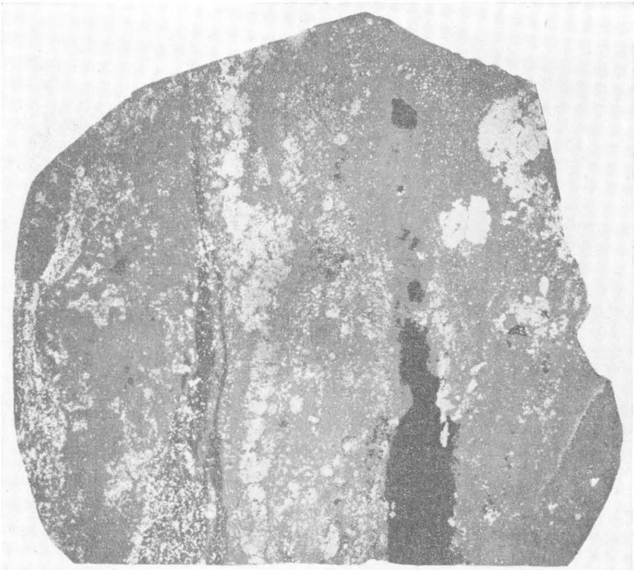
| | 47-JAS-242 | 47-JAS-243 | 47-JAS-247 | 47-JAS-248 |
|---|---|---|---|---|
| $SiO_2$ | 59 22 | 62 22 | 60 37 | 68 06 |
| $Al_2O_3$ | 16 36 | 16 57 | 15 81 | 18 14 |
| $Fe_2O_3$ | 1 38 | 6 45 | 7 03 | 58 |
| $FeO$ | 4 03 | 74 | 74 | 49 |
| $MgO$ | 1 93 | 53 | 82 | 38 |
| $CaO$ | 4 38 | 13 | 27 | 04 |
| $Na_2O$ [1] | 2 49 | 18 | 14 | 24 |
| $K_2O$ [1] | 2 11 | 4 47 | 4 13 | 7 57 |
| $H_2O-$ | 1 21 | 49 | 78 | 49 |
| $H_2O+$ | 3 79 | 3 20 | 3 06 | 2 74 |
| $TiO_2$ | 1 24 | 92 | 1 01 | 1 08 |
| $P_2O_5$ | 36 | 10 | 48 | 20 |
| $MnO$ | 11 | 03 | 04 | 03 |
| S | 02 | 5 60 | 6 29 | 07 |
| $CO_2$ | 1 48 | 07 | C5 | None |
| $SO_3$ [2] | | 34 | 74 | |
| Total | 100 11 | 102 04 | 101 76 | 100 11 |
| O=S | 01 | 2 80 | 3 14 | 03 |
| Total, less O=S | 100 10 | 99 24 | 98 62 | 100 08 |
| Sp gravity $^{30}/_4$ (powder) | 2 63 | 2 85 | 2 78 | 2 63 |
| Sp gravity (bulk) | 2 61 | | 2 58 | 2 27 |

[1] By W W Brannock, flame-photometer method
[2] Soluble $SO_3$
JAS-242 Sample from zone of limited hydrothermal alteration
JAS-243 Sample from zone of hydrothermal alteration near vein
JAS-247 Sample from zone of hydrothermal alteration near vein
JAS-248 Sample from zone of hydrothermal alteration and in zone of oxidation and leaching, within meters of surface




*A*. MARCASITE (BLADED) FILLING OPENINGS AND REPLACING A MIXTURE OF FINE-GRAINED PYRITE, SPHALERITE, GALENA, AND CHALCOPYRITE, ON LEFT. CALCITE (MEDIUM GRAY, ON RIGHT) IS LATER FISSURE FILLING. VUGS ARE BLACK. FRAY MARTÍN PROSPECT.


*B*. GALENA, SPHALERITE, CHALCOPYRITE, AND QUARTZ FILLING A FISSURE IN MANGANIFEROUS CARBONATE (GRAY, IN TOP THIRD AND ALONG BOTTOM EDGE). QUARTZ IN VEIN CONTAINS VUGS (BLACK). PATARA MINE.



DISSEMINATED PYRITE ARSENOPYRITE, AND SPHALERITE IN QUARTZ AND IN MANGANIFEROUS CARBONATE (DARK STREAK ON LEFT). LATE QUARTZ PARTLY FILLS FISSURE (DARK STREAK ON RIGHT). HUANCAPETÍ MINE.

PYRITE AND ARSENOPYRITE (GRAY) PARTLY REPLACING BRECCIATED AND ALTERED ANDESITE (LIGHT GRAY). FRAGMENTS IN LOWER LEFT ARE NEARLY COMPLETELY REPLACED. QUARTZ (WHITE) AND SOME SPHALERITE (DARK GRAY) ARE DEPOSITED IN BRECCIA VOIDS. COTURCÁN MINE.

At the Jecanca deposit, where the largest area in the Cordillera has been hydrothermally altered, a large block has been sericitized and argillitized, extending northward and northeastward from south of the principal vein to and beyond the limits of the mapped area (pl. 7*A*). South of this zone, altered rock is sporadic, in part limited to zones paralleling known veins In such areas, the alteration pattern may be useful as a prospecting guide should the deposit be explored

The siliceous and argillaceous sedimentary rocks are altered, but only to a relatively minor extent. In some deposits, small amounts of sericite, pyrite, and quartz were introduced, and the darker rocks were bleached Limestone was pyritized at some deposits, in others it was dolomitized where magnesia was present in mineralizing solutions At the one deposit where considerable dolomite was formed, in a contact zone with an intrusive, introduced silica reacted with magnesia and lime of the carbonate rock to form actinolite and garnet, it also was deposited as fine-grained quartz.

## COMPOSITION OF VEINS

Most veins in the Cordillera Negra contain argentiferous galena and sphalerite in a gangue of pyrite, quartz, gouge, and altered wall rock. Chalcopyrite is a constituent in one-third of the deposits, and enargite, tetrahedrite, and several other copper minerals, as well as stibnite and argentite, are seen in a few veins. In the several veins that do not contain galena and sphalerite, the mineral suites are: enargite-tetrahedrite-pyrite-quartz, stibnite-pyrite-quartz, silver sulfides and sulfosalts-calcite, and chalcopyrite-pyrite-quartz-secondary copper minerals. Some veins at old mines do not contain base-metal sulfides in present exposures, and may have been mined only for precious metals

In addition to pyrite and quartz, calcite and manganiferous-carbonate minerals form the gangue of half the deposits Arsenopyrite is present in some; and marcasite, pyrrhotite, specularite, rhodonite, and alunite occur locally in a few others. Relative amounts of the principal nonmetallic gangue minerals, quartz and carbonates, change from deposit to deposit; the gangue of most veins is largely quartz, but in a few is largely carbonates Several veins have little of either, and altered wall rock and gouge form the greatest part of their gangue.

In certain deposits, the mineral suites are different in each vein or even in the same vein, as shown by well-developed zoning patterns. This is best seen in the Santa Elena mine, where the central zone, 450 meters in diameter, contains only enargite, tetrahedrite, and pyrite in gouge and altered wall rock; enargite is more common near the surface and tetrahedrite predominates at depth. Around this zone, galena,

TABLE 3 —*Assays of channel and grab samples, Cordıllera Negra*

Assayed by S M Shelton, Chemıcal Laboratory, U S Bureau of Mines, report No EG-5, dated October 28, 1948 Serıal numbers are those of Bureau of Mınes ]

| Sample No | Ounces | | Grams [1] | | Percent | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Au | Ag | Au | Ag | As | Sb | Pb | Cu | Zn |
| 1615 | 0 01 | 2 01 | 0 31 | 62 5 | <0 05 | <0 05 | 8 7 | <0 05 | 3 6 |
| 1616 | 01 | 9 15 | 31 | 248 2 | 2 | < 05 | 16 0 | 9 | 12 3 |
| 1617 | 01 | 9 13 | 31 | 284 0 | -------- | -------- | 22 0 | 3 | 5 0 |
| 1618 | 01 | 2 25 | 31 | 70 0 | < 05 | < 05 | 7 | 1 | 10 4 |
| 1619 | 01 | 27 33 | 31 | 850 0 | 1 | 2 | 3 3 | 3 | 6 5 |
| 1620 | 01 | 58 35 | 31 | 1812 0 | < 05 | 3 | 7 9 | 6 | 11 4 |
| 1621 | 15 | 43 37 | 4 67 | 1349 0 | 2 9 | 2 | 0 6 | 2 | 1 0 |
| 1622 | 18 | 20 52 | 5 60 | 638 0 | 2 0 | 1 | 9 5 | 3 | 8 5 |
| 1623 | 40 | 18 42 | 12 44 | 573 0 | 1 0 | 3 | 3 4 | 1 | 5 4 |
| 1624 | 02 | 2 36 | 62 | 73 4 | 1 | < 05 | 2 9 | 1 | 13 6 |
| 1625 | 05 | 5 93 | 1 55 | 184 2 | 7 5 | 5 | 6 5 | 2 | 10 3 |
| 1626 | 06 | 1 74 | 1 86 | 54 2 | 7 4 | 4 | 1 0 | 07 | 1 2 |
| 1627 | 10 | 6 64 | 3 11 | 206 5 | 5 4 | < 05 | 1 5 | 3 | 4 2 |
| 1628 | 07 | 1 37 | 2 18 | 42 6 | 5 4 | < 05 | 2 | 3 | 25 0 |
| 1629 | 03 | 1 91 | 93 | 59 4 | 3 8 | 1 | 2 0 | 1 | 8 6 |
| 1630 | 08 | 53 04 | 2 49 | 1650 0 | 8 9 | , 6 | 17 2 | 3 | 10 2 |
| 1631 | 09 | 13 19 | 2 80 | 410 0 | 13 6 | 1 | 9 1 | 07 | 15 0 |
| 1632 | 04 | 9 46 | 1 24 | 294 0 | 7 1 | 1 | 2 9 | 05 | 8 5 |
| 1633 | 13 | 29 87 | 4 04 | 930 0 | 19 2 | 1 | 9 0 | 2 | 8 5 |
| 1634 | 02 | 15 70 | 62 | 488 0 | 4 | 1 | 13 9 | 2 | 28 2 |
| 1635 | 08 | 1 64 | 2 49 | 51 0 | 1 | 1 | 13 3 | 07 | 12 1 |
| 1636 | 02 | 15 44 | 62 | 480 0 | 2 | 1 | 10 1 | 4 | 38 0 |
| 1637 | 01 | 5 93 | 31 | 184 5 | 1 | 1 | 7 4 | < 05 | 20 8 |
| 1638 | 02 | 5 56 | 62 | 173 0 | 2 | < 05 | 11 7 | 2 | 25 4 |
| 1639 | 01 | 4 35 | 31 | 135 2 | 1 | 1 | 32 0 | 07 | 21 6 |
| 1640 | 01 | 5 83 | 31 | 181 5 | 2 | 1 | 23 0 | 5 | 38 0 |
| 1641 | 01 | 3 63 | 31 | 113 0 | 2 | < 05 | 21 2 | 4 | 16 6 |

[1] 1 ounce troy equals 31 1 grams

mined shortly thereafter. Colquıpocro was the sıte of very actıve mınıng operatıons ın the 1860's and 1900's, and the same was true of Patara Pflucker (p 29) found the Buena Cashma vein was a relatıvely large producer and Uchco was beıng developed and had a small lıxivıatıon plant. Velarde (1908, p. 63) noted that more than 200 people were employed at the many small Pueblo Lıbre mınes ın 1907.

Lıttle specific ınformatıon is avaılable for the perıod between the 1900's and the 1940's. Collaracra seems to have been worked for most of thıs tıme, and the Huancapetí mine also was worked on a large scale Santa Elena was developed for minıng on a large scale ın 1943 and was worked untıl copper ore was exhausted ın 1948 Jecanca was dormant foı most of the period but was worked for about a year by Cía. Santa Elena ın 1949 and 1950 while zınc prıces were hıgh The Colquıpocro deposıt was mıned sporadıcally in the 1930's and 1940's The small deposıts southeast of Colquıpocro evıdently were worked at least ın the late 1930's and early 1940's At the tıme we studıed the range, a total of 18 deposits were being mıned or prospected

Because transportatıon costs are high, the sılver content of base-metal ore stıll ıs ımportant to both small and large operators Rıchest sılver ores are near the surface, where supergene enrıchment has occurred and ore becomes leaner and more expensıve to mıne at depth, so that most small mines are abandoned at shallow depth Surficıal

TABLE 4—*Description of samples, Cordillera Negra*

| Sample No | Location | Type of sample | Length of channel sample (cm) | Width of vein or zone from which chip sample was taken (cm) |
|---|---|---|---|---|
| 1615 | La Recuperada prospect | Channel | 50 | |
| 1616 | Señor de Soledad prospect | do | 65 | |
| 1617 | Cerro Panicocha prospect | do | 10 | |
| 1618 | Prospect in Jatuncaca area | Chip | | 115 |
| 1619 | Huallpac mine, upper level | Grab sample from dump | | |
| 1620 | Huallpac mine, lower level | do | | |
| 1621 | Prospect in eastern veins, Uchco area | do | | |
| 1622 | Capalo mine | Chip | | 35 |
| 1623 | Santa Rosa mine, north vein | Grab sample from dump | | |
| 1624 | Patara mine, east end of vein 5 | Chip | | 45 |
| 1625 | Huancapetí mine, Alsacia vein, lower adit | do [1] | | 25 |
| 1626 | do | do [2] | | 26 |
| 1627 | do | do [1] | | 90 |
| 1628 | do | do [2] | | 40 |
| 1629 | Huancapetí mine, Huancapetí vein, stope 29 | do | | 68 |
| 1630 | do | do | | 37 |
| 1631 | Huancapetí mine, Huancapetí vein, stope 26 | do | | 45 |
| 1632 | Huancapetí mine, Huancapetí vein, stope 28 | do | | 25 |
| 1633 | do | do | | 65 |
| 1634 | Jecanca mine, Santo Toribio vein | Channel [2] | 32 | |
| 1635 | Cerro Maco mine | do | 50 | |
| 1636 | Jecanca mine, Santo Toribio vein | do [1] | 55 | |
| 1637 | do | do [3] | 25 | |
| 1638 | do | do | 115 | |
| 1639 | Cerro Maco mine, west working | do | 30 | |
| 1640 | Jecanca mine, Santo Toribio vein | do | 130 | |
| 1641 | do | do | 195 | |

[1] Hanging wall
[2] Footwall
[3] Center of vein.

areas are thoroughly mined and little can be seen of veins after mines are abandoned

At small mines and prospects, all operations are manual, including drilling and moving ore from workings to the surface Ore is hand crushed and sorted or hand-jigged if water is conveniently near. The concentrates are packed by beasts of burden to the nearest depot in the Santa Valley. Operations are not heavily capitalized and the life of any venture is dependent on continually finding new ore shoots If new ore bodies are not found with a minimum amount of exploration, then all available ore is mined and workings either cave or become flooded At some now-abandoned operations, hand-sorting was so thorough that it is difficult to determine from the waste rock what sulfides were mined.

Only the operations of the Anglo-French Ticapampa Silver Mining Co and the Cía. Minerá Santa Elena were mechanized. Electricity and compressed air were available, as were jackhammers, stopers, trams, and hoists, and the Collaracra, Huancapetí, and Santa Elena mines had adequate ventilation, drainage, and pumping systems in 1947. At Santa Elena, ore was moved by aerial tram from the haulage adit to the flotation plant in the valley below the mine Ore from the

Huancapetí and Collaracra mines was hand cobbed, then moved by aerial tram to Ticapampa for flotation.

The two major companies paid workers on a daily wage basis The small mines and prospects generally employed contract miners who were paid fixed sums per ton of concentrate Although mining costs are relatively low, transportation costs at small mines, including packing and thence trucking to port, are high; for this reason the silver content of ores is important to the operator, and sphalerite which has a low silver content is discarded or not mined.

Production figures, already given for the Anglo-French and Santa Elena operations (p 3), are difficult to establish for small operations Generally, prospects or mines worked by from one to four men produce a maximum of 5 tons of concentrate per month It is not possible to determine how many months a year the average mine is in operation, because wet weather from October to May hinders transportation of ore and supplies, and because most miners spend some time cultivating their own crops. Furthermore, decreases in market price or depletion of small ore shoots result in fluctuations in production of ore and breaks in the continuity of mining activity It is probable that the total annual production of all small mines in the Cordillera Negra is less than 1,000 tons of lead-silver concentrates per year.

Reserve calculations similarly are incomplete because of inaccessibility of old workings, lack of production records, and sporadic occurrence of ore at the smaller mines The reserves of the larger operating mines are judged to be past their peak in ground that was developed up to 1947 The Santa Elena mine subsequently was closed, but new veins were being explored by the Anglo-French Co.

## FUTURE POSSIBILITIES AND RECOMMENDATIONS

It is questionable whether mining in the Cordillera Negra can ever exceed the rate of production reached in 1946, when the two major companies mined 37,000 tons and small mines produced possibly 1,000 tons The rate has been much lower since, owing to the closing of the Santa Elena mine.

Because all larger deposits are fissure veins containing at most ore bodies of moderate size, the majority of which have been mined for many years, reserves of base-metal ores are not large. Many deposits were mined and abandoned, so it is difficult to determine how much ore remains in such veins. These factors, together with high transportation costs, militate against large-scale developments

Despite these negative factors, possibilities exist for successful mining operations on a medium scale In the summary of the section on mineral deposits, it was noted that strong faults or shear zones, particularly near porphyritic intrusive masses, seem to be those in which the major ore bodies are found. It might be added that some, but not all, are bordered by wide zones of silicified rock. Several veins as yet not extensively mined meet one or both of these conditions Others were thoroughly mined to what we judged were shallow depths, and it may be worth reopening old workings to study such sites in greater detail The possibility of drilling similarly should not be overlooked, because some deposits which seem to meet the above conditions crop out well above the base of major ore bodies (about 3,750 meters altitude) known in other parts of the range One area that seems to be favorable is west of the Huancapetí mine, and in the description of mines and prospects that follow, other areas will be noted.

Present mining practices probably do not result in maximum recovery Use of part of initial returns for more systematic development would permit greater exploration, and longer mining life might follow Similarly, practices of pulling pillars and caving workings when cursory exploration proves unfruitful reduces the overall production potential

The mines are widely scattered, so that construction of access roads to mines is not warranted in most of the Cordillera However, because they would also afford access to agricultural areas, two roads might be justified The first could extend from either Recuay or Ticapampa to Aija Construction of this road has long been contemplated and a completed road actually is shown on some government maps The road would benefit the area west of Huancapetí, and it would be of great use to the agricultural towns on the west flank of the southern part of the range The second road could extend from some point in the Santa Valley near Carás to Pamparomas, passing near Colquipocro It would benefit mining and agricultural groups in the north central part of the Cordillera Of the two, the Aija road may be the more useful to mine development

No specific sites for beneficiation plants can be suggested before more reserves of ore are found Local men have the resources to build the plants as they are needed For example, in 1948, Sr Jorge Cáceres began to build a flotation plant along the Río Santa below the Jecanca deposit because of the interest expressed in renewing operations in this area The plant was completed and was used by the Cía Minera Santa Elena during the period (1949–1950) in which it mined the deposit.

## MINES AND PROSPECTS

With the exception of certain groups, such as those around Huancapetí, Pueblo Libre, and southwest of Colquipocro, deposits are scattered and do not occur in districts For this reason, they are described in relation to three areas, the southern, central, and northern. The Huarás-Casma road and the latitude of Carás are the arbitrary boundaries (pl 1)

The names given deposits in this report are those used locally, and therefore may not be found in earlier works. Abandoned deposits for which no local name was known are arbitrarily given purely geographic names, derived from the most prominent peak or valley in the vicinity. Consequently, they may not be found in the Padrón General de Minas, the official roster of active mining concessions.

In addition to the deposits described in this report, several others have been noted in the literature by Raimondi, Dueñas, Pflucker, and Velarde. The locations of most are not precisely described and some may correspond to certain deposits for which we were not able to find local names while in the field. Others, however, are deposits which occur in areas that we did not visit during this examination.

Of those in the latter group, many small veins containing chalcopyrite and pyrite occur near Pira, a village south of Río Chacchán about opposite the El Carmen mine (pl. 1, loc. 24). Dueñas (1904, p. 27) considered them of little value at a time when even small showings were thought to have good possibilities. Pflucker (1906, pp. 15 and 21) and Raimondi (1873, pp. 419–428) mentioned several lead-zinc deposits around Aija that had been worked out at an early date, and both cited the magnetite veins near Aija. In 1948, it was reported that an ore of base-metals was found near Malvas, between Aija and Cotaparaco, but an assay proved the mineral to be magnetite.

We saw prospect pits in completely barren ground at many localities. Only those near deposits are mentioned as part of mine workings in the following descriptions.

## THE SOUTHERN AREA

Since 1860, the southern area has been the most important, both in number of deposits worked and in tonnage produced. In 1947, in addition to the three large deposits, the following small deposits were being mined: Tarugo, by Sr. Icaso, Wilson, Tuctu, Lucero, San Ildefonso, Soledad, and Fernandita, by Sr. César Masa Ríos; Cerro Panicocha, by Sr. Alejandro Alvarado, and Recuperada, by Sr. Gustavo Pohl. In 1948, Sr. Jorge Cáceres opened the Mercedes and Santa Cruz mines.

### COLLARACRA MINE

The Collaracra mine (pl. 1, locality 1), 4 kilometers west of Ticapampa, is on the north side of Quebrada Ichihuisca, a valley reaching the Santa valley just south of Recuay. Concessions on the veins of the area are held by the Anglo-French Ticapampa Silver Mining Company.

The Collaracra vein probably has furnished the largest tonnage of ore from the Cordillera Negra and possibly from the entire Departamento de Ancash. Raimondi (1873, p. 60, 1874, p. 153) visited the workings in 1860 and reported there were many small mines, only a few of which were in operation. Denegri (1905, p. 83) stated that the mineralized area had been acquired by the Compañía Minera de Ticapampa, a French concern, several years before 1899. It was reorganized under the name Anglo-French Ticapampa Silver Mining Co., in 1904, and thus is one of the oldest continuing operations in the history of modern mining in Peru.

Denegri (1905, p. 89 and 95) reported 61,000 kilograms of silver were produced in the 10 years from 1890 to 1899 inclusive, during which period the ore mined contained from 0.6 to 8.0 kilograms of silver per ton, and from 3 to 7 percent copper. Galena ores contained 45 percent or more lead. In 1947, hand-cobbed copper ore contained from 0.5 to 0.8 percent copper and 1 kilogram silver per ton. Hand-cobbed galena ore contained 15 percent lead and 1.5 to 2.0 kilograms of silver per ton, as well as 6 percent zinc from sphalerite, which was not recovered during flotation. Recent statistics published by the Peruvian Government list only the combined production of the Collaracra and Huancapetí mines, which averaged 500 tons lead, 6,500 kilograms of silver, and small amounts of gold and copper per year from 1945 to 1948 inclusive.

The main vein, the Collaracra, has a general east-northeast strike and can be followed for at least 2.5 kilometers. Despite its continuity and its operation by one company, the workings on different parts of the vein have different mine names. At the northeast are the Hurán and the Triunfo, and to the southwest are La Salteada, San Julio, Uchpapucro, and San José. In the northeast area, the Collaracra vein is paralleled by three other veins, all to the northwest. The first, the San Ignacio, is 60 meters from the Collaracra, the second, the San Fernando, is from 120 to 150 meters from the Collaracra, and the third, the Hurán, is 380 meters from the Collaracra. Of these only the Hurán is of major size. In addition, a cross vein, the Crucero, extends obliquely between the Collaracra and the Hurán. Raimondi and Denegri list many small veins in the Collaracra area but these evidently contained so little ore that they have since been forgotten. The principal adits for operations are the Triunfo, a 1,200 meter crosscut at an altitude of about 3,960 meters and just west of the mine camp in the main valley, and the Hurán, at an altitude of 4,200 meters and 0.5 kilometers to the north in a tributary valley.

The major geologic unit is a fine-grained porphyritic rhyolite intrusion. It cuts the closely folded volcanic group, which includes lava, tuff, and some shale. Part of its southwest margin is in contact with shale of unknown age. In places the intrusion contains moderately large xenoliths of volcanic rock and smaller xenoliths of sedimentary rock. The Collaracra vein crosses the intrusion and extends into the volcanic rocks on the northeast and into shale on the southwest. The other northeastern veins are entirely in the intrusion.

The Collaracra vein contains pyrite and lesser amounts of tetrahedrite, argentite, galena, sphalerite, and arsenopyrite, in a gangue of quartz and small amounts of calcium and manganese carbonate minerals. In the parallel veins at the northeast end of the system, the minerals are galena, sphalerite, and pyrite, and some stibnite, carbonate minerals and quartz. Strongly altered wall rock, thought to be largely kaolin clays, occurs along all veins in widths of as much as 5 meters.

Raimondi (1873, p. 338–378) and Denegri (1905, p. 83–84) also found chalcopyrite, jamesonite, boulangerite, bournonite, malinowskite, specular hematite, gold, cerussite, anglesite, limonite, malachite, and azurite in the veins.

Silver content was greatest in the zone of oxidation, which generally is not more than 5 meters deep. Below this zone the silver content decreases with depth, possibly suggestive of supergene enrichment. On the Collaracra vein it may also be attributed in part to decrease in tenor of argentiferous tetrahedrite.

Vertical zoning of mineral deposition within a depth of several hundred meters is clearly demonstrated on the Collaracra vein. Arsenopyrite is the chief gangue mineral at depth, whereas quartz, pyrite, and some carbonate predominate near the surface. On the Hurán vein, stibnite occurs in small amounts at depth and increases in quantity upward.

The outcrops and surface workings of the Collaracra vein extend from a tributary valley in the Hurán area across hills and valleys to beyond the southwest contact of the intrusion. Along its 2.5 kilometer extent, the dominant strike is N. 60°–70° E. and the dip generally is 70°–80° NW. Near the crest of Cerro Collaracra, the main hill above the Triunfo adit, the vein locally strikes N. 40° E. and dips 75°–90° SE. Nearby, the vein is offset 10 meters north on the west side of a small cross fault. In the southwestern area several veins of minor importance branch at small angles from the Collaracra vein. Further details of structures in now inaccessible workings on the vein are given by Denegri (1905, p. 86, and figs. 1–6).

In most of the Triunfo area, the Collaracra vein is from 2 to 3 meters wide, but minable sulfides are confined to narrower bands generally 50 to 60 centimeters wide, within gangue and altered wall rock. Although galena and sphalerite are present, argentiferous tetrahedrite forms the bulk of the ore mined. As was noted, arsenopyrite is the chief gangue mineral at depth, but pyrite and quartz, as well as some calcite, predominate at higher levels. In the southwest area, the vein is from 0.5 to 2 meters wide and together with its branches mostly contains pyrite which in part is argentiferous, as well as quartz and some stibnite. Calcite is less common. Several small lenses containing galena and sphalerite occur in parts of the southwestern vein system.

One-half kilometer north of the Triunfo adit is the Hurán adit, which follows the Hurán vein 460 meters to the southwest. The portal is just west of the contact between the rhyolite intrusion and the closely folded volcanic group. In the northeast 300 meters of this working, the vein strikes N. 60° E., dips 70°–80° NW., and contains only lenses of quartz. In the southwest 160 meters, the vein strikes N. 70°–75° E. and dips 75°–80° NW. This segment carries ore along nearly its entire length. The vein consists of a 2-meter width of strongly altered rhyolite which contains the ore shoot, a sulfide band from 20 to 60 centimeters wide that, in part, follows the hanging wall. Sphalerite, galena, and pyrite are the chief sulfide minerals, stibnite occurs in small amounts, and quartz is scarce or absent. The slight change in vein strike evidently controls the east limit of the ore shoot.

Several small veins branch from the Hurán structure in surface workings, and these same exposures show that parts of the main vein dip steeply southeast. In the Triunfo workings, some carbonate and quartz occur with the galena and sphalerite on the Hurán vein.

The San Ignacio and San Fernando veins, exposed both in the Triunfo workings and in surface outcrops, are comparatively barren and largely contain quartz. Both strike N. 60° E., but the San Fernando dips 65° SE., in contrast to the general northwest dip of the other veins of the area. The Crucero vein, exposed in the Triunfo and Hurán workings, as well as on the surface, strikes N. 20°–25° E. and dips 65°–70° NW. Evidently it is confined between the Collaracra and Hurán veins. Little was known of its mineral content in 1947, as it was first being explored at that time. One outcrop contained a 1.5-meter wide vein of quartz.

Ore is broken by hand drilling and blasting, but mechanized drilling equipment is used in preparation and development. Power trams are installed on the two main haulage levels, and a hoist brings up ore from deeper levels. Two loading stations on the aerial tram system are used for shipments to the concentrator at Ticapampa. In 1947, only the northeast end of the area was being worked, the principal mining was done on the Collaracra and Hurán veins, and development and exploration was done on the Crucero vein.

Along the Collaracra vein, all ore is mined out above the adit level in the Triunfo area, and most argentiferous pyrite ore was mined out of the southwest area. Because arsenopyrite increases at depth, to the exclusion of commercial sulfides, it is probable that little argentiferous tetrahedrite remains in the main Triunfo workings. It cannot be predicted at what level comparable zoning will affect the mineral composition of the Hurán vein, but in all likelihood its depth of ore will be no greater than that on the larger Collaracra vein. Reserves of galena in the developed section of the Hurán vein therefore are considered to be small, but in 1947 its southwestern extent had not been fully explored In the same year, exploration of the Crucero vein was not sufficiently advanced to determine its mining potential

### HUANCAPETÍ MINE

The Huancapetí mine, 9 kilometers west of Ticapampa, is on the north shoulder of Cerro Huancapetí and just south of the Ticampampa and Recuay trails to Aija (pl 1, loc 2) According to the company survey datum, the range in altitude of veins in workings and outcrops is from 4,535 to 4,765 meters, compared with surveying by Kinzl (1939), the local datum is 60 meters low Glacial debris conceals parts of the area, especially the basins and valleys Water is not abundant but suffices for camp use, and eucalpytus trees used for mine timber is grown in the Santa Valley

In 1860, Raimondi (1873, p 60 and 404–411, 1913, v 5, p 151) saw several workings which at that time were dormant and which he surmised had been opened during the Spanish Colonial period The principal mine had two levels More recently the property was acquired by the Anglo-French company, which has been actively mining it for many years, producing argentiferous galena ores In mining statistics, production data are combined with those of Collaracra, so rates of output for the mine are not known Ore is moved by aerial tram to Ticapampa, where it and galena ore from Collaracra are concentrated

Reserves in 1947 were relatively small, although the southwest end of the principal vein, beyond the company property line, was unmined at depth In a search for new ore bodies, an exploratory crosscut was being driven from the main workings southeast toward a group of unexplored veins between the Huancapetí and Carpa vein systems (pl 4) In 1947, the crosscut had been advanced 170 meters but had not reached these veins

The larger part of the Huancapetí area is underlain by the slightly folded upper group of volcanic rocks (pl 4) Most of the sequence consists of porphyritic rhyolite, rhyodacite, and trachyte flows, generally gray and green Some layers are dense and fine grained, and others consist of volcanic breccia In the southeast part of the area is one bed of agglomerate, consisting of boulders 5–35 centimeters in diameter, and one bed of coarse-grained tuff crops out several hundred meters to the north Volcanic rocks cropping out in the mapped area form a column at least 300 meters thick

West of the main ridge is a belt of closely folded volcanic rocks of the lower group, consisting of red, gray, and green lava, agglomerate, and tuff, some layers of which contain fragments of angular white quartz Most rocks contain quartz phenocrysts and probably are rhyolite and rhyodacite The sequence includes one bed of metamorphosed limestone containing garnet

Intrusive into the volcanic rocks and extending along the main ridge is a tabular mass of porphyritic rhyolite, grading locally, where quartz content is low, into trachytic rock In places the mass shows flow banding, and it is fine grained near contacts In one small area along its west contact it contains partly resorbed fragments of volcanic rock Several small sills of rhyolite and rhyodacite, near the west contact and in the more folded volcanic group, may be related to the main mass The main mass seems to be as much as 200 meters thick, but its outcrop pinches and swells, possibly indicating thinning and thickening along its length

An intrusive breccia, which is too altered to allow determination of its composition, crops out in the central part of the mapped area Several hundred meters to the southeast are three small porphyry intrusions, one is partly brecciated, and another is a small sill

All rocks are so altered—strongly near veins but appreciably even away from veins—that it is difficult to determine the composition of even the least altered material All dark minerals are chloritized, and feldspars are sericitized to various degrees

The older group of volcanic rocks strike north and dip 45°–90° E To the west, the less folded, upper group of volcanic rocks strike northwest and dip 30° SW , and apparently are unconformable on the older rocks East of the main intrusive mass, the less folded, younger group of volcanic rocks is warped into an anticline on the west and a syncline on the east, both of which seem to be plunging north Throughout most of the mapped area, the younger volcanic rocks dip from horizontal to 30°, but at one point dip as much as 50°

The main intrusive mass dips 30°–60° E In places its contacts are covered or are obscure owing to rock alteration Along the west contact, the intrusion is brecciated at several places As may be seen on the cross section of pl 4, it seems probable that the lower group of volcanic rocks have been upfaulted relative to the upper group of volcanic rocks to the east, and the main mass may have been intruded along a fault

The main fault system in the area is that followed by the large veins Segments branch intricately, with predominantly northeast strikes and steep northwest dips Several mineralized faults strike east and a few, northwest Displacements are judged to be small, where mineralized faults cross the main intrusion, the north sides are dropped and contacts are displaced at the most 30 meters Most fault zones are comparatively narrow, but along the larger veins, shear zones are as much as 10 meters wide in underground workings and 15 meters wide at the surface (pl 10) The major vein system, including the Huancapetí and Alsacia veins, is traceable for a distance of 2 kilometers

Other fractures include premineral cross faults, unmineralized faults, and joints. Several small premineral cross faults were seen on the Huancapetí vein that displace the main structures only at the most, 30 centimeters. Two unmineralized faults occur in the western part of the mapped area, one in the main intrusive mass and the other partly along the unconformity between the lower and upper groups of volcanic rocks, and others are seen in the new exploratory crosscut. Joints occur mainly in the younger group of volcanic rocks, striking east to northeast and generally dipping steeply north to northwest. Less prominent joints strike north-northwest.

Minerals in the veins of the Huancapetí deposit are galena, sphalerite, chalcopyrite, stibnite, pyrite, arsenopyrite, quartz, calcite, manganiferous carbonates and rhodochrosite, and clays. Silver occurs with galena and possibly as argentite. Near the surface, limonite and manganese oxides are common. In addition to these minerals, gouge and brecciated and altered wall rock form vein material. Raimondi (1873, pp. 404–411) also listed tetrahedrite, chalcocite, jamesonite, bournonite, and silver oxides as occuring in these deposits. He stated that during early mining, native silver had been present, and his analyses show a trace of gold.

The sulfide minerals occur mainly as fissure fillings, other than the pyrite, which also occurs as disseminated replacement of altered wall rock and quartz (pl. 8). On a small scale, sphalerite replaces quartz, and minute stibnite needles are in quartz and in carbonate minerals. In places ore is vuggy and banded. Sulfides tend to be fine grained, but some sphalerite, galena, and chalcopyrite are in grains as much as 1 centimeter in diameter.

Quartz occurs in both massive and crystalline forms, the latter small and lining vugs. Along parts of the veins, wall rock is silicified, and at the southwest end of the Huancapetí vein, one zone as much as 75 meters wide is nearly completely replaced by silica containing small amounts of pyrite. The quartz in replacement zones is gray, whereas that deposited as fissure filling is white.

Carbonate minerals grade from calcite, generally white, through manganiferous varieties to pink rhodochrosite. Calcite is fine grained, rhodochrosite is cryptocrystalline and in places is laminated and botryoidal. One specimen contains a white cryptocrystalline carbonate, too fine-grained to be identified by microscope. It occurs as thin plates between septa of medium-grained and vuggy quartz. Clays, probably kaolins derived from altered wall rock, are white and gray.

Owing to extensive mining for silver in the oxidized zone, little may be seen of the oxidized minerals. As shown in the table 1, various textures are evident in the manganese oxides derived from the maganiferous carbonates. Only gamma $MnO_2$ and an unknown manganese mineral occur in the different types.

The assays (analyses 1625 to 1633 inclusive, table 3) show the tenor of ore in the larger veins. Analyses 1626 and 1628 are from low-grade material which is not mined. The other assays indicate these ranges: lead, 1.5–17.2 percent, zinc, 4.2–25 percent, and copper, 0.05–0.3 percent. Antimony is comparatively low, from less than 0.05 to 0.6 percent, but arsenic ranges from 3.8 to 19.2 percent. Silver ranges from 59 to 1,650 grams per ton, and gold from 0.9 to 4.0 grams per ton.

Relating the assays to what minerals could be seen in the veins, we noted that galena, sphalerite, and arsenopyrite, together with pyrite, are the most common sulfide minerals. Chalcopyrite occurs only in small quantities, and tetrahedrite and bournonite, mentioned by Raimondi, were not seen in present workings. Silver content in a very general way is related to galena content, but ratios show a wide range, from 28 to 138 grams silver per 1 percent lead. Gold was not visible in the ore.

Vertical zoning of minerals can be seen on the largest vein. In the upper levels, galena and some sphalerite occur in a gangue of quartz, pyrite, and small amounts of arsenopyrite and carbonate minerals. At the lowest level, sphalerite, arsenopyrite, and carbonate minerals form an appreciably higher percentage of vein material, and quartz is present only in small amounts.

Wall rock along veins is highly altered. Chlorite, epidote—or rarely—clinozoisite, and calcite resulting from propylitization were succeeded by sericite and kaolin. Quartz, calcite, and pyrite were introduced into such altered rock. In end stages, the original porphyritic textures are completely destroyed. The wide silicified zones at the southwest end of the Huancapetí vein consist of very fine grained quartz (grains 0.01 to 0.02 millimeter in diameter) with a scattering of chlorite grains and pyrite crystals.

Three groups of veins with northeast strikes comprise the bulk of mineral-bearing structures. The largest is the group that includes the Huancapetí and Alsacia veins, extending from the northeast to the southwest corners of the mapped area. The group second in size is in the southeast corner and includes the Carpa vein. Between them is the third, a comparatively small group of veins. In addition, many small veins crop out on the east side of the mapped area, and others that strike east extend along the south side. Beyond the northwest edge of the mapped area and extending to the Ticapampa-Aija trail are other small veins that will be described with the deposits of Cerro Pucar.

The surface and underground maps show that the veins consist of relatively short branching and anastamosing shear zones (pls. 4 and 10). These contain lenses of ore having considerable range in size. In the Huancapetí vein, ore is nearly continuous for a length of 310 meters on level 4, and surface workings indicate ore minerals in this zone extend at least 75 meters southwest beyond the limit of the drift Although the zone is as much as 15 meters wide in places, most minable lenses in the lower levels are only from 1 to 2 meters wide and ore-bearing bands within these are from 37 to 90 centimeters wide Ore extends from level 5, at an altitude of 4,510 to the top of the ridge, at an altitude of 4,760 meters, a vertical range of 250 meters Both to the southwest and northeast of the main ore area, the vein breaks into complexly branching veins that contain little ore

On the northeast end of the vein, another ore-bearing segment, the Alsacia vein, is 50 meters long and as much as 1 meter wide The ore body on the Carpa vein is only 85 meters long and seems to be 1 meter or less wide Small workings in the Carpa and Alsacia areas expose shoots of even smaller dimensions

Description of sections across the veins at points where samples for assay were collected (tables 3 and 4), are given to illustrate typical composition and distribution of ore

Lower drift, southwest end, Alsacia vein 25 centimeters sphalerite, galena, pyrite, and quartz on hanging wall (assay 1625), 26 centimeters pyrite, quartz, and altered wall rock on footwall (assay 1626)

Lower drift, northeast end near raise, Alsacia vein 90 centimeters consisting of 5 centimeters sphalerite, 15 centimeters altered wall rock containing some sphalerite and pyrite, 70 centimeters pyrite and some quartz and sphalerite, with galena throughout in small amounts, on hanging wall (assay 1627), 40 centimeters sphalerite and pyrite on footwall (assay 1628)

Stope 29, southwest end, between levels 4 and 5, Huancapetí vein 68 centimeters consisting of 20 centimeters of silicified wall rock cut by irregular quartz veinlets on footwall, 18 centimeters largely of sphalerite and some pyrite and arsenopyrite, 18 centimeters of gray clay and small amounts of arsenopyrite and pyrite, and 12 centimeters of white clay containing small amounts of carbonate, galena in small amounts occurs with other sulfides (assay 1629)

Stope 26, Huancapetí vein footwall 10 centimeters arsenopyrite and pyrite, 1 40 meters calcite and gray and pink carbonates veined by later calcite and clay and containing small amounts of pyrite, 45 centimeters consisting of 3 centimeters carbonate containing arsenopyrite, pyrite, and sphalerite, 10 centimeters sphalerite, 10 centimeters gray clay and some pyrite and sphalerite, and 17 centimeters of mixed sulfides (assay 1631), 1 0 meter altered wall rock veined by arsenopyrite, pyrite, and sphalerite on hanging wall Total width, 2 85 meters

Stope 28, Huancapetí vein footwall 1 5 meters altered wall rock containing veinlets of galena and sphalerite 10 centimeters thick, 2 5 meters white and pink carbonate, 65 centimeters massive sulfides consisting of arsenopyrite, pyrite, galena, and sphalerite, veined by white quartz (assay 1633), 25 centimeters silicified wall rock cut by veinlets of quartz, pyrite, sphalerite, arsenopyrite and galena (assay 1632) Total width 4 90 meters

Workings on the Huancapetí vein include surface cuts near the crest of the ridge, and adits at altitudes of 4,545, 4,600, 4,638, 4,658, and 4,680 meters The lowest, level 4, is the main haulage level Other than in a few stopes between levels 4 and 3, all ore is mined out above level 4 as far as the southwest edge of the company property line In 1947 most mining was done between level 4 and level 5, a drift 35 meters below. An electrically operated hoist brings ore up to level 4, from which point it is trammed to the aerial-tram station outside the Alsacia adit. Pneumatic jackhammers are used for drilling and most ore is mined by cut-and-fill stoping.

Only two adits are opened on the Alsacia vein, one at an altitude of 4,545 and the other at an altitude of 4,555 meters. The main Carpa adit is at an altitude of 4,670 meters, and other workings in this area range from 4,640 to 4,710 meters. No ore is left in the accessible parts of these workings.

### PUCARÁ PROSPECT

The Pucará prospect (pl. 1, loc. 3), 8 kilometers west-southwest of Recuay, is on the south flank of Cerro Puyhuán and less than 1 kilometer east of the crest of the range. It is just north of the Recuay-Aija trail, at an altitude of 4,600 meters. The workings, now abandoned, are at the base of a 10-meter cliff near the edge of a broad area covered by alluvium.

The country rock consists of low-dipping lava flows. These are cut by a silicified breccia zone 1 meter wide, which was explored by a 30-meter trench and a short adit. The breccia zone contains veinlets and pockets of pyrite, and small amounts of copper sulfates are visible on the walls of the adit. The east end of the zone strikes N. 60° E. and the west end N. 80° W.; it seems to be vertical. Its copper content appears to be too small to be of economic interest and the structure evidently does not extend much beyond the exploratory workings.

### CERRO PUYHUÁN MINE

A small group of deposits lies on the east flank of Cerro Puyhuán, a broad peak on the north side of Quebrada Yanatsurro. The main group of workings, the lowest of which is at an altitude of about 4,500 meters, cover an area about 200 by 200 meters and several prospects lie a short distance to the west. The Cerro Puyhuán deposits are 7 kilometers west of Recuay, and may be reached by a spur trail branching from the Recuay-Aija trail, which in this area follows the south side of the quebrada (pl. 1, loc. 4). Raimondi (1873, p. 60) reported that the deposits contained rich silver ore in the 1860's.

The rocks in the area are quartzitic tuff and coarse-grained porphyritic diorite. In the vicinity of the principal working, the tuff is cut by faults striking northwest and northeast. These faults carry gouge and are bordered by altered wall rock; in parts of them minerals were deposited. The veins contain quartz, pyrite, sphalerite, and galena. They are from 0.01 to 2.0 meters wide and the wider segments consist of gouge and quartz. Little sulfide-bearing rock remains in the workings. Fragments on dumps indicate that the material recovered occurred in bands from 10 to 15 centimeters wide. Native silver and tetrahedrite were found in parts of the deposit during the 19th century (Raimondi, 1873, p. 411).

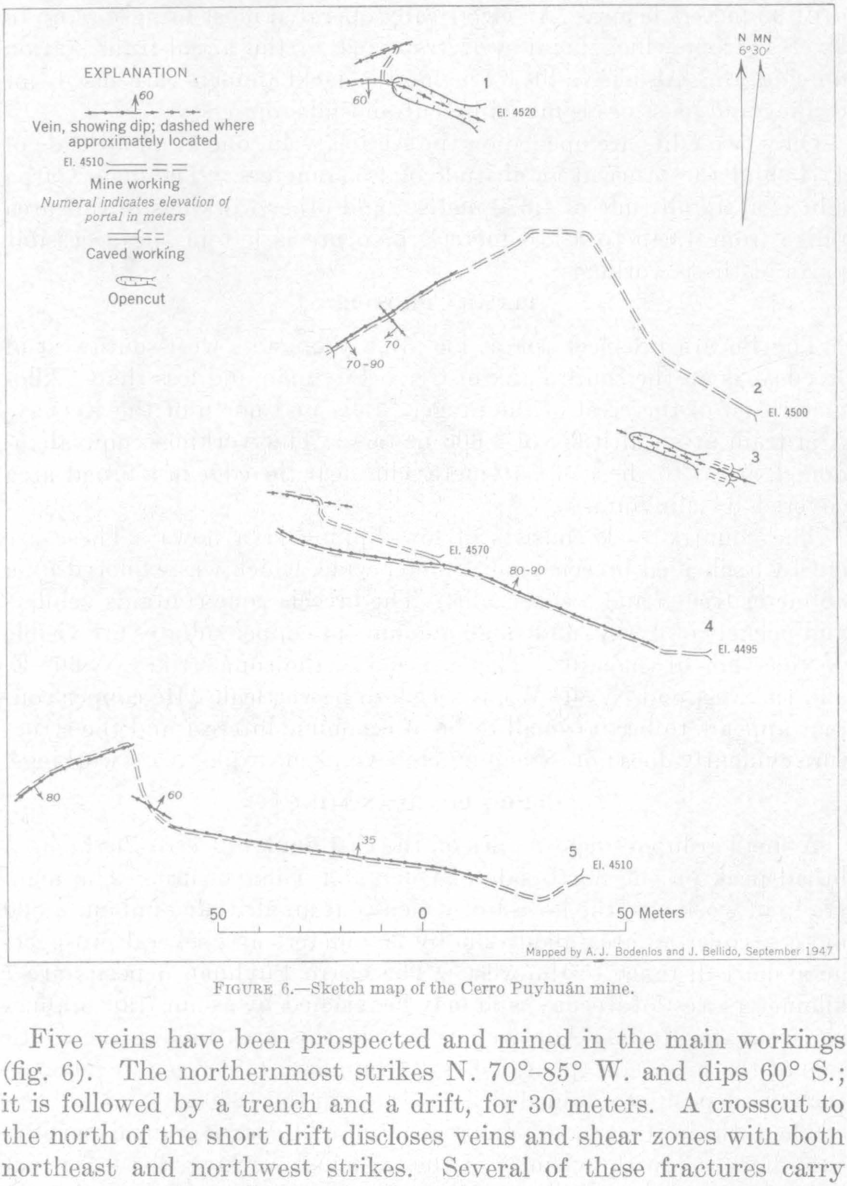



FIGURE 6.—Sketch map of the Cerro Puyhuán mine.

Five veins have been prospected and mined in the main workings (fig. 6). The northernmost strikes N. 70°–85° W. and dips 60° S.; it is followed by a trench and a drift, for 30 meters. A crosscut to the north of the short drift discloses veins and shear zones with both northeast and northwest strikes. Several of these fractures carry small amounts of sulfides and form veins that are narrow and apparently are of low grade. One stope, 5 meters long, was seen in the workings.

Working 2 is about 120 meters southeast of the first. A circuitous crosscut about 135 meters long reaches a vein striking N. 55°–70° E. and dipping 70°–90° SE. The vein has been stoped for a length of 25 meters, both above and below the drift, and the part that could be seen consisted mostly of altered tuff cut by irregular thin stringers of quartz The vein is from 0 1 to 1 5 meters wide and its attitude is irregular Near the filled southwest end of the workings, the vein seems to fray into complex fissures Some galena and sphalerite were seen in quartz-pyrite gangue on the mine dump

Fifteen meters S 20° W of working 2 is working 3, consisting of two caved adits and a trench, extending over a distance of 30 meters These seem to have followed a shear and alteration zone as much as 2 meters wide, which strikes N 70°–75° W Only minor amounts of quartz and altered country rock were seen on the dump

Sixty meters S 12° W of the portal of adit 2 is the portal of the lower adit of working 4 The adit follows a strong gouge zone for 90 meters The zone strikes N 65°–70° W and dips 80°–90° NE in the outer part of the working, then strikes more westerly, and finally hooks to N 65° W at the end of the accessible part of the drift Only quartz was seen in the workings or on the dump Seventy meters west-northwest from the portal is the portal of the upper adit Thirty meters from its portal it reaches a strong gouge zone, which strikes N 85° W and which evidently is the same one seen in the lower adit

Working 5 is a little more than 60 meters S 30° W of working 4 For a distance of 70 meters it follows a shear plane striking N 80° W , and dipping 35° N The shear plane beyond strikes N 50° W and dips 60° NE A mineralized vein 15 meters to the northwest strikes N 50°–70° E , dips 80° SE , is as much as 1 meter wide, and includes both shear planes and breccia in its structure Some galena, pyrite, and quartz are seen on the dump, but little remains in the workings

On a shoulder west of these workings are several veins which have been explored by trenches The largest strikes N 70° E , dips 60° NW , and is opened along its strike by a trench 60 meters long Quartz-bearing parts of the vein are at most 50 centimeters wide and pyrite was the only sulfide seen The wall rock is brecciated and altered diorite About 15 meters to the north a parallel structure was prospected by means of two trenches, it also is barren

High-grade silver ore near the surface evidently was mined out years ago, and the veins in the Cerro Puyhuán mine now contain only very small quantities of sulfide minerals.

### COTURCÁN MINE

The Coturcán mine is west of the crest of the Cordillera Negra and on the south slope of Cerro Pucará (pl 1, loc 5) Layered volcanic rocks, possibly andesitic in composition, strike N 0°–40° W and dip 25° NE The vein has been opened by a drift 90 meters long, partly stoped to the surface.

The vein largely is quartz and pyrite but contains some galena and sphalerite In the first 37 meters of the drift it strikes N 10°–40° W and dips 20°–25° NE , and its thickness ranges from 4 meters at the portal to 0 7 meters farther inward Along this part of the vein, the footwall has been stoped to the surface, a distance of as much as 50 meters updip About 80 meters from the portal, a small fault striking N 10°–15° E and carrying gouge intersects the vein Beyond this point, the vein is weak and contains quartz and pyrite, in part filling a breccia zone (pl 9)

The Guardaraza mine is on the south extension of the vein at an altitude of 4,400 meters The vein strikes N 10° W and dips 30° NE in this area

### TARUGO MINE

The Tarugo mine is on the north flank of Cerro Pucar, a ridge extending westward from the main peak at the Huancapetí mine It is about 2 kilometers from the west edge of the area of the map of the Huancapetí mine, and about 1 kilometer south of the main trail to Aija (pl 1, loc 6) The deposit is developed by two adits at altitudes of 4,600 and 4,670 meters In 1947 the mine had been worked a year by Sr Icasa, of Ticapampa and was producing hand-sorted argentiferous galena concentrate

Silicic volcanic rocks of the area are cut by a steeply dipping vein which strikes N 65°–80° W and which has been traced for a distance of about 1 kilometer The principal minerals in the vein are quartz, pyrite, galena, sphalerite, chalcopyrite, and arsenopyrite

The upper adit is 25 meters long At the portal, the vein has a width of 4 meters, of which a zone 0 8 to 1 0 meter wide contains high-grade sulfides Between 14 and 20 meters from the portal, the high-grade sulfide zone is 2 meters wide, but narrows to 0 75 meter at the face of the working The sulfide zone is bordered by white vuggy quartz The lower adit is 200 meters to the west and at an altitude of 4,600 meters Here the vein strikes N 65° W and dips 80° NE The silicified zone is 5 meters wide at the portal and consists of gray quartz cut by vuggy white quartz Within the working, the vein is partly stoped to the surface, a distance of about 12 meters Along the stope, the vein is from 1 0 to 1 5 meters wide, and at the face it consists of nearly massive sphalerite and galena 1 0 meter wide Occurrence of arsenopyrite only in the lower working possibly suggests vertical zoning of the type seen in the Collaracra and Huancapetí deposits

Ore exposed in the two adits contains an estimated minimum of 20 percent combined lead and zinc The mine is the most promising new operation in the Cordillera Negra, but in 1947 continuity of ore both in length and at depth had not been established

### PROSPECTS AND MINES IN CERRO PUCAR

Between the Tarugo mine and the west edge of the area shown on the map of the Huancapetí mine (pl 4) are several prospects and abandoned mines, all in the ridge named Cerro Pucar. Included with these in the following descriptions is a prospect at the pass on the Recuay-Aija trail. None was worked in 1947.

At an altitude of 4,620 meters and about 1 kilometer west of the edge of the mapped area is a prospect in a quartz-pyrite zone in altered volcanic rock. The zone is 4 meters wide and strikes N. 60°–75° E. and dips 60°–70° SE. To the northwest a similar zone striking N. 30° W. is as much as 20 meters wide and is traceable for a distance of at least 150 meters. Both silicified zones seem to be barren of commercial sulfides.

A vein that seems to be worked out is just northwest of the edge of the area of the map of the Huancapetí mine, about 175 meters northwest of the large dump in the north-trending valley (pl. 4). The lowest working on it is at an altitude of 4,620 meters, from which point other adits are found uphill to the southwest. Minerals in the vein include quartz, pyrite, calcite, sphalerite, and galena. The two lower adits are inaccessible.

The vein is 50 centimeters wide at the portal of the lowest adit, where it is vertical and strikes N. 10° E. At the portal of the second adit, the vein is 30 centimeters wide, strikes N. 50° E. and dips 85° SE. The adit above is accessible and 20 meters long. Here the vein strikes N. 45° E., dips 75°–80° SE., and is from 50 to 60 centimeters wide. It is partly stoped to the surface. At the portal of the uppermost adit, the vein is a wide quartz zone. The working, 42 meters long, contains stoped sections as much as 1 meter wide.

Fifty meters to the north of this vein are three parallel veins, about 7 meters apart. Between them the volcanic rock is altered and silicified. Prospect pits show the veins to be from 10 to 20 centimeters wide, to strike N. 70° E., and to dip 80° NW. Quartz and pyrite in the veins are accompanied by small amounts of sphalerite, and, in one place, by considerable tetrahedrite.

Farther north on the west slope of the same valley, at an altitude of about 4,500 meters, is an adit 30 meters long on a vein striking N. 35° E. and dipping 60°–80° SE. From 0.5 to 1.0 meter of highly altered country rock lies between shear-plane walls. Much dark sphalerite is on the dump. Fifteen meters to the northeast, another adit shows a vein of similar mineral content. About 60 meters to the north, a prospect pit exposes copper-stained rhyodacite along steeply dipping joints, which strike N. 80° E.

In the pass on the Recuay-Aija trail are two workings on a vein striking N. 55° E. and dipping 75° SE. The vein is traceable for about 150 meters and is several meters wide. Only quartz and pyrite are on the dump of the lower adit, but some dark sphalerite may be seen at the upper adit, which is about 45 meters to the northeast. The altitude of the lower working is about 4,520 meters; the upper outcrops of the vein cross the pass.

### PROSPECTS ON THE NORTHWEST FLANK OF CERRO HUANCAPETÍ

Several veins on the northwest flank of Cerro Huancapetí have been opened by small prospects, which range in altitude from 4,480 to 4,670 meters (pl 1, loc 7) They may be reached by poor trails crossing the crest of the range south of the Huancapetí mine area

Two prospects, 90 meters apart, are about 1 kilometer N 39° W of the peak of Cerro Huancapetí Country rock in this area is a fine-grained and dense silicic volcanic rock The southern prospect is at an altitude of 4,520 meters, and consists of an adit and trench on a vein striking N 75°–80° E and dipping 75°–85° NW The adit, 27 meters long, shows the vein to be 20 centimeters wide and to contain quartz, pyrite, and arsenopyrite In a trench 22 meters to the east of the portal, the vein has the same width and contains quartz and pyrite A vein branching southeast at this point strikes N 80° W and dips 75°–80° NE The branch is as much as 70 centimeters wide and contains veinlets of quartz, pyrite, arsenopyrite, sphalerite, and galena The galena and sphalerite form no more than 5 percent of the vein content

Ninety meters N 20° W of the trench is a shaft following brecciated volcanic rock The structure strikes N 80° E and dips 80° SE The breccia zone is as much as 1 meter wide, and its interstices contain quartz and thin veinlets of pyrite, sphalerite, and galena.

Another prospect, at 4,600 meters altitude, is 750 meters N 32° W of the peak The country rock in this area is porphyritic lava, the feldspars of which are partly epidotized The flows strike N 35° W and dip 15°–20° NE The prospect consists of an adit 39 meters long driven on a vein striking N 85° W and dipping 75° S The adit and small stope on the vein are as much as 1 meter wide The vein seen in the workings is from 10 to 25 centimeters wide, and contains a band from 5 to 20 centimeters wide of solid sulfide minerals consisting of pyrite, sphalerite, and galena, sphalerite forms as much as 25 percent of the band Parallel but thinner veins in the adit contain only quartz and pyrite

The third prospect, about 350 meters S 37° W of the second and at the same altitude, consists of a flooded adit and a pit Light-greenish-gray rhyodacite breccia is cut by a vein striking N 40° E and dipping 85° NW It is as much as 50 centimeters wide and consists chiefly of quartz and pyrite, together with small amounts of sphalerite and galena Joints in the rhyodacite are stained with malachite

The fourth prospect, about 800 meters N 81° W of the peak, is at an altitude of 4,640 meters It consists of minor surface gouging on outcrops of a vertical vein striking N 85° E The vein, as much as 75 centimeters wide, consists largely of fine-grained dense-gray quartz and coarser grained white quartz Much pyrite and arsenopyrite are in the vein, together with a few blebs of sphalerite and galena and small amounts of argentite Thirty meters to the west the width of the vein decreases to a few centimeters Forty meters farther west is a vein striking N 80° W and dipping 85° N , along which are two pits, 5 meters apart The vein consists of 20 centimeters of vuggy quartz and pyrite, together with small amounts of silver sulfides An intersecting vein to the south strikes N 40°–50° E and dips 80° SE It has similar width and consists mainly of quartz

The fifth prospect, about 850 meters N 88° W of the peak and S 30° W of the fourth prospect, is at an altitude of 4,670 meters The vein in this area strikes N 85°–90° W and dips 80°–85° N , and is opened by several pits over a distance of 80 meters At its west end it transects a blocky porphyry that may be intrusive, and at its east end is in a fine-grained white volcanic breccia The vein, 20 to 45 centimeters wide, contains quartz, pyrite, sphalerite, galena, and silver sulfides In its wider part, sphalerite content is from 5 to 10 percent

On the south side of the confluence of the valley from the Huancapetí mine and a valley from Cerro Huancapetí, at an altitude of 4,500 meters, is an adit 18 meters long on a vein striking N 85° E and dipping 65°–70° N Along most of this working the vein consists of a thin shear zone containing gouge, but in a small stope at the face of the drift is a quartz-sulfide lens as much as 50 centimeters wide Pyrite is the most abundant sulfide, occurring with lesser amounts of sphalerite, galena, tetrahedrite, chalcopyrite, and arsenopyrite

About 500 meters north of this prospect is an adit and pit at an altitude of 4,580 meters In this area, subrounded boulders of medium- to coarse-grained porphyritic granite and angular to subangular blocks of bedded chert, tuff, and other volcanic rocks form an intrusive breccia in altered rhyodacite This mixture is cut by a shear zone from 3 to 6 meters wide, along which quartz and sulfides were deposited Sulfides are confined to a band less than 1 meter wide on the south side of the adit In a pit about 30 meters east of the adit portal, the quartz is 3 meters wide and contains a pocket 2 meters long and as much as 70 centimeters wide, consisting of 25 percent coarse-grained galena The vein is vertical and strikes N 80°–85° E

The surface in the vicinity of this prospect is covered by soil, but inasmuch as this is the largest showing of galena on the northwest flank of Cerro Huancapetí, further prospecting seems to be merited

### WILSON MINE AND PROSPECTS

Several small deposits occur on the northeast flank of Cerro Huancapetí, about 2 kilometers south of the Huancapetí mine (pl 1, loc 8) The area is 8 kilometers west-southwest of Ticapampa, and is reached by a trail branching westward from the Ticapampa-Huancapetí mine trail just above the upper end of the Collaracra vein The valley leading to the cirque on the northeast flank of Cerro Huancapetí locally is known as Quebrada Taptash but is shown as Quebrada Llacsha on the map of Kinzl (1939) In 1947 the only operating mine was the Wilson, owned by Sr César Masa Ríos Sr Masa stated that production in that year was at the rate of 10 tons of hand-sorted concentrate per month

The Wilson mine is on the north side of the east spur of Cerro Huancapetí, and its main adit is at an altitude of 4,740 meters Country rock consists of low-dipping lava flows and flow breccia of rhyolitic or dacitic composition These rocks are cut by a vein striking N 70°–75° W and dipping from 70° NE to 70° SW, which is traceable on the surface 300 meters west and 100 meters east of the main working It is opened by a 200-meter crosscut and a 75-meter drift on the main level and by stopes from this to the surface, 45 meters above The vein is from 1 to 2 meters wide and contains pyrite, galena, sphalerite, quartz, and gouge The best ore seen in 1947 consisted of a band of sulfides from 20 to 30 centimeters wide in gouge and quartz, forming a vein 1 2 meters wide The main stope was about 30 meters long On the surface, several prospect pits have been cut on both the east and west extensions of the vein These show the same general mineralization but sulfide content in these areas is low Most ore has been taken from above the main drift, but a small reserve should be present below this working

The largest of the abandoned workings is low on the south slope of the cirque, 0 5 kilometer northwest of the Wilson mine and about the same distance S 67° W of the outlet of the lake in the floor of the cirque Epidotized volcanic andesite is cut by a breccia zone as much as 2 meters wide which strikes N 45°–55° E and dips 65°–90° SE Minerals in the breccia zone are quartz, pyrite, stibnite, galena, and sphalerite The zone is traced by pits and stopes for a distance of 70 meters, the lowest of these workings is at an altitude of about 4,650 meters The largest stope, now mined out, is 40 meters long and about 15 meters high The tenor of ore in the dumps of the workings is low

Another prospect, 0 5 kilometer west of the lake outlet and 0 7 kilometer northwest of the Wilson mine, consists of three short drifts The lowest, at an altitude of 4,550 meters, is caved Evidently it followed a vein striking about N 55° W, and dump material indicates it contained quartz and pyrite as well as a small quantity of galena and sphalerite About 20 meters to the west, the second drift, 7 meters long, follows a vein striking N 30° E and dipping 70° NW The vein is 15 centimeters wide but is accompanied by thinner stringers It contains quartz, pyrite, galena and sphalerite Pockets of galena are as much as 10 centimeters wide, but in general the vein is nearly barren The third drift, on the same vein, is several meters to the west and a little lower. It is 5 meters long and exposes a lens 5 centimeters wide of pyrite and galena.

Several prospects are near the crest of the cirque, on the north spur of Cerro Huancapetí. The country rock here is andesite agglomerate. The northeastern prospect is about 1 kilometer west of the lake outlet and at an altitude of 4,680 meters. A pit is cut on a vein striking N. 20° E. and dipping 70° NW. The vein contains quartz and pyrite, is as much as 1 meter wide, and can be traced for 30 meters. To the southwest and at an altitude of 4,720 meters, a 12-meter drift exposes a vein as much as 1 meter wide consisting of quartz and pyrite as well as very small amounts of sphalerite. The vein is vertical and strikes N. 50° E. About 50 meters to the south, an 8-meter drift exposes a similar vertical vein striking N. 55° E. Between the two drifts is a trench on a vein that contains the same minerals and which strikes N. 55° E. and dips 75° NW.

Mineralized zones on the northeast flank of Cerro Huancapetí extend over a moderately large area but ore bodies seem to be few and small.

## TUCTU MINES AND PROSPECTS

The cirque on the southeast flank of Cerro Huancapetí contains several small deposits, of which only the Tuctu was in operation in 1947 (pl. 1, loc. 9). The south fork of the stream in Quebrada Llacsha leads into this area and heads in two lakes occupying part of the cirque floor. The branch of the Ticapampa-Huancapetí mine trail affords access. Sr. César Masa Ríos, owner of the Tuctu mine, stated that it was producing from 10 to 15 tons of hand-cobbed concentrate per month. According to him, the concentrate contained 40 percent lead, 14 percent zinc, and 3 percent copper, as well as 1,800 grams of silver and 6 grams of gold per ton.

Most of the area is underlain by volcanic rocks of the slightly folded upper group, which consist of porphyritic flow lava, pillow lava, and agglomerate, in the trachyte and andesite range of composition. In contrast, the northeast end of the south ridge is underlain by flow lava and agglomerate of the closely folded lower group. The dips of the younger rocks are as low as 15°, those of the older rocks in places are as much as 90°.

The Tuctu deposit is near the base of the south wall of the cirque, about 1 kilometer southeast of the outlet of the lower lake. The portal of the northeast working is at an altitude of 4,700 meters. The deposit is in a strong shear zone, which strikes N. 55° E. and which cuts andesite flows. It has been opened for a length of 85 meters by two drifts, the northeastern drift is 25 meters long and the southwestern, about 55 meters long, in addition, a surface cut 16 meters long lies above the northeastern drift (fig. 7). These workings show two veins, the northeastern dipping nearly vertically or

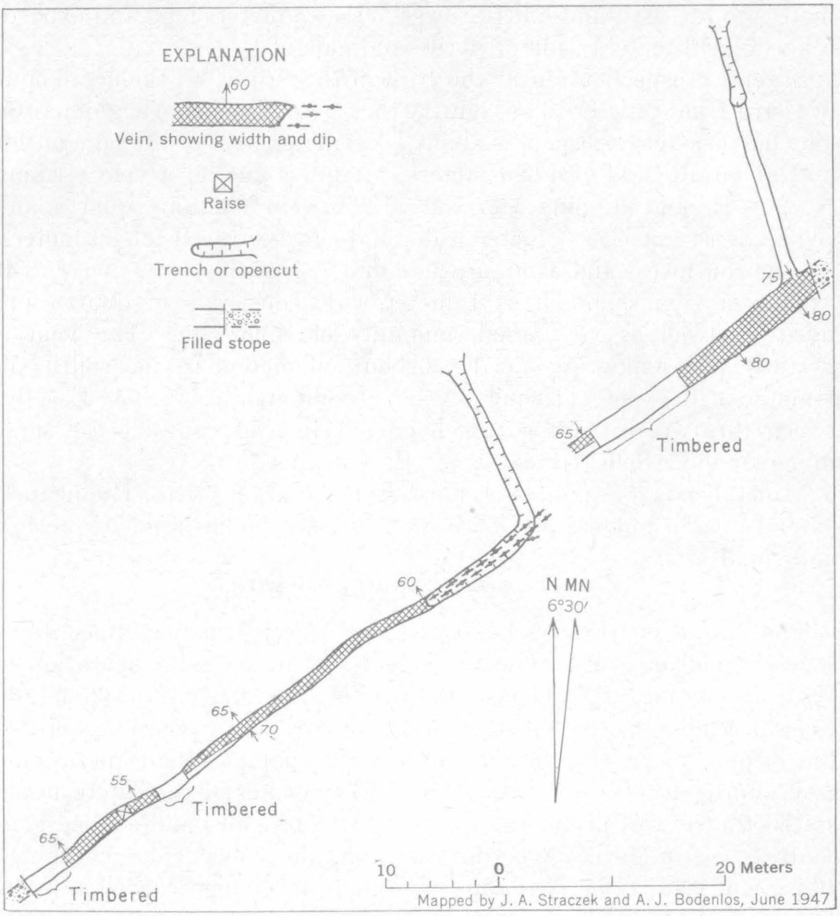



FIGURE 7.—Geologic map of drifts, Tuctu deposit.

steeply southeast, and the southwestern dipping from 55° to 70° NW. The two are nearly alined and it is possible that they may be parts of one vein, although a strong flexure in both strike and dip would be necessary to connect the two.

The andesite has been altered for a width of as much as 6 meters along the veins and movement along the veins has produced clay gouge as much as 1 meter thick. The veins are from 1.2 to 2.5 meters wide in the northeast drift and 0.7 to 1.0 meter wide in the southwest drift. The gouge zone contains veinlets and veins as well as lenses of pyrite, galena, sphalerite, and calcite; according to the statement of the owner some copper sulfides must be present but none were seen. Minable lenses contain from 50 to 75 percent sulfides and are as much as 50 centimeters wide.

Near the south rim of the cirque and several hundred meters southwest of the Tuctu mine is a vein which can be traced for 100 meters and which is opened by a drift 20 meters long It strikes N 30°–60° E and dips 75° NW. The vein contains sugary white quartz in widths from 0 5 to 2 0 meters, with veinlets of pyrite, galena and sphalerite No ore shoots worth mining were seen

About 700 meters northeast of the Tuctu mine is the first of a group of three prospects on veins in folded volcanic rocks; all are near the base of the southeast wall of the cirque and all are at about 4,500 meters altitude The southernmost, opened by Sr Masa in 1947, consists of a trench and drift totalling 10 meters in length It follows a vertical vein striking N. 75° E which consists of an altered zone as much as 60 centimeters wide and which contains as much as 12 centimeters of quartz, pyrite, galena, and sphalerite At the most, galena and sphalerite form 30 percent of the vein material Three hundred meters to the north, a vein in an altered zone as much as 1 5 meters wide contains as much as 30 centimeters of quartz and pyrite. The vein strikes N 70° W and dips 85° NE About 250 meters west of this barren structure is a vein striking east and dipping 80° S A 6-meter drift exposes only chloritized volcanic rock containing minor amounts of pyrite.

Two kilometers northeast of the Tuctu mine and on the north ridge of the cirque are other workings which follow 3 veins parallel to the bedding and 1 vein that crosses the bedding of steeply dipping andesite agglomerates The 7 openings in this area are from 4,425 to 4,560 meters in altitude

Where the southernmost vein is exposed on the crest, it strikes N. 75° E and dips about 75° SE. Evidently an ore shoot has been mined out by means of an open stope 15 meters long and 10 meters deep Only quartz and pyrite were seen on the dump The vein, also exposed in a crosscut of the adit at 4,515 meters altitude, is vertical, strikes N 85° E, and consists only of gouge 0.5 meter wide. About 10 meters to the north is the second vein, explored by a drift 25 meters long in the adit at 4,515 meters altitude. This vein is vertical, strikes N 75° W, and consists of quartz and pyrite as much as 40 centimeters wide The second vein also is opened by a pit at 4,530 meters altitude, where it contains only barren quartz On the dumps of a shaft at 4,500 meters altitude and an adit at 4,470 meters in altitude is material from the second vein which includes minor amounts of galena and sphalerite with the quartz and pyrite The third vein, several meters north of the second, is seen in the adit at 4,470 meters altitude and in a 6-meter drift at 4,450 meters altitude At the lower level it strikes N 70° W., dips 75° SW, and contains only a width of 20 centimeters of quartz at the face of the working Some galena and sphalerite were found on the dump The fourth vein, crosscutting the bedding of the folded volcanics is exposed in a small adit at 4,425 meters altitude. It strikes N. 60° W., dips 85° NE, is as much as 40 centimeters wide, and consists largely of quartz and pyrite together with small amounts of galena and sphalerite.

Although vein minerals are found in a zone about 2.5 kilometers long in the Tuctu area, all veins seem to be short and most contain only small amounts of sulfides.

### JESÚS MAGDALENA PROSPECT

The Jesús-Magdalena prospect is just east of the crest of the Cordillera Negra (pl. 1, loc. 10) in a cirque at the head of Quebrada Pachacruri. The area is 7 kilometers southwest of Ticapampa and 2 kilometers south of Tuctu, and is reached by way of the main south branch of the Ticapampa-Huancapetí mine trail. Workings are at an altitude of about 4,600 meters and are several hundred meters west of the largest lake in the floor of the cirque. Mineral concessions are held by the Anglo-French Ticapampa Silver Mining Co., but the property has not been developed for mining.

The country rock is light-gray to greenish-gray andesite and rhyolite, unconformably overlain by a conspicuous bed of red tuff cropping out higher in the walls of the cirque. In the floor of the cirque, the rock has been warped to form a syncline that dips 10° along its south limb and 20° along its north limb. A small fault crossing the floor of the basin strikes N. 20°–25° E. and dips southeast. The Jesús prospect is near its southwest end and the Magdalena prospect, about 300 meters distant, is near its northeast end.

At the Jesús prospect, the fault strikes N. 25° E. and dips 70°–75° SE. It contains a breccia zone 2 meters wide, in which are honey-colored sphalerite and small amounts of galena and chalcopyrite. Pyrite and a mixture of chert, quartz, and chlorite form the gangue. A pit and short adit expose an ore shoot 10 meters long and as much as 50 centimeters wide.

The northeast prospect, the Magdalena, is about 20 meters higher and consists of a trench 70 meters long. In this area the fault strikes N. 20° E. It dips 45°–50° SE. at the northeast end but is nearly vertical at the southwest end of the trench. The southwest end of the trench shows the fault to contain a quartz vein and the northeast end of the trench exposes sporadically distributed sulfide minerals with a maximum width of 30 centimeters along the fault. The volcanic wall rock is strongly chloritized and is sericitized to a lesser degree.

The Jesús-Magdalena vein is one of the longest in the southern part of the Huancapetí district, but the two exploratory prospects reveal comparatively little ore.

Another prospect is at the crest of the cirque, about 0.5 kilometer southeast of the Jesús working. A small vertical vein striking N. 75° E. contains no recoverable minerals in the small trench cut on the structure.

### LA RECUPERADA AND EL LUCERO PROSPECTS

Two prospects occur on the northwest side of a valley locally known as Quebrada Carhuascansia, which drains southwest into Quebrada Tauri-Mallqui, and which is opposite the eastward-draining Quebrada Pachacruri La Recuperada prospect is near the head of the valley, about 1 kilometer south of the Jesús prospect, and at an altitude of about 4,600 meters El Lucero is several hundred meters to the southwest of La Recuperada and is at an altitude of 4,450 meters (pl 1, loc 11) A trail branching southwest from the head of Quebrada Pachacruri affords access St Gustavo Pohl, owner of La Recuperada, had several men developing the deposit in 1947 El Lucero was being prospected by Sr Masa

At La Recuperada, a fault in andesite and rhyolite lava flows strikes N 20°–30° E It contains principally gouge and calcite, together with pyrite, galena, and sphalerite A channel sample 0 50 centimeters wide shows the ore to contain 62 grams of silver per ton, 8 7 percent lead, and 3 6 percent zinc (See analysis 1615, table 3)

In 1947, the new and lower adit was 3 meters long In the adit the vein strikes N 30° E and dips 75°–80° NW. The face showed vein material as much as 60 centimeters wide of which about 30 percent consisted of sulfides Thirty meters to the northeast and about 10 meters higher is the second and older adit, which follows the vein for 15 meters In this working the east wall of the vein dips 75°–85° SE , the west wall 50°–60° NW , with an average strike of N 20° E The largest sulfide lens on the vein was 2 meters long and as much as 25 centimeters thick

At El Lucero, light-green-gray fine-grained lava flows are cut by a strong shear zone striking N 35° E and dipping 65° SE At the pit the zone is 0 7 meter wide On the footwall of the zone is a band of high-grade sulfides 10–20 centimeters wide, consisting of pyrite, galena, sphalerite, and chalcopyrite At the time of our visit, El Lucero was being opened by a 4-meter pit

Neither prospect was large enough in 1947 to determine the potential size of the veins or their ore bodies Lenses worth mining exposed at that time were very small

### SAN ILDEFONSO, LA IMPROVISADA, AND MARISCAL MINES

A shear zone along the southeast side of Quebrada Carhuascansia contains mineral deposits opened by three groups of workings known as the San Ildefonso, La Improvisada, and Mariscal mines The top of the scarp at the edge of the valley and just east of the shear zone forms the crest of the Cordillera Negra in this area The deposits are 9 kilometers southwest of Ticapampa and are reached by the southwest spur trail from the Jesús prospect (pl 1, loc. 12). The San Ildefonso and La Improvisada areas are on concessions of Sr César

Masa Ríos, who had recovered several tons of hand-cobbed concentrates in 1947. Workings in the Mariscal area, owned by Sr. Eufugenio Huerta, were dormant in that year

Most of the area is underlain by volcanic rocks of the slightly folded upper group The sequence, between 250 and 300 meters thick in this area, is best exposed on the northeast side of Quebrada Tauri-Mallui, extending to the peak just above the deposits From the base in the quebrada to the peak, the sequence is andesite flow lava, thin-bedded calcareous tuff, columnar-jointed lava, thin-layered andesite, cliff-forming lava, red tuff beds, and cliff-forming lava The red tuff beds are the same as those exposed in the walls of the cirque above the Jesús-Magdalena prospects In the San Ildefonso-Mariscal area (fig 4), flows and beds strike from north to northwest and dip from 0° to 25° NE , in most places dips range from 10° to 15° NE

At the southwest end of the area, the slightly folded group of volcanic rocks have been stripped from an irregular area about 0 5 kilometer in diameter, in which a strongly folded and faulted sequence of sedimentary rocks is exposed Among these older rocks are units of tuff, limestone, and black slate, cherty and tuffaceous limestone, chert and novaculite, and quartz-pebble conglomerate

The shear zone, starting at its southwest end in the sedimentary rocks, obliquely ascends the northeast wall of the quebrada It nearly reaches the red tuff beds at its northeast end, thus crossing most of the sequence of volcanic rocks Its main unit is a strong shear plane with slightly undulating northeast strike and generally steep northwest dip, although in places it is vertical or dipping steeply southeast. In the San Ildefonso area, a second strong shear plane is about 40 meters to the southeast of the main shear plane To the southwest it diverges to a distance of about 150 meters and then parallels the main shear In La Improvisada area, a third strong shear plane lies 50 to 70 meters northwest of the main shear plane, it seems to be a branch of the main plane.

In addition, another set of steeply dipping fractures cross the strong shear planes obliquely at small angles Only the more conspicuous are on the geologic map (fig 4), which show that most are in La Improvisada area. Vertical displacement along the three main shear planes seems to be small and the oblique fractures probably are little more than joints along which only slight movement has taken place Gouge, breccia, and slickensides are common features along all the shear and fracture planes. A pebble dike occupying the northwest shear plane in La Improvisada area consists of rounded and subrounded pebbles of quartzite and highly altered material, which may have been of volcanic origin, and angular fragments of shale, all embedded in a matrix of soft gray clay. It can be traced for 30 meters and is from 0 5 to 1.0 meter wide.

Sulfide minerals in the deposits include galena, sphalerite, chalcopyrite, and pyrite Quartz is the most common constituent of the gangue, and ranges from sugary white to fine-grained gray and green material In places wide parts of the shear zone are strongly silicified Some rhodochrosite also is found in the San Ildefonso mine area Sr Masa stated that some ore from the La Improvisada mine contained as much as 1 percent bismuth, and that its relative abundance was in direct proportion to the silver content (oral communication) Wall rock near the three main shear planes is chloritized and to a lesser degree sericitized Altered rock contains introduced quartz, pyrite, and some carbonate

The Mariscal mine is near the northeast end of the shear zone and at an altitude of 4,660 meters The main shear plane strikes N 25° E and dips 75° SE , several meters to the east, a strong but local shear plane is concave to the main plane and dips 50° SE Between the two are breccia and subsidiary steeply dipping shear planes In the main working, a pit 15 meters long, the shear zone is silicified and openings are occupied by pyrite, galena, and honey-colored sphalerite At the south end of the pit, most of the material in the zone is quartz At the north face, a zone 1 6 meters wide contains about 15 percent of sulfides The tenor of the ore at this mine is low

The San Ildefonso workings, from 0 6 to 1 2 kilometer southwest of the Mariscal pit, are at altitudes from 4,620 to 4,710 meters and on the north and south slopes of a prominent shoulder crossed by the shear zone The main shear plane strikes N 25°–45° E and dips steeply In the northeast end of the area, the second strong shear plane is southeast and is as near as 40 meters to the main shear plane In this vicinity intensely silicified rock extends nearly across the block between the two main shear planes, and the block is cut by minor shear planes striking about N 50° E Several deposits occur along these minor shear planes or at their junctions or intersections with the main planes

The most northeasterly of the workings, on the north slope of the shoulder, is at an altitude of 4,670 meters An adit 35 meters long follows a vein along small shear plane that may intersect with the main shear plane At the portal, the vein strikes N 50° E and dips 75° NW Twenty meters within the working, the vein strikes N 40° E and dips 50°–60° NW Along this less steeply dipping segment, the vein has been stoped for a length of 15 meters and to about the same height; beyond the stope the drift is inaccessible The vein is from 0 5 to 1 0 meter wide and contains fine-grained gray-green quartz, pyrite, galena, sphalerite, and chalcopyrite, as well as some manganiferous carbonate The unstoped parts of the vein and material on the dump have only small percentages of sulfide minerals

About 50 meters S. 15° E. of the portal, a pit has been cut along the second strong shear plane, which in this area strikes N. 25°–30° E. and dips 85°–90° SE. Slickensides along the plane plunge 15° NE. and show that, relatively, the block on the east side of the plane moved south. At the northeast end of the pit, a branch shear plane strikes N. 45° E. and dips 35°–40° SE. In the southeast face of the pit, sulfide minerals including pyrite, galena, sphalerite, and chalcopyrite, are sparse. Volcanic rock extending westward toward the main shear is strongly silicified. Material on the dump contained less than 25 percent total sulfides.

Opposite this pit and along the main shear zone are several small trenches in which sulfide minerals are sparse or absent. About 100 meters to the southwest, at an altitude of 4,710 meters, a pit 10 meters long and 5 meters deep follows the east side of the main shear zone which at this point is 8 meters wide. At the pit, a branch shear plane striking N. 60° E. and dipping 60°–65° SE. intersects the main zone. Sulfide content in the pit is small.

On the south side of the shoulder three workings explore the main shear zone. The uppermost, at about 4,700 meters in altitude, consists of a pit and a caved adit. The zone strikes N. 45° E. and dips 75° NW. Although it is 3.5 meters wide, it is only sparsely mineralized. A second working about 100 meters to the southwest reveals even less sulfide. The third working is near the base of the hill and at an altitude of 4,620 meters. In a pit with an adit at its northeast end shows the west wall is along a branching shear plane striking N. 50° E. and dipping 85° NW. The east wall is along the main shear plane which strikes N. 30° E. and dips 80°–85° NW. The two merge at the portal, where the vein is 0.7 meter wide. Little can be seen in the workings, but about 50 kilograms of fair-grade ore were on the dump at the time of the examination. The ore contained galena, sphalerite, chalcopyrite, and pyrite.

La Improvisada mine consists of five workings near the southwest end of the shear zone, all on the third strong, or northwest shear plane, or on smaller branching shear planes. They are near the crest of a sharp ridge crossed by the shear planes, and range from 4,690 to 4,720 meters in altitude. The veins contain the same minerals as at San Ildefonso. In addition calcite and bismuth were found in some ore. The deposits were not being worked in 1947.

The lowest working on the north slope is a crosscut at 4,690 meters altitude. It trends S. 55° W., crossing a 30-meter wide area of sheared volcanic rock. Sulfide minerals are sparse in this area. About 50 meters to the southwest and at an altitude of 4,705 meters, an adit 87 meters long explores a cross-fissure striking N. 80°–90° E. and dipping 60°–80° S. A 10- to 15-centimeter wide vein of calcite extends along most of the working. This becomes as much as 50 centimeters wide about 75 meters from the portal and the last 12 meters of the drift have been stoped upward One ore shoot is 5 meters long and contains sphalerite, galena, and calcite

The main working on the south slope is an adit at an altitude of 4,705 meters It follows the northwest shear plane, which is from 2 to 3 meters wide in this area, and which in part is occupied by the pebble dike The shear plane strikes N 45° E and dips 85°–90° SE Sulfides are said to have been found in stringers several centimeters thick, which occur where intersection fissures meet the shear plane

Although the present mine workings have uncovered only small amounts of sulfides in this shear zone, the zone is one of the largest in the southern part of the Cordillera Negra As may be seen on fig 4, most components of the shear zone as yet have not been prospected and those workings that have been opened are shallow More detailed geologic study, therefore, may indicate other parts of the area worthy of exploration As the result of this brief reconnaissance examination, we conclude that sulfide minerals are most abundant at intersections or junctions of minor shear planes with the major planes, especially where major planes are within a short distance of each other and the interposed block of volcanic rock has been silicified This is best shown at the northeast end of San Ildefonso

Another clue to sites of mineral concentration is that of direction of relative movement in the zone Slickensides on the face of the plane in the pit along the southeast strong shear plane at the San Ildefonso mine showed the block on the east side of the plane moved south If this is true for the entire area, the subsidiary cross fissures striking more easterly than the main shear planes would represent the planes opened by tension The above descriptions show that several of these do contain ore shoots

#### SEÑOR DE SOLEDAD AND FERNANDITA PROSPECTS

The Señor de Soledad and Fernandita prospects, the most southerly we visited in the Cordillera Negra, are 11 kilometers northeast of the village of Cotaparaco They are about halfway up the ridge known as Cerros Murpa, on the southeast side of Quebrada Parín They lie about 1 kilometer southeast of the Santa Valley-Cotaparaco trail (pl 1, loc 13) In 1947 the deposits were being opened by Sr Cesar Masa Ríos

The Señor de Soledad prospect, at an altitude of 4,500 meters, consists of a pit 5 meters long cut on a vein striking N 65° W and dipping 65°–70° NE The vein is in light-gray propylitized andesite, and is from 1 2 to 1 5 meters wide Sulfide minerals occur on the hanging wall, forming a vein as much as 65 centimeters wide and that consists of fissure-filling and wall rock replaced to a minor extent Minerals in the deposit are galena, sphalerite, chalcopyrite, pyrite, and pink and white carbonate; quartz is present in small amounts A channel sample of the sulfide-bearing part of the vein assayed 284 grams silver per ton, 16 percent lead, 12 3 percent zinc, and 0 9 percent copper (see analysis 1616, table 3) At the time of our examination the vein was not sufficiently explored along its length to determine its potentialities

The Fernandita prospect, at an altitude of 4,550 meters, is about 1 kilometer northeast of Señor de Soledad It consists of a drift 15 meters long, opened on a vein striking N 75° E and dipping 85° NW Galena, sphalerite, and pyrite are the sulfide minerals The vein is high grade but is only 5–15 centimeters wide A subsidiary shear plane, striking N 85° E and dipping 45° N at the portal, intersects the main wall about 8 meters from the portal At this point, a pocket of high-grade sulfides is found, measuring 30 to 40 centimeters wide and 2 meters long According to Sr Masa, hand-sorted galena concentrate contains as much as 435 grams of silver per ton As is true for the Señor de Soledad deposit, the Fernandita deposit contains good ore but is not as yet sufficiently explored in length to estimate its reserves

### MINE ON CERRO PILLAC

A mine, the name of which is not known, lies on the southeast flank of Cerro Pillac above a south-draining tributary valley of Quebrada Huamanpinta (pl 1, loc 14) The area, although only 11 kilometers south of Aija, is relatively inaccessible It may be reached by a west branch of the circuitous trail between Aija and Cotaparaco The altitude of the workings is about 4,500 meters

Flat-lying andesite lava flows are the country rock Near one vein is a pebble dike containing subangular pyritized quartz pebbles Four veins in a zone 15 meters wide radiate from a common point about 15 meters in front of the portal of the workings All contain only quartz and pyrite, to widths of as much as 90 centimeters but generally are considerably narrower The largest vein, the northern, strikes N 85° W and dips 80°–90° S The second largest, the southern, is vertical and strikes N 60° W Possibly they were mined for silver

### SAN VICENTE MINE

An abandoned mine at an altitude of 4,750 meters is on the southwest flank of Cerro San Vicente It is several kilometers northwest of Laguna Pancán, the lake at the head of Quebrada Yanco (pl 1, loc 15) A branch trail leading down the quebrada connects with the Aija-Cotaparaco trail The nearest settlement is Succha, about 8 kilometers to the northwest

The country rock consists of lava flows Three adits, now inaccessible, opened a vein striking N 25° W, and dipping 85° NE Quartz-pyrite rock was seen at the portals and on the dumps One piece of float contained pyrite, stibnite, and calcite No lead or zinc minerals were seen in the vicinity.

### CERRO PANICOCHA PROSPECT

Cerro Panicocha is a local name for one of the peaks of the Cerro San Vicente–Cerro Condorpunta ridge, northeast of Quebrada Yanco (pl 1, loc 16) In this prominence, not definitely located on the map, is a small vein that was prospected in 1947 by Sr Alejandro Alvarado, by means of a pit at an altitude of about 4,600 meters

The vein is in low-dipping andesite lava flows It strikes N 5°–15° E , dips 65° NW , and is from 25 to 30 centimeters wide, containing mostly quartz and galena An assay of a sample collected from the sulfide-bearing band, 10 centimeters in width, shows the ore to contain 283 grams of silver per ton, 22 percent lead, 0 3 percent copper, and 5 percent zinc (analysis 1617, table 3) At another and older pit in a valley 100 meters to the south, copper carbonates occur with the quartz and galena.

Additional prospecting would be necessary to determine if ore shoots occur in this vein.

### CERRO MULLUOCTU PROSPECTS

In the Cerro San Vicente–Cerro Condorpunta ridge, another peak, locally known as Cerro Mulluoctu, is several kilometers northwest of Cerro Panicocha (pl 1, loc 17). The area around the peak lies near the Aija-Cotaparaco trail Prospects near the crest and on both flanks of the ridge are at altitudes from 4,440 to 4,620 meters The country rock consists of rhyolite or dacite lava flows, which at one point on the ridge strike northwest and dip 35° NE

The veins are on the northwest side of Cerro Mulluoctu The southwestern vein consists of a breccia and alteration zone as much as 5 meters wide In its hanging wall, which strikes N 10°–25° W and dips 70°–85° SW , copper carbonates occur over a width of 1 meter. The upper prospect, at an altitude of 4,560 meters, is an adit 10 meters long, and the lower prospect, at an altitude of 4,540 meters, is an adit 5 meters long.

The northeastern vein is explored by an adit which is 150 meters N 28° E of the lower adit on the breccia zone The working, at an altitude of 4,440 meters, is 4 meters long The southwest wall of the vein is vertical and strikes N 30°–35° W In the face of the working it contains a lens of sulfides which include galena, sphalerite, and chalcopyrite Its maximum width is 20 centimeters, but it pinches out upward. The northeast wall of the vein strikes N. 25° W and dips 70° SW Quartz, pyrite, and galena on this wall occur in pockets as much as 10 centimeters wide The overall sulfide content in this prospect is very low.

At an altitude of 4,620 meters and on the southeast flank of the ridge, a pit and a now inaccessible adit several meters below were cut on a silicified fault striking N 35°–40° W. and dipping 80°–90° SW

Fractures in massive quartz and vugs in crystalline quartz contain small amounts of pyrite and chalcopyrite The silicified zone is as much as 1 5 meters wide and can be traced in barren outcrops for a distance of 50 meters to the southeast About 30 meters northwest of the pit, a second quartz ledge similarly low in sulfide content strikes N 60° W and dips 40° SW It is traceable about 100 meters to the southeast and is as much as 5 meters wide

There is no indication of material worth mining in the deposits of this area

### SANTA ELENA MINE

The Santa Elena mine, at Huinac, is 24 kilometers southwest of Huarás (fig. 1, loc 18) It is on the south flank of Cerros de Carpapampa, part of a high lateral ridge between the Río Casma and Río Huarmey drainage systems The north side of the ridge is drained by Río Cajamarquilla and the south side by Río Llactur, the mine area is in the headwaters of the latter The mine may be reached via the Huarás-Casma road and a company road extending south from the pass at Punta Callán, distances are 31 kilometers from Huarás to Punta Callán and 29 kilometers from that point to the mine camp A trail connects the mine to Aija, 12 kilometers to the south-southeast

According to the company survey datum, the divide in the mine area is as high as 4,460 meters in altitude The lowest mine adit is at an altitude of 4,089 meters, and the mill and camp are several hundred meters lower Slopes near the divide are comparatively gentle, but steepen southward where valleys are more deeply incised Overburden varies in thickness, concealing most bed rock on the lower slopes of valleys The area is glaciated near the divide, resulting in damming of drainage and formation of several small lakes (Steinmann, 1930, fig 264, p 269) Water for mill and camp use is taken from a lake northeast of the main mine workings (pl 5), and from the main stream, which forms one of the principal sources of the Río Llactur, and is carried to the various installations by pipes and canals Timber, cannot be obtained in this vicinity and must be trucked from Huarás

In 1868, Raimondi (1874, p 300) found the mine inoperative, owing to low silver content of ore At that time only two veins were known, one striking east-northeast, the other west-northwest A working at their intersection had furnished good ore but was flooded (1873, p 421) Pflucker (1906, p 20–21) stated the Huinac workings were not in shape for mining, but that an English concern was developing the property and building a plant to handle 10 tons of ore per day. Velarde (1908, p 68) reported the principal vein was as much as 1 8 meters wide and that ore averaged 8 to 12 percent copper and 1 to 2 kilograms silver per ton

In the early 1940's, the Cáceres family of Huarás sold the property to the Cía Minera Santa Elena, S A In 1943, this company built a flotation plant and developed the mine for mechanized mining on a large scale Ore was mined at a rate of about 25,000 tons a year from 1944 to the end of 1948, at which time the better grade copper-silver ore had been mined out Copper content ranged from 2 to 6 percent during this period

Sedimentary rocks in the vicinity of the mine are largely shale but include beds of siltstone, calcareous shale, limestone, sandstone, chert, and conglomerate Coal beds crop out in the slopes east of the mine camp The identification of a fossil of Hauterivian age by Srta. Rivera indicates that at least part of the section is equivalent to those beds assigned to the middle unit of the Barremian sequence by Steinmann The presence of coal beds suggests that some strata of lower Neocomian age occur in the area

In the northeast corner of the mapped area, sandstone, grit, and conglomerate, which in part are cemented by lime, seem to lie unconformably over the rocks of Cretaceous age (pl. 5) These in turn are overlain, either conformably or with only slight unconformity, by a sequence of flat-lying volcanic rocks, largely rhyolite but also including some dense green andesite The volcanic rocks extend along the ridge at the north and northwest margins of the mapped area

The main intrusion is a complex mass of porphyritic andesite that extends across the entire mineralized area and consists of interconnected plugs, sills, and dikes It is not only irregular in horizontal dimensions, but also in its vertical extent, as may be seen on maps of mine workings (pls 11–13 and fig 8) It intrudes both the sedimentary rocks of Cretaceous age and the Tertiary volcanic sequence. In turn the andesite and the sedimentary rocks are intruded by masses of explosion breccia consisting of material grading from material entirely of volcanic origin through mixtures to material entirely of sedimentary Breccia blocks range from 1 meter to several centimeters The largest areas underlain by masses of explosion breccias are in the vicinity of the principal veins Most small dikes are related to the porphyry intrusive, but some may be the product of still another phase of igneous activity

Folds and faults in the sedimentary rocks trend northwestward to northward. In the southwest part of the mapped area, the dominant structure seems to be anticlinal In the east and northeast parts of the mapped area, most of the beds are vertical The main intrusive elements, both the main intrusion and the mass of explosion breccia tend to be elongated parallel to the axes of the folds in the sedimentary rocks, so that is probably that they followed bedding planes and strike faults. Locally, shale appears to have been squeezed into attitudes parallel to some dikes, and along the margins of explosion vents, both dike and shale have been shattered (p. 35).

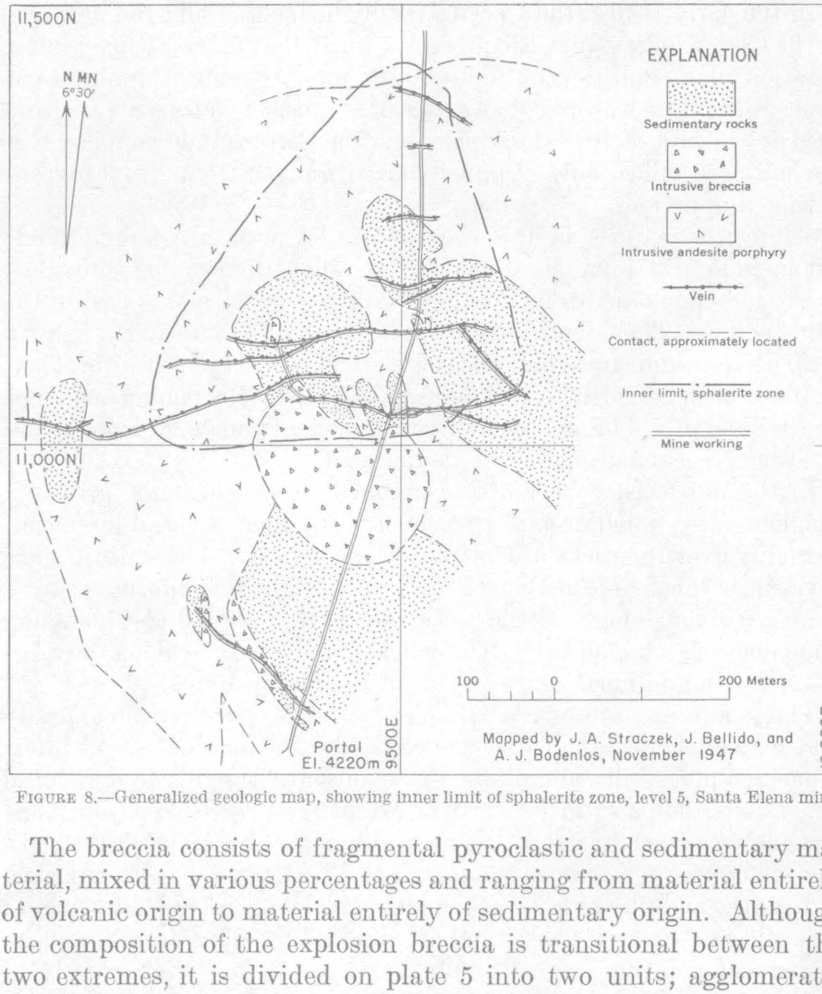



FIGURE 8.—Generalized geologic map, showing inner limit of sphalerite zone, level 5, Santa Elena mine.

The breccia consists of fragmental pyroclastic and sedimentary material, mixed in various percentages and ranging from material entirely of volcanic origin to material entirely of sedimentary origin. Although the composition of the explosion breccia is transitional between the two extremes, it is divided on plate 5 into two units; agglomerate, where igneous material exceeds 50 percent, and breccia, where sedimentary material exceeds 50 percent.

Southeast of the mapped area, along the road between the main camp and the maıgin of the main intrusive, several fault zones cut the shaly sediments. The rocks are sheared and brecciated in zones as much as several meters wide. Such material differs from explosive breccia in that it is more finely broken and does not contain igneous fragments. Elsewhere, some of the shale has developed a rudimentary slaty cleavage and a few siltstone beds show pencil cleavage.

All rocks in the mineralized area have been altered. Sedimentary rocks have been pyritized and bleached, and igneous and volcanic rocks propylitized, sericitized, pyritized, and kaolinized to some degree. The zone of most intensive alteration is around the larger veins, yet it extends hundreds of meters south. All intrusive masses of explosion breccia are altered, so the wider area probably was altered by passage of gases accompanying the explosive phase of igneous activity

Minerals in the veins of the Santa Elena mine are pyrite, enargite, tetrahedrite, sphalerite, galena, quartz, calcite, and manganiferous carbonates Stibnite was seen at only one locality, and a pink mineral thought to be alunite was visible at several places in the lower levels Iron oxides and copper stain are common, especially in the upper parts of the veins Silver is associated with the copper minerals and galena Raimondi (1873, pp 421–422) also listed chalcopyrite and bornite as present in these veins

In the central part of the main vein system, ore consists chiefly of pyrite and copper minerals in altered wall rock and gouge, with which occurs a small amount of quartz Enargite is more common near the surface, tetrahedrite predominates at depth Peripheral to this copper zone, sphalerite, galena, and some calcite and manganiferous carbonate appear On level 5, at an altitude of 4,220 meters, the sphalerite-free copper zone is about 450 meters in diameter (fig 8 and pl 11) On level 4, at 4,260 meters altitude, the southern of the main veins contains sphalerite During the period in which the Cía Minera Santa Elena operated the mine, the tenor or ore was 6 percent copper during the first two years and from 2 to 3 percent toward the end of operations In 1946, ore averaged 2 6 percent copper and contained 229 grams silver per ton

The veins occupy weak fault zones consisting of short curving and branching shear planes, carrying gouge and bordered by altered wall rock Displacement, seen where veins cross geologic contacts, generally is less than 2 meters horizontally

Ore bodies mined were irregular in shape Veins and ore shoots were as much as 2 meters wide and as much as 150 meters long on any one level Between levels 4 and 5, the Elizabeth vein had ore at some point or another for a length of 300 meters The maximum vertical extent of ore on any one vein was between 250 and 300 meters, uncertainty as to the exact figure is due to lack of knowledge of the uppermost and lowermost levels

The principal vein system consists of four main veins, which occupy an area only 600 meters long and 130 meters wide The four veins branch and link to each other in relationships which change from level to level The three largest veins strike east to east-northeast, the fourth strikes northwest. They dip south about 60° to 80°

Outcrops of veins are short and inconspicuous, and the system is best exposed on level 5, the most thoroughly explored in the mine (pls 11–13) The south vein of the four main veins is the Huinac, the north, the Elizabeth The Enlace Elizabeth vein branches from Elizabeth and cuts obliquely across the east end of Huinac The east end of the fourth, the Crucero Huinac vein, lies between Elizabeth

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and Huinac, but its west end extends several hundred meters beyond both.

As may be seen in pl. 11, the Huinac vein is followed by drifts for a distance of 260 meters. Its west end, having comparatively irregular strikes, contains little ore but has been stoped above for a length of 75 meters. Its east end splits into two veins, the north and south branches. The main vein and the south branch have been stoped for a length of 125 meters. The north branch has been stoped for possibly a length of 35 meters. On level 6, at an altitude of 4,185 meters, the Huinac vein has been followed by workings for only 150 meters (pl. 12). West of the crosscut the vein is weak and carries little or no ore; the eastern 60 meters were stoped to level 5. The vein was not explored on level 8 (pl. 13), a working which was being developed during our examination in 1947.

On level 4, at an altitude of 4,260 meters, the west end of the Huinac vein swings to northwest strike and links to the Crucero Huinac; the east end of its north branch is terminated by the Enlace Elizabeth. The length from the Cruzero Huinac vein to the Enlace Elizabeth is 290 meters, from its west end to the end of the drift on the south branch is a distance of 325 meters. On level 3, at 4,295 meters altitude, several splits occur at the west end and relationships with the Crucero Huinac vein are comparable to those on level 4. Total length of the vein on this level is 280 meters. On level 2, at an altitude of 4,325 meters, the vein was followed only 190 meters and junctions with flanking veins were not reached.

The Elizabeth vein is followed by the drift on level 5 for a distance of 325 meters, and is ore-bearing for 300 meters of this length. A weak north branch in the west part of the vein is barren. The Elizabeth vein evidently did not contain ore east of its linkage with the Enlace Elizabeth. On level 6, it was opened for a comparable length but ore occurred in shorter shoots and for only a length of 260 meters. On level 8 the vein was very weak in the 90 meters of drift which had been completed in 1947.

On level 4, the east end of the Elizabeth vein was followed by a drift for 185 meters. The south branch at the west end was explored by a drift 110 meters long, with 30 meters between it and the east drift. On level 3, the vein was followed only 240 meters.

The Enlace Elizabeth vein contained ore only as far southeast as the Huinac vein on level 5. Only its northwest 60 meters carried ore on level 6. On level 4 its drift is 135 meters long and ore extended several meters beyond the junction with the Huinac. The drift on level 3 is 190 meters long, extending 100 meters southeast of the junction with the Huinac vein. The vein also has been mined from adits at 4,353, 4,365, and 4,378 meters altitude (pl. 5). Although no sphalerite occurs on the vein at level 5, this mineral becomes increasingly abundant toward the surface.

The Crucero Huinac vein is opened by a drift 310 meters long on level 5 It is ore-bearing for about 180 meters of this length Its west end curves northwest and is terminated by a vein striking east, the Paralela, a structure that is only weakly mineralized Near the east end of the Crucero Huinac, a crosscut to the north shows a weak northeast branch vein On level 6, the Crucero Huinac is opened for a length of 250 meters and was ore-bearing for a length of 165 meters either above or below the drift The northeast branch is followed by the drift at this level, and the Paralela vein is opened for a length of 55 meters On level 8, the Crucero Huinac was opened for a length of 130 meters, in which distance it contained no ore

On level 4, the Crucero Huinac drift is 240 meters long The northeast branch is the stronger vein on this level On level 3 the Crucero Huinac vein is traceable 170 meters, and the northeast branch links to the Elizabeth vein

Other veins explored on level 5 are weak and carry little ore Forty-five meters from the portal, the Julia vein is followed by a drift for a length of 175 meters It has a sinuous northwest strike and dips steeply southwest and northeast Four veins occur north of the main group These strike west to northwest and dip steeply south An ore shoot less than 15 meters long was found in the northern vein, and raises on the southern vein indicate that it had a shoot possibly 50 meters long

The surface map shows additional small veins in the area, of which the largest are those of the Monte Cristo group, 250 meters northeast of the outcrops of the Enlace Elizabeth The veins strike northwest and have been opened by four adits between the altitudes of 4,280 and 4,315 meters Other veins have been trenched or explored by adits in the valley east and southeast of the miners' main camp Near the west margin of the mapped area and 250 meters north-northwest of the engineering office, two adits explore a vein that may be on the extension of the Julia

The Santa Elena veins are probably the smallest veins in the Cordillera Negra that have furnished a moderately large tonnage of ore In most of the other larger deposits, veins are from two to four times the length of those in this mine The surprisingly small vertical extent of ore, at the most 300 meters, is considerably less than in deposits elsewhere in the Cordillera This feature in part may be due to the comparatively weak vein system

The mine is opened by eight levels, the altitudes of their adits are as follows

| *Level* | *Altitude in meters* | *Level* | *Altitude in meters* |
|---|---|---|---|
| 1 | 4,352 and 4,359 | 5 | 4,220 |
| 2 | 4,326 | 6 | 4,183 |
| 3 | 4,294 | 7 | No adit |
| 4 | 4,258 | 8 | 4,089 |

The upper levels were developed and the ore mined out by previous companies The Cía Santa Elena had the mine well equipped with compressed air, jackhammers, electric trams, and drainage and ventilating systems The ground was systematically mined by cut-and-fill stoping A hydroelectric turbine at Pariac, 5 kilometers south of Huarás, provided electricity, as much as 240 horsepower, which was carried by a line directly across the Cordillera to the mine The flotation plant was about 1 kilometer southeast of level 8, it had a capacity of 160 tons a day Ore was moved from the mine to the plant by aerial tram, and concentrates were trucked to Huarás before shipment to ports

The accompanying tabulation of incomplete production figures is in part from Hohagen (1944)

TABLE 5 —*Production of ores and base metals, in tons, and precious metals, in grams, Santa Elena mine, 1944–48 inclusive*

| Year | Ore | Copper | | Lead—Metal | Silver | Gold |
|---|---|---|---|---|---|---|
| | | Concentrates | Metal | | | |
| 1944 | | | | | 67,669 | 1,208 |
| 1945 | | | | | 7,461 | 8,835 |
| 1946 | 27,620 | 2,303 | 645 | | 50,919 | 973 |
| 1947 | | | 122 | | 5,168 | |
| 1948 | | 976 | | 276 | 4,115 | |

## MERCEDES PROSPECTS

Two small deposits near the Santa Valley road are about 10 kilometers south of Huarás and 1 kilometer north of Quebrada Jauna The area locally is known as Colquipampa and is just south of the hamlet of Patchuyaco (pl 1, loc 19) Mercedes, the larger deposit, is several hundred meters east and 30 meters higher than the road, near the base of Cerro Llacsha and at an altitude of 3,300 meters Carmen, the smaller deposit, is west of the road and just above the Río Santa They are owned by Sr Jorge Cáceres, who opened the Mercedes deposit in 1948 At that time 10 tons of ore were produced in two months, with an average lead content of 12 percent and a silver content of 420 grams per ton

The country rock is rhyodacite, a part of the closely folded volcanic group At the edge of the Río Santa, one bed contains semirounded quartz pebbles

The Mercedes deposit is opened by an adit 22 meters long and by an incline cut in the floor of the main drift The vein follows a fracture zone consisting of weak shear planes, the largest of which strikes N 80° W and dips 75° SW, joints striking northeast, and irregular fractures Minerals occur sporadically in the various openings and consist of galena, sphalerite, pyrite, gypsum, and some calcite The bulk of the vein is strongly altered and pyritized rhyodacite, largely a mixture of sericite and quartz but also containing some epidote and chlorite A soft claylike material, spectrographically analyzed by J M Axelrod of the Geological Survey, proved to be fine-grained calcite and mica

The Carmen deposit is southwest of Mercedes, and is explored by a small cut just 4 meters above the Río Santa The mineralized zone strikes N 50° W and dips 20° NE , possibly parallel to the bedding of the volcanic rocks The zone is altered rhyodacite, 2 meters wide The upper half is high in pyrite and low in galena The lower half contains streaks and scattered blebs of coarse-grained galena, its lead content possibly is from 1 to 2 percent.

The sulfide content in both deposits is low and reserves seem to be small

### SANTA CRUZ DEPOSITS

A group of small veins is near the settlement of Santa Cruz, 6 kilometers south of Huarás and 1 kilometer from the power plant at Pariac (pl 1, loc 20). They are west of the river and a small cableway affords access from the Santa Valley road Adits on the veins are from 3,065 to 3,100 meters in altitude The owner, Sr. Jorge Cáceres, had several men working on one vein in 1948, but production was small

Volcanic rock in the area is so altered that its original composition is unknown It is traversed by several veins that in general strike northeast and dip southeast Most are 1 meter or less in width, but a breccia zone as much as 15 meters wide also is partly mineralized The structures carry sphalerite, galena, pyrite, chalcopyrite, calcite, quartz, gypsum, celestite, and gouge

Of the 7 adits in the area, only 5 were open in 1948, as shown on fig 9 Working 1, at an altitude of 3,070 meters, is a drift along a vein striking N 50° E and dipping 70° SE and then a crosscut traversing the breccia zone 15 meters wide The vein is only from 10 to 30 centimeters wide, containing mostly gypsum and celestite but also carrying small pockets of sphalerite, galena, and calcite The wall rock contains pyrite crystals as much as 4 millimeters in diameter The breccia zone is cemented by gypsum and at its south end contains a few blebs of galena The end of the working is caved

The portal of working 2 is 45 meters to the south and at an altitude of 3,090 meters The adit, 58 meters long, follows a vein striking N 70° E and dipping 45°–75° SE Sphalerite, galena, calcite, gypsum, and gouge occur in the vein and in subsidiary fissures The vein generally is from 15 to 20 centimeters wide but for several meters is as much as 1 meter wide The maximum sulfide content is in a lens 20 centimeters thick that contains about 50 percent sphalerite

Workings 3 and 4, at altitudes of 3,100 and 3,090 meters, are 85 meters to the northwest of working 2. In working 3, a fracture zone

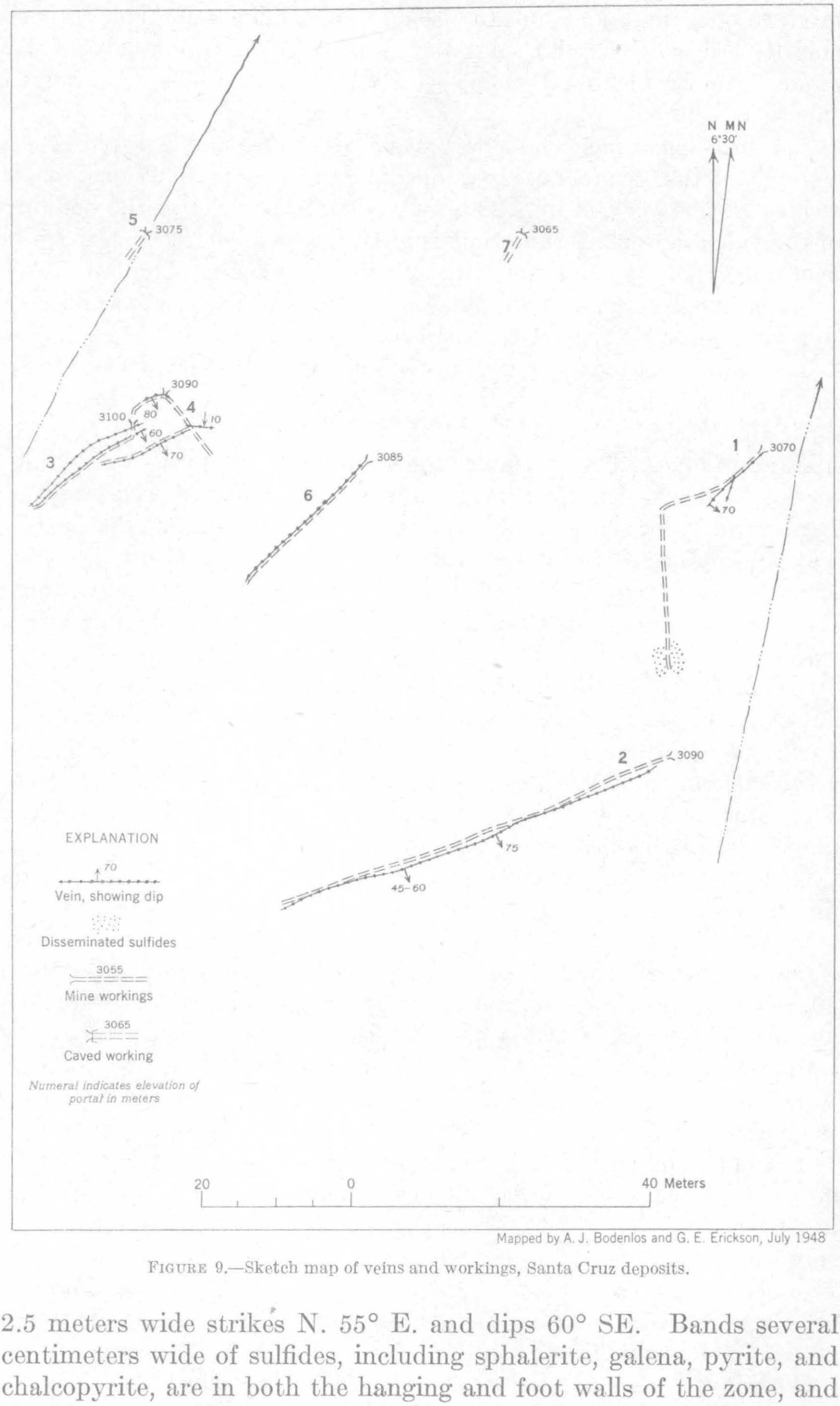


FIGURE 9.—Sketch map of veins and workings, Santa Cruz deposits.

2.5 meters wide strikes N. 55° E. and dips 60° SE. Bands several centimeters wide of sulfides, including sphalerite, galena, pyrite, and chalcopyrite, are in both the hanging and foot walls of the zone, and and calcite, quartz, and gypsum also are present. In working 4, the same vein is explored but contains even less sulfide On this level it strikes N 70° E and dips 65°–70° SE Its northeast end is terminated by a barren fissure striking east and dipping 10° S , and which is followed 5 meters downdip by an exploratory incline Another barren vein several meters to the northwest strikes N 70° E and dips 80° SE

About 30 meters east of working 3 is working 6, a 23-meter drift at an altitude of 3,085 meters The vein strikes N 45° E It averages 20 centimeters in width, consists largely of gouge, gypsum, and calcite, and contains a few veinlets of sulfides

Workings 5 and 7, at altitudes of 3,075 and 3,065 meters, were inaccessible

Of the group, the vein in working 2, which was being mined on a small scale in 1948, is the only one to contain ore but even there ore shoots are small

## THE CENTRAL AREA

Although the central area contains more mineralized localities than the southern and has about the same number of large deposits, its production seems to have been relatively small The Colquipocro deposit, from which principally silver is recovered, is about the only one to have been mined with any degree of continuity since 1860 The Jecanca deposit was actively mined in the early part of the century and again for a brief period in 1949 and 1950 The Uchco and Buena Cashma veins seem to have been mined for a relatively short period during the 1900's

In 1947 and 1948, in addition to Colquipocro, the following deposits were being mined or prospected El Carmen, by Sr Jorge Zimic, Cerro Maco, by Sr Arturo Dias, Fray Martín, by Sr Teodoro Presa, and Atahualpa, by Sr Octavio Gastelmendi

### JECANCA MINE

The Jecanca mine is 7 kilometers northwest of Huarás, on the east flank of a peak variously named Cerro Ruqui on the Huarás quadrangle map, (pl 1, loc 21), Cerro Huacramarca on the map of Kinzl, and Cerro Huaytapallanca in early reports The largest stream in the locality flows in Quebrada Collana, north of the principal veins, and a small valley heading in the deposit area carries some runoff into the Río Santa at a point 3 kilometers north of Huarás From a point just west of the bridge crossing the river at Huarás a trail leads northwest to the area A more convenient but less direct route is furnished by a road built in 1950 by the Cía Minera Santa Elena, which extends from the Huarás-Casma road at a turnoff east of Punta Callán northeast to the deposit area The distance from Huarás to the turnoff is about 25 kilometers and from the turnoff to the mine is about 10 kilometers

Outcrops of veins extend from 3,900 to 4,260 meters in altitude Slopes are steep and grass covered Water supply is good only in

Quebrada Collana, the only water in the vicinity of the deposits is supplied by drainage from mine workings and a few potable springs.

The mine had been worked before the visit of Raimondi (1873, p. 319, 1913, p. 148–149) in 1860, evidently it had produced high-grade silver ore. In that year, samples taken by Raimondi had a silver content that was relatively low as compared to other mines in the range, and the deposit area was not considered to offer a profitable source of silver. Dueñas (1904, p. 27) came to the same conclusion, but, according to local reports, an American engineer named Smith developed and mined the more important veins in the following years. Thereafter, the workings were dormant until 1949, when the Cía. Minera Santa Elena took a two-year option on the property, opened some of the old caved workings, and mined zinc and lead ore until prices dropped in 1950. Ore was hauled to the small concentrator built in 1948 by Sr. Jorge Cáceres on the banks of the Río Santa 2 or 3 kilometers north of Huarás. Ownership of the deposits is divided among various members of the Vizcarra, Cáceres, and Oliveiri families.

The Jecanca area is underlain by volcanic rocks intruded by a stock (pl. 6). Folded volcanic rocks lie west of the stock. They consist chiefly of lava flows and agglomerate beds, with smaller amounts of tuff and several thin dark limestone and siltstone beds. The tuff is red and contains quartz grains and a few pebbles. The lava flows and agglomerate beds contain no visible quartz and probably are andesitic in composition. Flat-lying volcanic rocks lie east of the stock and consist chiefly of agglomerate and volcanic breccia. One bed cropping out in the valley below the Jecanca vein contains angular to subrounded quartzite fragments, very much like the inclusions in volcanic rock at the Carmen prospect.

The stock of intrusive rock may be as much as 5 kilometers long and 1.5 kilometers wide, extending 1 kilometer northeast and several kilometers south of the deposit map area (pl. 1). The north half and the plug in the southeast corner of the mapped area consist of coarsely porphyritic trachyandesite, in places containing sufficient quartz to range into the composition of rhyodacite. The south half is a fine-grained porphyritic andesite. The contact between the two types is in an area so altered that it can be only generally placed.

Owing to soil cover and alteration, contacts between the stock and the volcanic rocks are obscure. The contact between the trachyandesite and volcanic rocks is fairly well fixed in several places, but that between the andesite and volcanic rocks was approximately established along only part of the west margin of the mass.

A few small dolerite dikes crop out near the west margin of the andesite block and in several other parts of the intrusive. None are wide and strike lengths of their outcrops are short.

The areas of altered rock in the Jecanca area are the most extensive in the Cordillera. Even those outcrops with freshest appearance and best defined texture have been chloritized and epidotized (table 2). With subsequent pyritization and sericitization, these rocks become bleached and mineral outlines less well defined. Rocks which subsequently have been leached and kaolinized are light gray or cream, and at places are stained reddish by residual iron oxides.

The zones of altered rock shown on pl. 6 were mapped only on the qualitative bases of bleaching and textural sharpness, but roughly they correspond to areas that have, at the least, been moderately sericitized. Owing to limited extent of outcrops and to the transitional nature of altered rock zones, contacts are generalized. The map shows that altered zones occur along all outcrops of veins. Nearly the entire block of trachyandesite has been altered—from south of the main vein to the bottom of Quebrada Collana, and most outcrops on the north side of that valley also are altered. The block of fine-grained porphyritic andesite is extensively altered only immediately south of the main vein, beyond which altered-rock zones are sporadic and relatively small. It also may be noted that alteration extended laterally into the volcanic rocks flanking the stock.

In 1947, little could be seen of the type of deposit, owing to inaccessibility of most underground workings and to the nearly complete removal of ore from most surface workings. In the south area, sphalerite and galena, with quartz, pyrite, and some marcasite and carbonate minerals, together with altered wall rock and gouge, comprise the material in the Santo Toribio vein. The main south vein, the Jecanca, also has pyrrhotite and pellets of gray chert. Along the main north vein, the Toro, quartz, pyrite, and altered wall rock comprise nearly all material seen in cuts or on dumps, although a few fragments of sphalerite and galena and scarcer chalcopyrite are left in places. In a small vein between Jecanca and Toro, some bornite and covellite also were seen on dumps. Veins on the north side of Quebrada Collana contain small amounts of galena and sphalerite in a gangue consisting chiefly of quartz and pyrite.

Arsenopyrite was reported from the area by Raimondi (1939, pp. 54–60), who also noted that in 1860 the silver content of oxidized quartz-pyrite rock ranged from 125 to 1,500 grams per ton. The late Dr. Otto Welter, of the Instituto Geológico del Perú, saw the Toro vein on the 3,985 level, before this working caved. One sample collected by Welter assayed 8 percent copper, occurring chiefly as chalcopyrite.

The best exposures of ore in 1947 were in the Santo Toribio adit, at 4,040 meters altitude. The north-striking vein followed by this working was channel sampled, and assays show the ore to range from

113 to 488 grams silver per ton, 7 to 23 percent lead, and 17 to 38 percent zinc (assays 1634, 1636–1638, and 1640–1641, table 3) Ore mined from the Jecanca vein itself by the Cía Santa Elena may have contained less sphalerite, but the vein system carries the best zinc ore in the Cordillera

The strongest veins in the area strike nearly east The Toro vein, the largest, actually consists of linked segments striking east-northeast and west-northwest Smaller veins extending the width of the mapped area parallel the larger structures Between the Toro and Jecanca veins are other small veins which strike N 30° E They might represent tension fractures, if it is postulated that the main mineralized zone had been subjected to a horizontal shear couple, with movement west on the north side and east on the south side of the area In the southeast part of the mapped area, small veins striking north contain only quartz and iron and manganese oxides

Small unmineralized faults, traceable for short distances and containing only breccia and gouge, occur in several parts of the area Their short horizontal extents probably indicate minor displacement A cross-fracture more than 1 kilometer long is suggested by the alinement of the main southern tributary of Quebrada Collana and a northern tributary of the south stream No displacement occurs where its trace crosses the Toro vein, so it probably is not a major fault

The Toro vein, at the south edge of Quebrada Collana, is traceable for 1,200 meters, its outcrops range from 3,960 to 4,150 meters in altitude Its overall strike is slightly north of west and it seems to be dipping north at steep angles The western 500 meters is an unexplored gossan of quartz and limonite as much as 70 meters wide, and to the south of this segment are several irregular and smaller bodies of the same material The eastern 500 meters is ramified, splitting into two main veins and subsidiary branches Even in the eastern area, quartz-pyrite rock is as much as 40 meters wide along parts of the veins The workings in this area are extensive, consisting of many short adits and large surface cuts The deepest working, now caved, is the crosscut from the north, the portal of which is at an altitude of 3,985 meters

It is probable that the Toro vein was mined for the silver content of oxides in the secondarily enriched zone at the surface, inasmuch as base-metal sulfides are scarce or absent in most exposures Earlier reports, including those of Raimondi and Welter, indicate that galena, sphalerite, and chalcopyrite were present

The Jecanca vein, on the south slope of the southern valley, strikes north of west and dips steeply north It consists of several segments and branches, several of which dip steeply south toward the main structure. Outcrops are traceable for a distance of 550 meters, from

4,085 to 4,260 meters in altitude. Workings extend from an adit at 3,995 meters to the uppermost outcrop. The vein is from 1 to 5 meters wide. Owing to strong alteration and heavy ground, most underground workings on the vein are caved. From what could be seen in surface cuts and one accessible adit, as well as on rock dumps, sphalerite, galena, pyrite, and quartz, together with gouge and strongly altered wall rock, are judged to be the chief constituents of the veins.

The lower adit, the Crawford, bears S. 67° W. and in 1947 was caved 73 meters from the portal. The working was reopened by the Cía. Santa Elena in 1949. The adit above, the Santo Toribio, reached the vein but drifts were caved. The lower adit on the north segment, at an altitude of 4,172 meters, bears N. 87° W. In 1947 it was open for a distance of 90 meters. Only one short ore shoot was seen, about 75 meters from the portal, although quartz and pyrite occur in other parts of the drift.

The Santo Toribio vein was the most intensely mineralized of any of the veins striking northeast. Its adit, at 4,040 meters, also served for access to the Jecanca vein. The vein has an irregular strike, averaging N. 30° E., and dips 30°–50° NW. In places it is as much as 3 meters wide. In stopes above the drift, the vein contains high-grade zinc and lead ore in widths from 1.12 to 1.95 meters (analyses 1634, 1636–1638 and 1640, 1641, table 3).

Although the Santo Toribio adit is 170 meters long, the vein is exposed in only the first 50 meters of the adit and for another 30 meters in stopes above. Beyond this, the walls and backs of the working are timbered and cribbed as far as the beginning of the east-striking fissures of the Jecanca system. Another short drift and a stope are cut 12 meters above the main adit, and a raise from the main stope reaches the surface 10 meters above the upper drift.

The only other veins striking northeast that contain much base-metal-sulfide ore are 250 meters north of the Santo Toribio adit. They are opened by surface cuts and adits over a strike length of 85 meters. The hanging-wall vein strikes N. 30° E. and dips 40° NW. The footwall consists of short en-echelon segments striking N. 45° E. and dipping 70° NW. Small lenses, containing galena, sphalerite, and minor amounts of copper sulfides, none of which seen were more than several meters long, form the ore. Workings range in altitude from 4,050 to 4,080 meters. Some sphalerite and galena are on the dumps of workings cut on another northeast-striking vein which lies 200 meters east of the Crawford adit. The vein is traceable about 75 meters and little ore could be seen in accessible workings.

None of the small veins striking east seem to contain much base-metal sulfide. Several have open adits. The two south of the Jecanca vein contain small amounts of galena and arsenopyrite with quartz and limonite. The vein 110 meters north of the Toro is opened for a length of 81 meters, but little sulfide was seen, other than on the dump where a few fragments contain small amounts of galena and sphalerite.

Three deposits are on the north side of Quebrada Collana. The westernmost is a shatter zone several meters wide, trending N. 85° W., that contains veinlets of sphalerite, pyrite, some galena, and calcite. The country rock is altered lava. It is opened by a surface cut 16 meters long, at an altitude of 4,135 meters, and by a crosscut, now caved, several meters vertically below the pit. The second deposit, at the northwest corner of the mapped area, is opened by a trench 40 meters long and by adits which now are caved. Evidently the vein strikes N. 65° W., and contains pyrite and sphalerite. The main dump is at an altitude of 4,100 meters, and workings follow the vein and its branches for a distance of 90 meters. In the northeast corner of the mapped area is the Pascua mine, which consists of surface cuts about 100 meters long on the principal vein and shorter cuts and trenches on two parallel veins, as well as adits which are caved. Only traces of galena and sphalerite are on dumps. The veins strike N. 45°–90° W. Altitudes of workings range from 3,895 to 3,965 meters.

The two main veins in the Jecanca area are wide, and the surrounding altered-rock zone are correspondingly wide, which indicates movement of considerable amounts of solutions during mineralization. Although enriched silver ore has been mined, much of the Toro vein has not been explored. More detailed work at this deposit may indicate the site of base-metal-sulfide lenses which may have mining possibilities under more favorable prices.

### BOLICHE MINES AND PROSPECTS

The southeast shoulder of Cerro Ruqui contains several veins that have been extensively prospected and several veins that have been mined. The area is about 6 kilometers west of Huarás and may be reached by trail from that city (pl. 1, loc. 22). The deposits are near the south end of the intrusive mass extending from Jecanca. Most veins contain pyrite and quartz and small amounts of galena and sphalerite, stibnite and manganiferous carbonates occur in several. Rock adjacent to veins is strongly altered.

The westernmost deposit is in a saddle south of the peak. The vein strikes N. 45°–60° W. and dips 80°–85° NE. It consists mainly of silicified and pyritized breccia and contains only small amounts of galena. Workings range from 4,350 to 4,400 meters in altitude and extend for a distance of 160 meters. The lowest is an adit bearing N. 10° W., crosscutting to the vein, and above it are an incline and several surface cuts.

Several hundred meters southeast and at about the same altitude is a prospect pit on a vein striking N 75° E and dipping 75° SE The vein is only 10 centimeters wide and contains small amounts of galena and stibnite About 400 meters to the east of this pit are two pits spaced 30 meters apart, at an altitude of about 4,300 meters These expose a vein striking N 85° E and dipping 60°–90° N The silicified shear zone about 1 meter in width contains much pyrite and small amounts of galena and sphalerite

Farther east and at 4,200 meters altitude is a pit on a fault striking east and dipping 80° N The vein on the fault is only 10 centimeters wide and contains pyrite and quartz A branch fault strikes N 55° W and dips 30° SW Rock in the footwall is brecciated near the junction with the fault striking east Thirty meters to the northwest is a pit on the branch fault The dump contains some quartz, manganiferous carbonate, pyrite, and small amounts of galena

The Boliche mine is farther downslope, at an altitude of about 4,000 meters, and near the trail from Punta Callán to Jecanca The main vein, traceable in pits for at least 150 meters, consists of a breccia zone as wide as 15 meters which strikes N 75° E and dips steeply southeast On dumps, low-grade ore consists of quartz, pyrite, galena, sphalerite, and stibnite North of the westernmost pits is another breccia zone It strikes N 60° W and dips 60° SW , and is as much as 6 meters wide

On the shoulder to the north, at an altitude of about 4,120 meters, a pit and adits which are now caved were opened on a shear zone striking N 60° E and dipping 65° SE The shear zone is as much as 4 meters wide, and in both the hanging and footwalls are sulfide-bearing bands as much as 25 centimeters wide Quartz, pyrite, and stibnite are the only minerals The vein is traceable for 10 meters beyond both ends of the pit

Near the Boliche mine and at about the same altitude are a group of trenches and adits exploring several veins which generally strike N 65°–70° E and dip steeply south At the east end of the workings is a segment striking east and dipping 65° S Vein zones are from 1 to 7 meters wide but are nearly barren of base-metal sulfides The workings extend for a distance of about 180 meters Adits on parallel veins are 75 and 90 meters south of the east end of these workings Some low-grade stibnite ore was seen on the dump of the southermost adit

On the south side of the same valley are a group of trenches and pits following a vein for a distance of 150 meters. The trend of the vein is N 60° E No base-metal sulfides were seen in the workings or on the dumps Sixty meters to the southeast is a similarly barren vein striking N 50° E Workings extend for a distance of 300 meters on this structure

### TRES HERMANOS AND SAN JUAN PROSPECTS

The Tres Hermanos prospect is in the upper part of a valley, locally known as Quebrada Pullpullac, just north of Quebrada Collana Volcanic rocks in the area strike N 20° E and dip 30° SE The lower adit on the main vein is at an altitude of 4,150 meters Trails from the Jecanca deposit lead to the area (pl 1, loc 23)

Two adits on the larger vein, both caved, show it to be a narrow mineralized fracture that strikes east and dips 40°–65° S At the lower adit the vein is from 30 to 35 centimeters wide, white vuggy quartz on the dump contains sphalerite, galena and pyrite At the upper adit, 30 meters northeast of the lower adit, the vein is about 50 centimeters wide The same suite of minerals, and clay gouge, are found on the dump

A second vein, 100 meters to the southwest, strikes N 85° W, dips 75° S, and is 10 centimeters wide at the adit The same sulfide minerals, in quartz-carbonate gangue, are found on the dump The adit is 30 meters in length

Ore shoots in these veins evidently are small

In the valley west of Tres Hermanos is the San Juan prospect, at an altitude of 4,230 meters The vein was explored by means of a pit, whose walls are now slumped About 30 tons of rock on the dump contain pyrite, sphalerite, and galena This material contains a comparatively high percentage of sphalerite

### EL CARMEN MINE

The El Carmen mine is several hundred meters north of the Huarás-Casma road, 55 kilometers west of Huarás and 23 5 kilometers west of the pass at Callán (pl 1, loc 24) The location shown on the map is estimated, because the road is winding and includes many switchbacks The deposit is in a small, sharp valley of a tributary of the Río Chacchán Water is moderately plentiful, and eucalyptus for mine timber is available in the area

An antimony deposit in this area reported by Raimondi (1873, p 430) may correspond to the El Carmen deposit An assay by Raimondi showed the ore to contain 360 grams silver per ton Before 1948 the deposit had been mined along its outcrop, at the level of the stream, about 3,130 meters in altitude, and from an adit, level 2, at 3,100 meters in altitude (fig 10) The property was acquired by Sr Jorge Zimic in 1948(?) who mined some ore between levels 1 and 2, and who started a crosscut at 3,054 meters altitude to reach ore below level 2 At the time of our examination the crosscut had been driven 65 meters of the 200 necessary to reach the vein Ore mined by Sr Zimic averaged 30 percent antimony It was hand cobbed and sold to dealers in Huarás

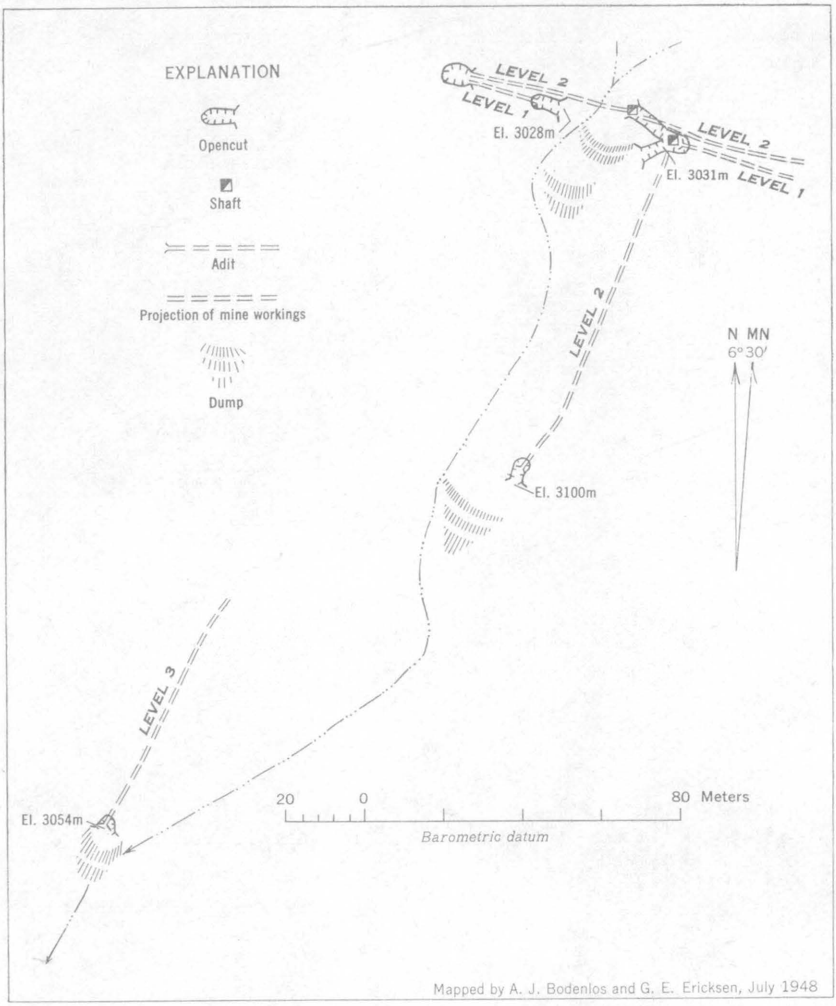


FIGURE 10.—Sketch map of workings, El Carmen mine.

The rock at the deposit is altered, but seems to be an intrusive mass of diorite. The principal vein, traced in workings for 100 meters, strikes N. 75° W. and is vertical or dips at steep angles either north or south (fig. 11). Several splits branch to the southwest, and in the crosscut on level 2, a vein striking east and containing only pyrite was found 50 meters from the portal.

The vein consists of stibnite in quartz gangue, a few calcite veinlets, and small amounts of pyrite. Gouge along the vein is moderately thick in places and consists of buff and green varieties of clay. An X-ray pattern of the green clay, made by J. M. Axelrod, did not match any patterns on file.

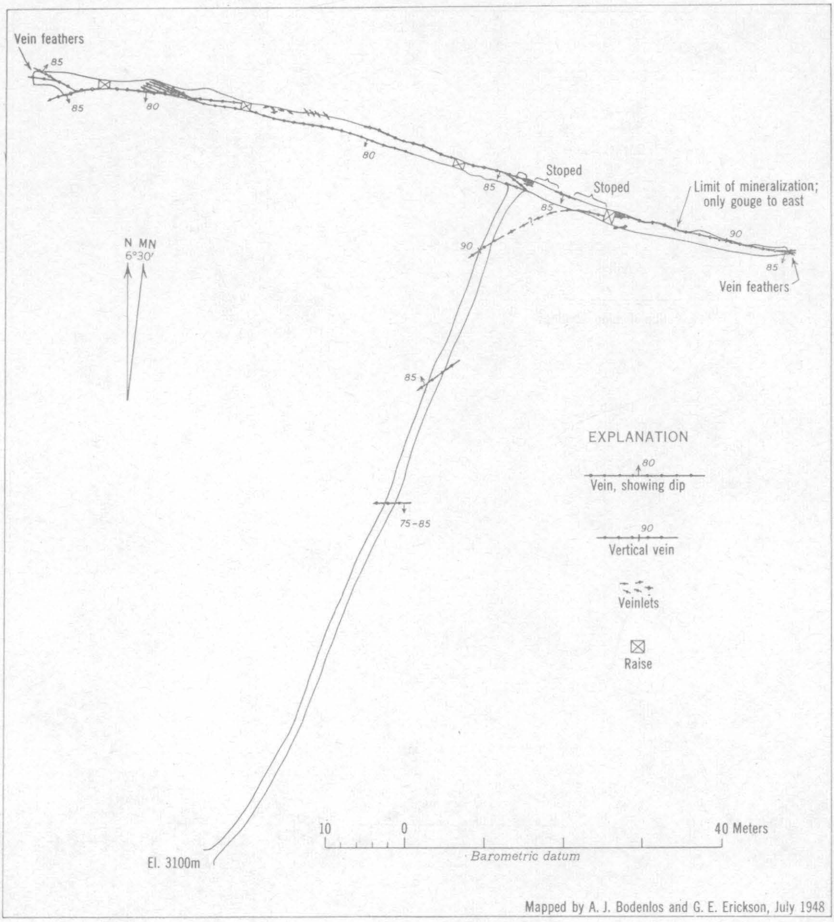


FIGURE 11.—Geologic map of level 2, El Carmen mine.

The better parts of the vein occur where branching shear planes are common. Some ore occurs in breccia zones and some in gouge; smeared stibnite in gouge and along several shear planes indicates some postmineralization movement along the vein. The bulk of the stibnite is closely associated with quartz, and the mineral is absent or scarce where pyrite or secondary oxides of iron occur. In places the vein is as much as 2 meters wide, but most parts worth mining are from 10 to 60 centimeters wide.

On level 1, three small ore shoots were found. On level 2, the main ore shoot was east of the crosscut and 20 meters long. It has been mined out up to level 1. Several small lenses of stibnite also have been mined out from the west end of level 2. Therefore, reserves are small above level 2. No geologic evidence was seen indicating whether stibnite ore would either improve or diminish in grade or quantity on the new level being driven 45 meters below level 2.

### CERRO MACO MINE

The Cerro Maco mine, on the southwest slope of the peak of the same name, is 7 kilometers northwest of the hamlet of Tinco on the Huarás-Casma road (pl. 1, loc. 25). The lakes at the foot of the peak are at the head of Quebrada Llanca Tabla, which trends southwest to join the valley of Río Chacchán. A comparatively poor trail connects the deposit to the road at Tinco.

The property is owned by Sr. Arturo Dias. In 1947, hand-jigged concentrates were produced at the rate of several tons per month.

The deposits are near a pond about 400 meters northwest of the outlet of the largest lake. In this area the most widespread rock is a coarsely porphyritic volcanic rhyodacite that dips at low angles. It overlies a basal conglomerate containing angular fragments of quartzite and slate, which in turn lies on folded quartzite. Both lower units crop out in a small area southwest of the deposits. A small mass of rhyolite seems to be intrusive into the quartz-bearing rocks, but its contacts are faulted.

The main vein strikes N. 70°–85° E. and dips 75°–80° NW., its strike changing to N. 60° E. at its northeast end. The vein is followed in part by workings for a distance of 70 meters, and it is as much as 1.5 meters wide. Twenty meters to the south of its southwest end is a second vein, which strikes N. 45° E. and dips 85° NW. Minerals in the veins include galena, sphalerite, chalcopyrite, pyrite, quartz, and calcite. Volcanic wall rock has been propylitized, sericitized, and silicified.

Southeast of the main vein, a crosscut 60 meters long and trending N. 35° W. was driven at an altitude of 4,450 meters but in 1947 had not reached the vein. The largest working on the vein itself is an open stope about 15 meters long and about as deep. Slickensides on the walls of the vein plunge 50° SW. In this area the vein has its maximum width. Both the hanging wall and the footwall have a band of nearly massive sulfides from 10 to 15 centimeters wide. A channel sample 50 centimeters long across a narrower part of the vein that included the two sulfide bands and the barren horse between them assays 51 grams silver per ton, 13 percent lead, and 12 percent zinc (assay 1635, table 3). Forty meters to the west a surface pit and an adit 10 meters long show the vein contains an ore shoot about 7 meters long and as much as 30 centimeters thick. In part the upper extension of the ore shoot is cut by a fault striking N. 20° E. and dipping 20°–30° SE. Slickensides on the vein walls plunge 30° SW. A channel sample across the widest part of the shoot assays 135 grams silver per ton, 32 percent lead, and 21.6 percent zinc (Assay 1639, table 3.)

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On the southern vein, a short shaft has been cut on a lens 5 meters long and as much as 35 centimeters thick that pinches out completely at both ends

About 150 meters northwest of the outlet of the largest lake is a prospect pit on a breccia zone striking N 25° E and dipping 70° SE In a width of 30 centimeters only about 10 percent consists of sulfides, which fill interstices in the breccia

The ore shoot in the stope at Cerro Maco is one of the better ore bodies found in the small mines of the Cordillera Negra

#### FRAY MARTÍN, JATUNCACA, SAN JUDAS, AND OTHER PROSPECTS

The Fray Martín, Jatuncaca, San Judas, and other prospects are on a ridge between Quebradas Jacayurac and Colcapampa, about 6 kilometers west of the hamlet of Paltay on the Santa Valley road, and from 10 to 11 kilometers south of Marcará (pl 1, loc 26) Only the Fray Martín, owned by Sr Teodoro Presa, was being explored in 1947 The San Judas deposit, owned by Sr Arturo Dias, was not examined The deposits are at altitudes from 3,790 to 4,020 meters and are accessible by trails from the Santa Valley

The country rock in this area is quartzite and shale of Cretaceous age The beds are folded and faulted In most places they strike northwest and dip either southeast or northwest Bedding-plane faults and breccia zones are the sites of most mineral deposits in this area

The Fray Martín deposit is at an altitude of 3,960 meters and is just north of the ridgecrest Sedimentary rocks strike N 25° W and dip steeply The veins contain galena, sphalerite, chalcopyrite, marcasite, and calcite (pl 7, *A*), as well as some quartz-sericite rock In the lower of two adits, a vein striking N 45° W and dipping 85° NE is sparsely mineralized for a distance of 22 meters Small sulfide-bearing veinlets also occur several meters below the footwall at the southeast end of the workings On the upper level, 6 meters higher in altitude, only a few veinlets are seen which may be related to the mineralized zone on the lower drift (fig 12 ) The drift on the upper level follows a bedding-plane fault striking N 35° W and dipping 70°–75° SW This fault truncates the southwest extension of a small mineralized zone striking northeast found in the middle of the drift

The new prospect being opened in 1947 is an underhand stope cut near the portal of the upper working A zone of irregular veins of calcite containing about 10 percent sulfides strikes N 35° E and dips 35° SE , crosscutting the steeply dipping sedimentary strata The zone is about 1 meter wide and was exposed for a strike distance of 4 meters The pit exposes a reverse fault that strikes N 40° E and dips 30°–60° SE Its location and attitude suggests that it intersects the vein zone below the floor of the underhand stope

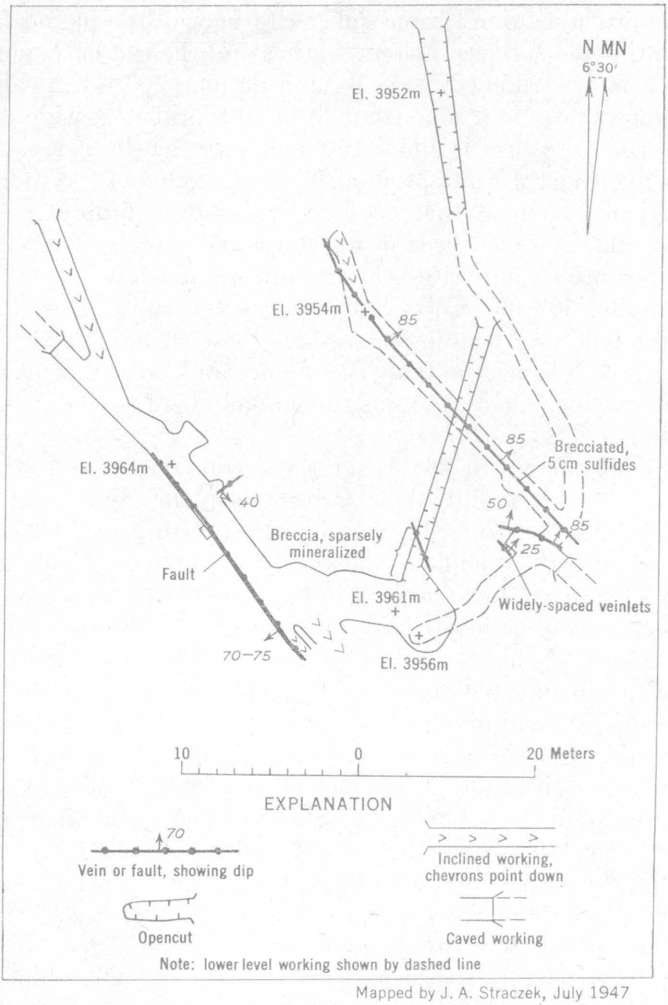


FIGURE 12.—Geologic map of adits, Fray Martín deposit.

Southward from the crest of the ridge, are five prospects that follow the north side of a tributary valley of Quebrada Colcapampa. They lie in a zone which trends northwest and which is about 450 meters long. The San Judas mine, on the south side of the tributary valley, is on an extension of the zone.

The most northeasterly of the prospects is at the ridgecrest and at an altitude of 4,030 meters. Here quartzite and shale are cut by a fault striking N. 50° W. and dipping 70° SW. The fault contains pyrite in widths ranging from 30 to 50 centimeters. East of the pit, a line of shallow cuts follows a mineralized bedding-plane fault for a distance of 20 meters. This fault strikes N. 20° W., dips 15° NE., and contains pyrite and some sphalerite in widths ranging from 10 to 50 centimeters. Seven meters southeast of the last cut, another pit exposes a fault striking N. 35° W. and dipping 70° NE., which contains some sulfides in a zone from 20 to 30 centimeters wide.

The second prospect is about 150 meters to the southeast, opposite a sag in the ridgecrest and at an altitude of 3,960 meters. The upper working is a pit cut at the nose and in the lower limb of a local recumbent fold, in which beds of quartzite and shale strike N. 55° W. One bed contains a pyrite-bearing zone as much as 50 centimeters wide, dipping 50°–90° SW. Four meters vertically below the pit a short adit follows a bedding-plane fault that strikes N. 45° W. and dips 80° NE. Along the fault is a fissure and breccia zone as much as 2 meters wide, which contains small amounts of pyrite, galena, and sphalerite.

About 100 meters S. 30° E. of the second prospect is the third prospect, a 10-meter adit along a bedding-plane fault that strikes N. 50° W. and dips 70° SW. A zone from 1 to 2 meters wide contains about 5 percent sulfides, mostly pyrite in association with some galena and sphalerite. The rock in the zone is thin-bedded shale.

The Jatuncaca, or fourth, prospect consists of three workings, the northernmost of which is 150 meters east of the third prospect and at an altitude of 3,820 meters. Thin-bedded quartzite and shale strike N. 50° W. and dip 70°–90° NE. Considerable pyrite and very little galena occur in a zone 1 meter wide along one bed. To the south, at an altitude of 3,790 meters, a short adit follows a fault striking N. 45° W. and dipping 80° SW., in which occur small amounts of oxides. Bedding is parallel to the fault but dips 55° NE. northeast of the structure and 35° NE. on the opposite side. A pyritized and altered zone 1 meter wide parallels the bedding southwest of the fault. Six meters west of the adit, a working inclined 30° follows steep faults parallel to the bedding which strikes N. 20°–50° W. The faults contain small amounts of pyrite.

The fifth prospect, at an altitude of 3,820 meters and 100 meters south of Jatuncaca, is in the creek bed at the floor of the tributary valley. In this area two veins parallel to the bedding are 4 meters apart. The northeastern vein strikes N. 50° W. and dips 85° SW. Although it is as much as 1.8 meters wide at one point, it pinches out 12 meters to the northeast. Sulfides, largely pyrrhotite and sphalerite, constitute 75 percent of the lens. An assay of chips taken across a width of 1.15 meters shows the ore to contain 70 grams silver per ton, 0.7 percent lead, and 10.4 percent zinc (analysis 1618, table 3). The southwestern vein is vertical and is from 0.5 to 1.2 meters wide. It contains similar minerals and is traceable for a distance of 18 meters in outcrops and a short adit.

Ore shoots containing commercial sulfides are small and low grade in this group of prospects.

### QUEBRADA QUIRHUAC MINES

A mineralized zone nearly a kilometer long is in the upper Quebrada Quirhuac, a valley reaching the Río Santa between the towns of Marcará and Pariahuanca The area is 8 kilometers southwest of Marcará and about 4 kilometers east of the crest of the range (pl 1, loc 27) Trails following the quebrada afford access from the Santa Valley Workings on the veins are on both sides of the quebrada and at altitudes from 4,000 to 4,100 meters The mines seem to have been abandoned for some time and only a few adits are still open. In places, therefore, it is difficult to determine which fractures contained ore From the size of dumps, it appears that considerable mining was done

The country rock consists of a sequence of steeply dipping, dark-gray, porphyritic andesite flows, some tuff, and several quartzite beds The andesite has been propylitized, sericitized, and silicified in the vicinity of the deposits About 1 kilometer to the west, the steeply dipping sequence is unconformably overlain by low-dipping agglomerate and porphyritic lava

The dumps consist largely of altered andesite but include smaller amounts of quartz-pyrite rock and a few boulders that contain some galena, sphalerite, and calcite

The deposits occur in a zone that trends northwest across the quebrada, which in this area trends eastward The southeast end of the zone is on a shoulder projecting northeast into the quebrada The lowest working is a caved adit at an altitude of 4,030 meters Galena and sphalerite in quartz-pyrite gangue are on the dump Fifteen meters to the southwest is an opencut 8 meters long on a lens as much as 20 centimeters wide, containing only pyrite and quartz Undercuts 4 meters long to the southwest and southeast also are barren of galena and sphalerite Twenty meters to the northwest of the adit is a pit in which only altered volcanic rock is exposed Ninety meters southwest of the lower adit is a second adit at an altitude of 4,085 meters bearing S 20° W The adit is open but flooded 20 meters from the portal At this point is the beginning of a vein striking N 20° E and dipping 20° SE, and which apparently is followed by the flooded section of the adit Sulfides at the beginning of the vein are only 4 centimeters thick A crosscut to the southeast shows a silicified breccia zone barren of sulfides along the hanging wall A vein between the flooded section and the portal strikes north and dips 75° W , and contains low-grade sulfides lenses as much as 15 centimeters wide About 35 meters S 30° W of the upper adit is an incline at an altitude of 4,100 meters It bears S 20° W and is caved 6 meters from the portal It explores the silicified breccia zone but is as barren of sulfides as the structure seen in the adit below

About 200 meters N 60° W. of the lower adit is a large pit trending S 63° E , at an altitude of 4,000 meters. A band of highly altered and silicified volcanic rock is 15 meters wide in the pit and extends uphill, 75 meters to the southwest of the working. The pit is 60 meters long and follows a vein striking N. 45° W. and dipping 30° SW. The vein is exposed only at one point in the working, where it is 0.5 meter wide and consists of black clay gouge, apparently pyritized, and fragments of brecciated quartz. The only sulfides seen on the dump are pyrite and galena. Sixty meters southeast of the mouth of the pit is an adit at an altitude of 4,025 meters. The working bears S. 53° W. and is flooded 25 meters from the portal. About 10 meters beyond the flooded section ore was mined from two levels. The strike of the weak shear zone followed by the adit gradually changes from N. 55° E. at the portal to N. 35° E. at the point where the adit becomes impassable. Most of the short discontinuous shear planes are barren, but 25 meters from the portal one lens is 3 meters long and as much as 15 centimeters wide. Material on the dump contains fragments moderately rich in galena and sphalerite, associated with pyrite, quartz and calcite.

The workings on the north side of Quebrada Quirhuac are about 500 meters northwest of the large pit. They are cut on two veins about 75 meters apart that strike northwest. The northeast vein is explored by only one adit, about 20 meters long, at an altitude of 4,000 meters. The vein and an altered zone, 2.5 meters wide, strike N. 60° W. and dip 85° NE., in quartzite near its contact with andesite. Only irregular veinlets of pyrite, quartz, and small amounts of sphalerite, with a maximum width of 4 centimeters, are in the zone.

The southwest vein strikes N. 35°–50° W. and dips 75°–90° NE., and a branching breccia zone has a parallel strike but dips as little as 50° SW. The main vein is opened at 4,000, 4,025, and 4,090 meters altitude, by two adits and a shaft. Andesite is altered along the vein in widths from 5 to 15 meters in the vicinity of the shaft. Quartz and pyrite seem to be the only abundant minerals. The branching breccia zone is followed by surface cuts and small open stopes from 4,040 to 4,055 meters altitude. Some galena occurs with the quartz and pyrite along the zone, the greatest sulfide content at any point is 20 percent, consisting mostly of pyrite.

The few exposures of veins in the workings of the Quebrada Quirhuac deposits show a comparatively small amount of galena and pyrite. Nevertheless, mining seems to have been fairly extensive, so ore shoots must have been present in areas now inaccessible.

### CERRO HUARANCAYOC PROSPECT

Small deposits on the north side of Cerro Huarancayoc have been prospected by pits, opencuts, and one adit. The area is 13 kilometers west-southwest of Carhuás and is 3 kilometers south of the Carhuás-Pariacoto trail (pl. 1, loc. 28). It is on the south side of a broad basin containing many lakes, which drain westward into Quebrada Chacchan, and is 2 kilometers west of the crest of the Cordillera Negra The main working is at an altitude of 4,600 meters

The principal vein is in low-dipping porphyritic andesite flows The main working is an open cut 15 meters long, from which an adit 21 meters long continues southward These workings follow the vein, which strikes north and dips 85° W in the cut, swinging in strike to N 30° E about 10 meters within the adit, and to N 55° E at its face Slickensides are nearly horizontal The vein is on a fault and breccia zone pinching out at the north end of the surface cut and 70 centimeters in width at the portal of the adit It contains a band of nearly massive sulfide from 4 to 15 centimeters wide

Within the adit and 11 meters from the portal, a strong, mineralized vertical fracture branches to the southwest, striking N 55° E At the intersection, where a pocket of high-grade sulfides 30 centimeters in maximum width occurs, a short raise has been cut At the face of the adit, the vein is less than 5 centimeters in width Fourteen meters from the portal, a crosscut to the southeast and 15 meters in length follows a barren fracture, which strikes N 70° W and dips 75°–80° SW Near the end of the crosscut, a barren gouge zone strikes N 20°–25° W Sulfide minerals in this prospect are galena, sphalerite, chalcopyrite, and pyrite

Another breccia zone, also striking north and nearly vertical, crops out 12 meters west of the main cut A pit on it shows the zone to be as much as 2 meters wide and to contain a few veinlets of sulfides from 1 to 5 centimeters wide Twelve meters east of the cut, other small mineralized fractures, from 3 to 4 meters long, strike N 5°–10° E and dip 75°–80° NW

About 200 meters S 55° E of the main cut are four veins in a zone 40 meters in width, each opened by a small prospect pit The country rock in the area is andesite agglomerate The narrow veins and breccia zones strike northeast and dip steeply either southeast or northwest The three western veins are nearly barren of sulfides The eastern vein, a comparatively strong mineralized fault, strikes N 10° E and dips 70°–75° W, and is bordered by an altered zone as much as 2 meters wide The vein minerals occur over a width of as much as 40 centimeters and consist of specular hematite, sphalerite, galena, chalcopyrite, pyrite, and quartz

All ore shoots are small, and, as the area was well prospected, it is doubtful that larger ones will be found

### HUINCHOS AND MEDIZA PROSPECTS

The Huinchos and Mediza prospects are in a ridge known as Cerros Pucajirca at its upper end and as Cerro Huinchos several kilometers to the west Their deposits are 22 kilometers southwest of

Carhuás, and are within 2 kilometers of the Carhuás-Yautan trail, which follows Quebrada Hurancorral north of the ridge (pl 1, loc 29) The Huinchos prospect is south of the ridgecrest, in a small cirque draining to the southwest The northwest adit, at an altitude of 4,740 meters, is about 300 meters N 65° E of a small lake in the floor of the cirque The Mediza prospect is on the north side of the ridge, in a small valley near its crest and about 1 kilometer northeast of the Huinchos prospect The pit on the east vein is at an altitude of 4,800 meters Neither prospect was worked in 1947

Volcanic rocks underlie the area and consist principally of porphyritic andesite lava flows having greenish and grayish colors and displaying several sizes of phenocrysts Some porphyritic andesite agglomerate also occurs in the sequence Between the two veins at the Huinchos prospect, a block of highly altered light gray rock, which seems to be a welded tuff, probably is faulted into its present position In the ridge northeast of the mine and extending to the Mediza deposit, a block of trachyandesite, in part having clastic texture, possibly is a small intrusive plug All rocks have been propylitized and sericitized to some degree, and, in the vicinity of the veins, are intensely altered

Two veins striking east, one 30–35 meters south of the other, have been mined and explored in the workings of the Huinchos deposit The north vein, traceable on the surface for a distance of 220 meters, is opened by two adits, the lower at 4,740 meters, and the upper, 140 meters to the east, at 4,780 meters altitude The lower adit is 15 meters long, in it the vein strikes N 85°–90° W and dips 75°–80° S, and is 5 to 30 centimeters in width Only quartz and gouge are in the vein, but fractures in a zone extending 1 5 meters to the north and several meters to the south of it contain considerable pyrite In this pyritized zone volcanic rock is altered and in places is silicified The upper adit is open for a distance of 53 meters where a raise is driven to the surface In the drift the vein strikes N. 80°–85° E. and dips 70° S Small quartz lenses and gouge along the vein are at the most 15 centimeters wide Three slightly mineralized fractures, striking N 65°–70° W and dipping 70°–80° SW, intersect the vein in the working On the surface, the vein changes in strike to N 60° E at the end of the outcrops 30 meters east of the raise Only veinlets of arsenopyrite, pyrite, and quartz occur in fragments lying on the dump

Thirty-five meters south of the lower adit on the north vein and at an altitude of 4,725 meters is the lower adit on the south vein, a working 32 meters long The south vein is in welded tuff(?), and andesite crops out to the south The strike of the vein is N 75° E at the portal, swings to east and then to N 85° E at the face, the dip is 70°–90° N throughout the length of the adit Although the south vein is 1 meter wide at the portal, where it consists of sheared, silicified, and pyritized rock, it is only one-tenth that in the adit and carries no ore The upper adit on the south vein, inaccessible in 1947, is 60 meters east of the lower adit The vein is vertical and the strike is N 70° E at the portal, but changes to east in the slope above The rock at the portal is welded tuff(?) The dump contains small amounts of quartz with galena and pyrite, as well as barren andesite The south vein is traceable to the east to a point 30 meters south of the upper adit on the north vein

The Mediza prospect consists of two small pits in trachyandesite The east pit is on a vertical vein striking N 35° E The northwest wall of the vein carries from 10 to 15 centimeters and the southeast wall 5 centimeters of quartz and small amounts of pyrite, galena, sphalerite, and chalcopyrite The barren trachyandesite between them is altered The other pit, 60 meters to the west, is on a vein 50 centimeters wide, striking east and dipping 85° S One band 15 centimeters wide contains quartz, pyrite, and small amounts of galena and sphalerite, the rest of the vein consists of thin stringers of the same minerals in the country rock

Ore seems to be scarce in the veins of these deposits The possibility of finding ore shoots worth mining is small

### PUCAJIRCA PROSPECTS

The Pucajirca prospects are a group of small workings in a cirque just north of the east peak of the Cerros Pucajirca ridge The area is 20 kilometers southwest of Carhuás and one-half kilometer south of the Carhuás-Yautan trail (pl 1, loc 30)

A fault that strikes from north to northeast and dips from west to northwest brings andesite flows east of the fault in contact with quartz conglomerate and overlying flow breccia west of the fault Several pits extending about 100 meters along the fault expose short mineralized zones containing small amounts of pyrite and even less galena and sphalerite. Minerals along the fault itself make a vein only a few centimeters in width, but stringers and pockets of sulfides extend into the conglomerate and breccia to form zones as much as 2 meters wide Some breccia fragments are partly replaced by sulfides In none of the pits does sulfide content exceed 5 percent, so ore shoots evidently are lacking

### HUISCOR AND YANACÓN PROSPECTS

The Huiscor and Yanacón prospects are on the northeast flank of the ridge southwest of Carhuás, named Cerro Matiascancha on the map of Borcher (1939) A trail from the Santa Valley road, crossing the Río Santa 3 kilometers northwest of Carhuás, ascends the quebrada below and east of the deposits, connecting to the Carhuás-Pariacoto trail at Cerro Pilcocancha, the prominence at the south end of the Matiascancha ridge (pl 1, loc 31) Despite the proximity to

Carhuás, only 9 kilometers to the northeast, the deposits are reached only with difficulty, because of lack of connections with the main trails below and above and because of steep and strongly dissected slopes The workings at Huiscor are from 4,390 to 4,420 meters in altitude, and those at Yanacón from 4,310 to 4,370 meters in altitude Neither prospect was in operation in 1947

The contact between volcanic rocks and underlying sedimentary rocks extends between the two deposits at Yanacón and several hundred meters northeast of the Huiscor deposits Andesitic and rhyolitic lavas, a few agglomerates, and flow breccias are found in the vicinity of Huiscor Their attitude at the deposit is not known but they dip 20°–30° SW in the ridge above Lava at the mine is highly propylitized and sericitized Sandstone, conglomerate, shale, and limestone comprise the sedimentary sequence at Yanacón The beds strike northwest and dip 30° SW

The veins in the Huiscor prospect are short and narrow, containing quartz and pyrite with some galena and sphalerite The northeastern working, at an altitude of 4,390 meters, is an adit that for its first 10 meters follows a weak fault striking N 45° W and dipping 80°–90° NE and then follows the vein which strikes N 10° W and dips 70° SW Although the volcanic rock is altered for a width of 1 meter, the vein contains only a few centimeters of sulfides About 15 meters above and to the south is the upper adit, following a vein striking N 20° E and dipping 80° NW, with a maximum width of 50 centimeters Two branch veins strike N 5° E and N 10° W About 5 meters south of their junction with the main vein is a shaft which connects to the adit below, evidently following the vein striking northwest The adit follows the N 20° E vein for a distance of 10 meters south of the shaft, then a mineralized cross-fissure striking N 25° W and dipping 40° NE for a distance of 5 meters, and finally a vein striking N 10° W and dipping 80° NE for a distance of about 10 meters The southern segment is as much as 30 centimeters wide but is nearly barren of sulfide minerals

About 15 meters southwest of the upper adit is a pit in which the vein is barren Twenty meters beyond, at an altitude of 4,420 meters, a second pit is cut on a vein striking N 55° E and dipping 60° SE The vein is only 10 centimeters wide and contains mostly quartz and pyrite

At an altitude of 4,380 meters and about 300 meters north of the lower drift is a vein striking N 15° E and dipping 40° NW It has been prospected and mined by two surface cuts and one underhand stope Only minor amounts of quartz and manganiferous carbonate, and a few grains of pyrite and galena, were seen in the accessible workings In most places the vein is only a few centimeters thick in the distance of 70 meters along which it can be traced

The lower Yanacón prospect is about 1 kilometer northwest of the north Huiscor deposit and at an altitude of 4,310 meters A cut 20 meters long follows a vein striking north and dipping 65° W Near the mouth of the cut, the south end of the vein branches into two segments, one striking N 10° E and the other N 20° W At most the vein is 10 centimeters wide and contains quartz, pyrite, galena, and sphalerite About 12 meters north of the cut is a pit exposing a vein striking east, which dips 50° S , and which is nearly barren of sulfides

The upper prospect, in tuff and lava, is 200 meters southwest of the lower and at an altitude of 4,370 meters An adit 13 meters long follows a vein striking N 65° E and dipping 55°–60° SE The vein is thin and in the back is intersected by a fault striking east and dipping 15°–20° S Sulfides are sparse in the vein.

Veins on the northeast flank of Cerro Matiaschancha are short, are interrupted by other fractures, and contain few minable lenses

### HUALLPAC MINE

The Huallpac mine is at the head of the Quebrada de Punya, near the rim of a shallow cirque and several hundred meters south of a lake in the floor of the basin It is just north of the Carhuás-Pariacoto trail which in this area follows the cirque rim The deposit is at an altitude of about 4,600 meters and is 13 kilometers southwest of Carhuás (pl 1, loc 32). The mine was dormant in 1947

In the lower part of the cirque the volcanic rocks are the closely folded, lower volcanic group and around the rim they are the slightly folded upper group The veins occur in the closely folded group Fine-grained light-colored felsitic rocks and porphyritic andesite occur in the vicinity of the deposits

The south vein is opened by drifts on two levels, the lower of which is inaccessible The upper is 75 meters long and is stoped between the two levels, as well as 10 meters upward nearly to the surface in the inner 50 meters of the working The stope is from 0 5 to 2 0 meters wide At its beginning the vein strikes N 70° W and dips 50° NE , at the face it strikes N 60° W and dips 75° NE Mining was so thorough that little can be determined of the nature of the vein Wall rock is altered and pyritized to 5 meters on both sides of the vein On the dumps of the two workings, altered rock contains quartz, pyrite, galena, and sphalerite A grab sample taken from the dump of the upper level assays 850 grams of silver per ton, 3 3 percent lead, and 6 5 percent zinc, a grab sample from the dump of the lower level assays 1,810 grams of silver per ton, 7 9 percent lead, and 11 4 percent zinc (analyses 1619 and 1620, table 3)

About 400 meters north of the workings, at about the same altitude, are several prospect pits along a silicified zone as much as 50 meters wide and about 200 meters long The zone strikes N 70° W Locally the quartz is pyritized and contains small amounts of galena and sphalerite

In the north zone, the concentration of galena and zinc seems low Owing to the inaccessibility of the lower adit and the end of the upper adit, it is not known whether any ore remains in the south vein Yet the silver content is as high as most of the better ore recently mined in any part of the Cordillera Negra, and because of the presence of at least one large shoot (50 meters in length, as much as 22 meters in height, and from 0 5 to 2 0 meters in width), opening of the old workings or further prospecting for silver may be warranted

### MACÓN MINE

The Macón mine is near the head and on the east wall of Quebrada de Punya, northeast of the lake and about 2 kilometers north of the Huallpac deposits (pl 1, loc 33) Secondary trails lead to the area from the Carhuás-Pariacoto trail The workings are 12 kilometers southwest of Carhuás and at altitudes from 4,580 to 4,610 meters Some prospecting and mining of the deposits was done by Sr Teodoro Presa

The southern vein is in folded volcanic rocks, principally andesitic lava flows and agglomerate which contain quartzite cobbles; at the deposit a block of graywacke is faulted against these rocks The andesites, which strike N 45° W and dip 60° SW, are overlain by low-dipping rhyolite The north veins are in low-dipping porphyritic andesite Along the veins, volcanic rock is altered and silicified, converted to either quartz-sericite or quartz-epidote rock, with some chlorite and tourmaline Sulfides in the veins are pyrite, chalcopyrite, galena, and sphalerite

At an altitude of 4,610 meters the south vein is opened by a cut 21 meters long and an adit 7 meters long, trending southeast to east These follow a slightly mineralized fault striking N 75° W and dipping 60° NE Branching southwest from it is a shear zone striking N 15° E and dipping 65°–75° NW, explored by an undercut 4 meters in length Sulfide-bearing fissures in the shear zone total 25 to 30 centimeters in width but are dispersed over a width of 1 5 meters Graywacke occurs in the segment east of the shear zone and south of the fault

The northern veins are several hundred meters from the southern ones The northern adit, at an altitude of 4,580 meters, is 12 meters long It follows a vertical vein striking N 60°–80° W, along which altered and silicified zones of volcanic rock are as much as 2 meters wide Sulfides remaining in the working are sparse, but one lens 3 meters long and as much as 25 centimeters wide was mined near the portal The other adit, 10 meters long, is 33 meters to the south The vein opened by the working is vertical and strikes N 80° W.

Wall rock is weakly silicified and pyritized for a width of 2 5 meters. At the face of the adit, sulfides in several thin stringers, none more than 2 centimeters wide, comprise less than 5 percent of the vein which is 90 centimeters wide at this point

All sulfide-bearing veins in the area seem to be short, and ore shoots exposed in the workings are small

### CERRO PLUMISA MINE

The Cerro Plumisa mine, 15 kilometers southwest of Carhuás and just north of the Carhuás-Yaután trail, is on the south flank of a small peak just west of the crest of the Cordillera Negra (pl 1, loc 34) The lowest workings are at an altitude of 4,700 meters and are just north of a small lake draining into a tributary of Río Chacchán The mine was dormant in 1947

The deposit is opened by three adits and connecting stopes and chutes The lowest level, at an altitude of 4,700 meters, is caved 150 meters from the portal The next level, 17 meters above, consists of an open cut 8 meters long and an adit which is caved 28 meters from the portal The upper level, 9 meters above the second, consists of an open cut 20 meters long and an adit 13 meters long (pl 14)

The country rock, probably rhyolite, is fine-grained, light-colored, and contains quartz phenocrysts At the deposit it is highly altered, converted principally to sericite and kaolinite clay minerals Some ankerite and pyrite occur in the altered material The rhyolite(?) is intruded by a plug of coarsely porphyritic dark-green andesite, also altered near the vein The intrusive is in fault contact with the rhyolite (?) along the upper adit of the mine

The vein is nearly vertical and has an overall strike of a few degrees east of north, but is slightly sinuous both in horizontal and vertical dimensions Minor cross faulting is seen near the end of the lower adit Minerals in the vein are quartz, and manganiferous carbonate, pyrite, some galena and sphalerite, and small amounts of arsenopyrite and rhodonite

In the lower adit, ore and gangue minerals occur along the comparatively strong fault zone for a distance of 110 meters On this level gouge occurs along most shear planes, but breccia is uncommon Quartz and pyrite occur along nearly the entire length Lenses containing sphalerite and galena are from 6 to 15 meters long and, on the average, are as much as 0 5 meter wide Location of ore shoots in part seems to depend on configuration of the shear-plane pattern

In stopes above the lower level, the mined shoots were as much as 2 meters wide Shoots on the upper levels seem to have been about as long as those on the lower levels

The comparatively small ore bodies are mined out above the lower adit and from one winze below this level Nothing is known of the nature of ore shoots beyond the caved parts of the lower and second-level adits

### LAGUNA SHAULLÂN PROSPECTS

Two deposits are in the Laguna Shaullán area, one on the southeast flank of the cirque and about 1 kilometer from the lake, and the second south of the cirque and on the ridge forming the divide of the Cordillera Negra in this area (pl 1, loc 35) The first deposit is reached by a poor secondary branch trail, the second is a few meters south of the Carhuás-Yaután trail Workings are from 4,685 to 4,715 meters in altitude Neither deposit was being worked in 1947

Folded lava, tuff, and quartzite underlie the area The veins occur in small blocks of altered andesite that may be intrusive into the folded volcanic rock

The deposit southeast of the lake consists of several short veins The western is exposed in an open cut and an adit 12 meters long, at an altitude of 4,700 meters The vein dips 70° N , striking N 80° W but swinging to N 80° E near the face of the adit Andesite along the north wall is only slightly altered but more strongly altered along the south wall The vein, 30 centimeters wide, lies between gouge-bearing shear planes Calcite and manganiferous carbonate occur on the north wall, quartz lenses with pyrite, galena, and sphalerite on the south wall Sulfide content in the vein is small About 100 meters S 70° E of the adit, a pit 3 meters in length is cut on a vein striking N 85° W and dipping 70° N The vein, only 10 centimeters wide, carries quartz and sulfides Ten meters east of the pit a similar vein is seen in an outcrop It strikes N 55° W and dips 80° NE

The deposit south of the main trail at the divide is a vertical vein striking N. 85° W , opened along a strike length of 80 meters. The vein is as much as 1 5 meters wide, consists mainly of quartz, coarse-grained calcite, and pyrite, together with small amounts of galena and sphalerite, and is in an altered zone as wide as 2 5 meters At its east end is a caved adit Forty meters to the west is a shaft, at an altitude of 4,700 meters, and 50 meters S 60° W of the shaft is the portal of a crosscut, at an altitude of 4,685 meters Only quartz and pyrite are seen in the vein where it is reached at the end of the crosscut

No minable ore shoots were seen in any of the veins southeast of Laguna Shaullán

### UCHCO MINES AND PROSPECTS

The Uchco mines and prospects are on the west flank of the Cordillera Negra, 20 kilometers west-southwest of Carhuás and at altitudes between 4,280 and 4,450 meters (pl 1, loc 36). The veins are in the ridge northeast of the junction of Quebradas Uchco and Mangan (fig 13). The area may be reached over branch trails from the Carhuás-

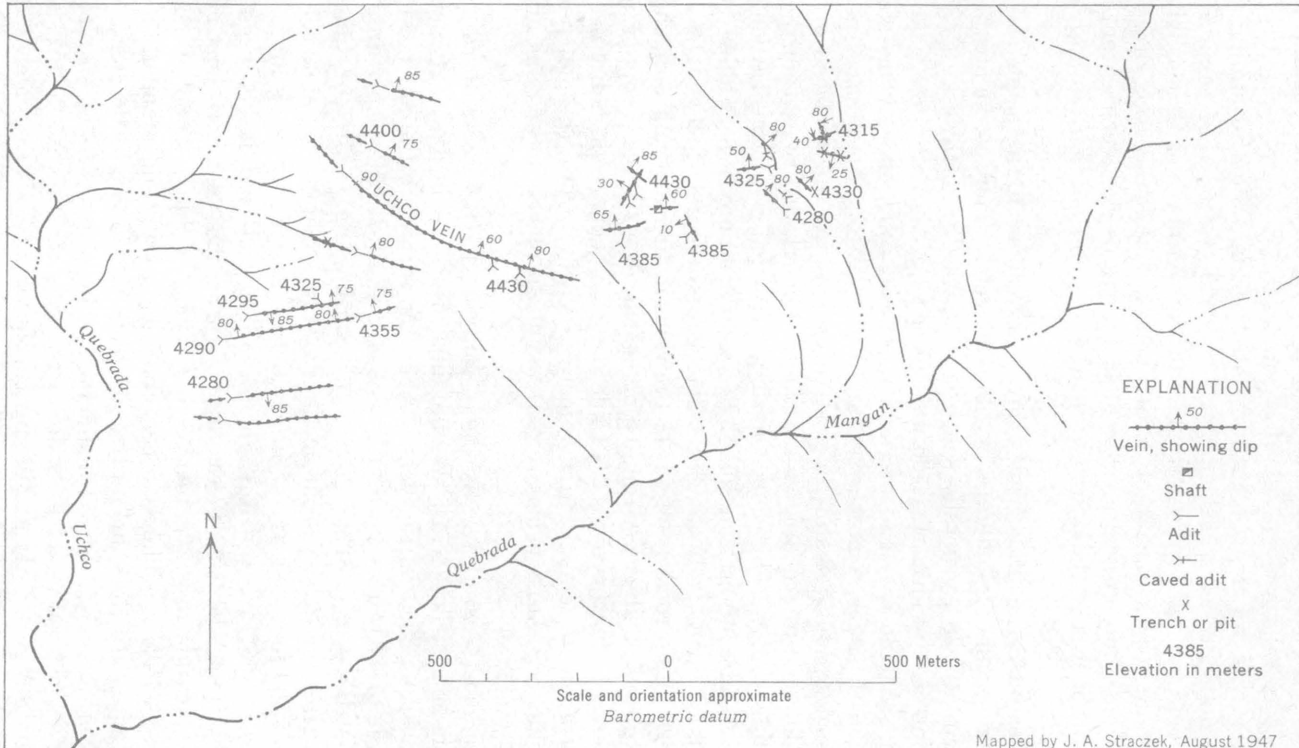


FIGURE 13.—Sketch map of veins and workings, Uchco deposits.

Yautan trail via Laguna Shaullán, or from the Buena Cashma area (pl 1, loc 39) via Quebrada Mangan

The veins are exposed in numerous workings but no mining was being done in 1947 Pflucker (1906, p 29) stated that some veins were being mined in the early part of the century and that a lixiviation plant with capacity of 3 tons per day was processing ore At that time some ore had a tenor of 15 kilograms of silver per ton, but the author was of the opinion that the area did not contain large ore bodies

Volcanic rocks underlie the area Included in the sequence are flow lava, tuff, agglomerate, and flow breccia They strike northeast and dip 10°–25°, generally southeast but locally northwest

Veins occupy an area 1,400 meters east-west by 700 meters north-south At the east end of the mineralized zone, short veins strike east, northeast, and northwest, and dip 10°–80°. Small cross faults intersect several veins in the eastern group At the west end of the area, longer and arcuate veins strike from northwest to east-northeast and dip steeply The veins contain quartz, manganiferous carbonate, pyrite, and some galena, sphalerite, and arsenopyrite Sulfide content is comparatively low but silver content is relatively high An assay of dump rock, from one of the veins in the eastern group, shows 1,345 grams of silver per ton, 0 6 percent lead, 0 2 percent copper, and 1 0 percent zinc (assay 1621, table 3) The copper probably occurs as tetrahedrite-tennantite, a mineral reported from these deposits by Pflucker Most veins are narrow but in places they are as much as 1 5 meters wide

The most easterly vein which contains pyrite and altered flow breccia only strikes N 75° W and dips 25° SW Two pits, 20 meters apart, are opened on the vein About 50 meters to the north, at an altitude of 4,315 meters, a pit is cut on a faulted and steeply dipping vein striking N 30° W. Several centimeters' width of quartz, sphalerite, and galena occur on the fracture About 75 meters southwest of the first vein is a vein opened by an adit 8 meters long It strikes N 60° W. and dips 75°–85° NE , and contains only gouge and pyrite About 75 meters southwest of this vein is a short adit, at an altitude of 4,280 meters, on a vein striking N 55° W and dipping 70° NE The vein contains only pyrite and manganiferous carbonate. In the same gully and about 100 meters to the north are two workings and also an abandoned mine camp At 4,325 meters altitude, an inaccessible adit follows a vein striking N. 20° W and dipping 80° NE Manganiferous carbonate and some sphalerite and galena are seen on the dump Twenty meters S 40° W is the portal of an adit bearing west North of a crosscut 10 meters long, a drift follows a vein striking N 80° E and dipping 50° NW. The vein is from 30 to 50 centimeters wide, and is largely quartz and manganiferous carbonate but contains some sulfides Branching veins strike

N 80° W. and N. 25° W.; these are nearly barren of sulfides. Small ore shoots on the main vein have been stoped

Another group of veins and workings are in the head of the next gully, about 250 meters west of the abandoned camp. The southeastern vein, striking N. 30° W and dipping 10°–15° SW , is from 10 to 30 centimeters wide and contains quartz and oxides It is explored by an 8-meter crosscut adit, which is at an altitude of 4,385 meters Ninety meters to the northwest and at an altitude of 4,400 meters, a shaft is cut on a vein striking N 80° E and dipping 60° NW. The vein is 80 centimeters wide and consists largely of quartz and carbonate, but according to the assay (1621, table 3), contains considerable silver About 100 meters southwest, at an altitude of 4,385 meters, an adit 50 meters in length and bearing N. 10° E., extends to a vein striking N. 65° E. and dipping 60°–75° NW The vein is followed by a drift 18 meters to the southwest and 50 meters to the northeast, and stopes extend from this level to the surface The vein is from 10 to 70 centimeters wide and in unmined segments consists largely of quartz, manganiferous carbonate, and gouge About 80 meters northwest of the shaft, two adits, at altitudes of 4,415 and 4,430 meters, bear northwest to a vein striking N 20°–30° E and dipping 30°–35° NW. The vein, from 15 to 30 centimeters wide, contains quartz and some sulfides To the north, an opencut and a drift follow the vein for a distance of 22 meters An intersecting vein at the northeast end of the workings strikes N. 30° E and dips 35° NW.; it does not displace the main structure

The veins in the western group are described from north to south The northernmost, containing no ore, is opened by one adit. The vein to the south of it, also opened by one adit, has small amounts of ore on the dump The next vein, to the south, the Uchco, is traceable nearly 700 meters, is arcuate, and dips 60°–90° N The uppermost working, an adit at 4,430 meters altitude, follows the vein, which is 1 0 to 1 5 meters wide, for at least 60 meters. Another working, 15 meters lower in altitude, is 60 meters to the east. Downslope and several hundred meters to the west, another adit is at 4,400 meters altitude Little ore was seen in any of these workings The vein south of Uchco is also opened by several adits but contains little ore To the south of it are two parallel veins about 60 meters apart, each opened by several adits Galena, sphalerite, pyrite, and arsenopyrite in quartz are seen on the dumps, but no ore shoots are left in the workings The two veins at the south edge of the group are similarly barren

The veins of the Uchco area are comparatively well explored by means of adits, most of which still are accessible The amount of galena and sphalerite seen in these workings is small and reserves seem to be insufficient to warrant mining However, it is possible that further exploration may reveal some high-grade silver ore.

### CERRO SIERNEN PROSPECT

A prospect high on the north side of Cerro Siernen may be reached by a secondary trail from Laguna Shaullán (pl 1, loc. 37) The area, 14 kilometers west-southwest of Carhuás, is underlain by folded lava flows and tuff.

The vein strikes N 30° E and dips 35° SE Altered and sheared volcanic rock, as much as 30 centimeters wide, contains small amounts of pyrite, sphalerite, galena, and quartz. A pit and caved adit, at an altitude of 4,570 meters, explore the comparatively small deposit.

### BUENA CASHMA AND MANGAN MINES

The Buena Cashma and Mangan mines are at the head of Quebrada Cashma, the west branch of Quebrada Punya. A trail from Carhuás leads directly to the deposits which are 14 to 16 kilometers west of the town (pl 1, locs 38 and 39) The Buena Cashma deposit is just below the trail and on the north side of the quebrada, its lower adit is at an altitude of 4,420 meters The Mangan deposit cuts across Cerro Mangan, a peak at the crest of the range and at the south side of the quebrada Lower workings on the veins are at an altitude of about 4,575 meters Other small prospects extend from southwest of Cerro Mangan to northwest of Buena Cashma

At the Buena Cashma mine, Pflucker (1906, pp. 28–29) found that 4 veins were opened by workings in 1905, of which only 1, the Pilar, had been extensively mined High-grade ore contained 15 kilograms of silver per ton, low-grade ore, 1.5 kilograms of silver per ton. Production from 1902 to 1906 was at the rate of 6 tons per month of high-grade ore. Velarde (1908, p. 64) stated that 70 to 80 tons per month of both low- and high-grade ore were being mined, furnishing concentrates at the rate of 12 tons per month. Neither author mentioned the Mangan deposits, so it is not known if these had been worked out or as yet had not been discovered.

The contact between folded sedimentary rocks of Cretaceous age and the slightly folded group of volcanic rocks trends northwest and lies just southwest of the Buena Cashma deposit. The north end of a belt of the more folded group of volcanic rocks extends to the north side of Cerro Mangan Along the contact between the sedimentary and slightly folded group of volcanic rocks, northwest of Buena Cashma, is a stock of intrusive porphyritic andesite, and a cupola of the same mass is intruded at the north end of the Mangan deposits, near the contact between the more folded and the slightly folded groups of volcanic rocks (pl. 1) The intrusive material grades toward anorthosite where feldspars are numerous and toward rhyodacite where quartz phenocrysts occur.

In the lower level of the Buena Cashma mine, a crosscut bearing N. 60° W and 145 meters in length leads to the veins The Pilar vein is followed by a drift 52 meters to the southeast and 235 meters to the northwest of the crosscut. The vein strikes N. 25° W., dips 60° SW, and is from 10 to 35 centimeters wide in the southeast part of the working. It contains quartz and calcite. To the northwest it strikes N. 25°–35° W., swinging to N 80° W at the caved or filled end of the drift, and dips 50°–60° SW. The vein has been stoped for widths of 0 5 to 1.0 meter at four places in a length of about 100 meters A smaller vein 35 meters southwest of the Pilac vein strikes N 45° W. Seven meters beyond it a second small vein is parallel in strike and dips 55° NE. A third small vein is 10 meters beyond the second, strikes N 25° W and dips 60° SW. None contains recoverable sulfides

The upper level, at an altitude of 4,460 meters, probably corresponds to the working described by Pflucker In 1905 the Pilar vein had been followed 520 meters northwest of the crosscut adit and 35 meters to the southeast The average vein width was 35 centimeters, and about one-third of its length contained a sulfide band 20 centimeters wide. The vein consisted of gouge containing tetrahedrite, galena, sphalerite, and small amounts of pyrite and quartz

Little sulfide was seen in the workings, and only quartz and carbonates, principally rhodochrosite, together with small amounts of pyrite and silver sulfides or sulfosalts were seen on the dumps Evidently all ore has been mined out above the lower level

A small prospect is on the north side of Laguna Cashma, about 2 kilometers northwest of the Buena Cashma mine It consists of a slumped pit at an altitude of 4,550 meters Only quartz and pyrite, in altered andesite, were seen on the dump.

Another small vein lies about 1 kilometer south of Laguna Cashma, on the west side of a small knoll underlain by intrusive andesite The vein strikes north and dips 80°–85° E., transecting the contact between the andesite on the north and a small block of sedimentary rock caught in folded volcanic rocks on the south The south working is a shaft, and 30 meters to the north is an incline. Pyritized manganiferous carbonate and quartz were seen on the dumps Another shaft is 30 meters west of the incline, evidently used to explore another fissure, but only altered andesite was on the dump This shaft is at an altitude of 4,440 meters Commercial sulfides seem to be absent in the area

The Mangan vein crosses the southwest flank of the Cerro, extending several hundred meters southeast and about 1 kilometer northwest of the ridgecrest The northwest part of the vein is along or close to the drainage divide between the upper tributaries of Quebrada Cashma to the northeast and Quebrada Mangan to the southwest Workings on the vein range in altitude from 4,575 to 4,680 meters The vein was most extensively worked on the lower flanks of the northwest side of Cerro Mangan ridge The mine was dormant in 1947 and evidently has been abandoned for some time.

Folded porphyritic rhyolite, or possibly beds of welded tuff, having some interbeds of sandstone and quartz congolomerate, form the host rock. The volcanic material has been strongly propylitized, sericitized, and kaolinized along the vein

The main vein strikes N 30°–40° W and dips steeply southwest Mineralized branching shear planes are common, and the vein zone, averaging from 1 to 2 meters in width, is as much as 8 meters wide at one point Owing to caving and slumping of workings, little of the vein itself may be seen Quartz, calcite, rhodochrosite, alabandite, and pyrite, together with very small amounts of silver sulfides or sulfosalts are among the minerals present No lead, zinc, or copper sulfides were visible

The prospect at the north end of the Mangan vein is several hundred meters south of the prospect in the knoll south of Laguna Cashma The northwest working, at an altitude of 4,590 meters, is a pit 20 meters long The southwest wall is vertical and strikes N. 20° W , in a pit 15 meters to the southeast, the same structure strikes N 30° W The east wall strikes N 40° W and dips 80° NE , it also is exposed in a shaft 30 meters to the southeast The country rock is quartz conglomerate on the southwest wall and altered volcanic rocks on the northeast wall Quartz-carbonate rock, which contains small quantities of silver sulfosalts, is seen on the dump.

Several hundred meters to the southeast are two pits on a shear zone branching from the main vein This branch zone strikes N 65° W and dips 80°–85° SW and consists only of silicified volcanic rock.

Seventy-five meters south of the pits on the branch zone is an outcrop of the Mangan vein, a silicified shear zone 5 meters wide and striking N 35° W Thirty meters southeast, a pit shows the zone, dipping 70° SW , to be 2 meters wide Ten meters southeast of the pit, an adit on the zone follows a vein of calcite 60 centimeters wide. About 175 meters southeast of the pit, at an altitude of 4,580 meters and on the divide between Quebradas Casma and Mangan, a shaft is cut on the Mangan vein where it intersects a spur vein The Mangan vein consists of a silicified zone 1 meter wide The spur strikes N 65° W , dips 70°–80° SW , and similarly is 1 meter wide Silicified and altered rock on it may be traced 40 meters to the southeast Another 75 meters to the southeast on the Mangan vein is a pit disclosing a barren shear zone striking N 35°–40° W and dipping 70° SW An additional 40 meters to the southeast is an opencut on two other branch veins which strike N 50°–55° W , one dipping 80° NE and the other 80° SW Quartz and rhodochrosite, together with a manganese mineral, which probably is alabandite, are on the dump of this working

The main group of workings on the Mangan vein are about 100 meters beyond the prospects just described Several inaccessible adits are found in a zone several hundred meters in length along the strike. Quartz-carbonate gangue, in part manganiferous and including pyrite, are on all dumps

Between the main workings and the crest of the Cerro Mangan ridge are several prospect pits The altered shear zone along the vein is 8 meters wide in the saddle where the vein crosses the ridge The vein is traceable several hundred meters south of this point.

Another small prospect is in the ridge on the northwest side of Quebrada Mangan, about 1 kilometer S. 60° W. of the main workings on the Mangan vein. The working is an adit 16 meters long, opened at an altitude of 4,650 meters. It follows a vein striking N. 50° W. and dipping 85°–90° SW.; the vein is from 5 to 20 centimeters wide and contains gray calcite, quartz, pyrite, sphalerite, and galena Near the face of the working, a small shoot on the wider part of the vein has been stoped upward for several meters

Owing to the inaccessibility of the main workings, the minerals in the ore mined from the Mangan vein are not known Lead, zinc, or copper sulfides were not seen on the dumps, but this is true also at the Buena Cashma deposit, where earlier descriptions by Pflucker indicate they were present in the ore It is surmised that they were comparatively scarce, and, as at Buena Cashma, ore containing a high tenor of silver probably was the chief product The Mangan vein is one of the largest in the Cordillera Negra, so reopening of some some adits may show whether additional exploration in the area is warranted.

## MINES AND PROSPECTS, PUEBLO LIBRE DISTRICT

A group of deposits are from 2 to 5 kilometers southwest of Pueblo Libre, a hamlet at an altitude of 2,500 meters and 7 kilometers south of Carás The stream draining this area is one of the larger tributaries in the Cordillera Negra of the Río Santa; the valley is known as Quebrada Huashcap in its lower reaches and as Quebrada Chanahuasai in its southern extension The mines immediately southwest of Pueblo Libre (pl. 1, loc 40) range in altitude from 2,800 to 3,300 meters. Those farther west and southwest (pl 1, locs 41 and 42) are at altitudes from about 3,600 to 3,800 meters. All are accessible via trails from the Santa Valley.

The district had not been developed in the 1860's when Raimondi (1873, p. 101) was visiting the mines in the Cordillera In contrast, it was reported by Velarde (1908, p. 63) that 14 mines were being worked in the early 1900's and that 250 men were employed. All the old mines seem to have been worked out, caved, and abandoned, and inhabitants of the area no longer remember the names of the various workings Table 6, translated after Velarde, indicates that high tenor of silver in oxidized ores characterized the major production.

From this it is assumed that most workings were comparatively shallow If the more recent and accessible deposits are representative of the district, it may also be inferred that the ore shoots in the old mines were comparatively small

In 1947 only the Buena Fe and Atahualpa mines were in operation

TABLE 6 —*Mines and nature of ores in deposits worked in early 1900's near Pueblo Libre*

[Translated after Velarde (1908, p 63)]

| Mine or mines | Tenor of ore | Description |
|---|---|---|
| El Topacio | 9–10 kilograms silver per ton | Values in oxidized ore, tetrahedrite also present |
| Monserrate, Santa Rita, Libertador | 6–7 kilograms silver per ton | Do |
| Trinidad, La Porfía | | Oxidized ores |
| Recompensa, La Carmen | 1 5 kilograms silver per ton | Oxidized ores and argentiferous galena |
| Tres Amigos | 1 kilogram silver per ton, and 20 grams per ton gold | Oxidized ores |
| Cuatro Naciones | 1–2 kilograms silver per ton and 22 percent copper | Do |
| Tublacaín | 0 6 kilogram silver per ton and 25–30 percent copper | Do |
| Independencia | 2–3 kilograms silver per ton and 35 percent copper | Oxide and sulfide ores |
| Apóstol Chico, Santiago | 2 5–3 0 kilograms silver per ton | Argentiferous galena |

Rocks in the area, interbedded quartzite, sandstone, and dark shale, are part of the lower Neocomian sequence of Steinmann and are closely folded and irregularly crushed and faulted Their dominant strike is northwest but locally is west-northwest. Six kilometers southwest of Pueblo Libre is a small stock of granite, about 1 5 kilometers in diameter Near the main group of deposits, several small dikes cut the sedimentary rocks, but are so highly altered that their original composition could not be determined

### BUENA FE MINE

The Buena Fe mine, owned by Octavio Gastelmendi, is 4 kilometers southwest of Pueblo Libre, on the southeast side of a tributary valley locally known as Quebrada Huapulahuran It is in the southeast corner of the group shown at locality 40, on plate 1 Workings range from 3,060 to 3,235 meters in altitude The mine was in operation in 1947.

The deposit consists of three veins striking north to north-northwest and dipping northeast, in a belt trending east-northeast and about 500 meters long. Minerals in the veins include sphalerite, galena, pyrite, arsenopyrite, and quartz The veins are shear zones as much as 1.5 meters wide, but mineralized bands therein generally are less than 0 5 meters wide Ore shoots are comparatively small both in horizontal and vertical extent

The southwestern vein is opened by an adit 20 meters long at an altitude of 3,205 meters. The working is on a vein striking north and dipping 65° E at the portal, swinging in strike to N 25° W at the face A shear zone in quartzite is from 40 to 80 centimeters wide but contains only a thin band of quartz with minor sulfides.

The principal adit on the main vein is 150 meters N 60° E of the portal of the southwest vein The adit, at an altitude of 3,160 meters, consists of a crosscut about 170 meters in length which bears N 40° W The vein strikes N 25°–30° W and dips 50° NE The drift at this level follows the vein a short distance to the northwest and 100 meters to the southeast In this length the vein is largely quartz and pyrite, from 5 to 15 centimeters wide, occurring in a shear zone from 0 5 to 1 0 meter wide Ore of a short underhand stope at the southeast end of the drift, 15 meters deep and from 0 5 to 1 0 meter wide, was being mined in 1947 Upslope and about 90 meters northwest of the principal adit is a second adit on the vein It is at an altitude of 3,205 meters, bears S 60° W , and is inclined downward at an angle of 30° Only small amounts of quartz were seen on the dump About 80 meters west of the incline and at an altitude of 3,235 meters, a short crosscut extends to the vein Material on the dump from this working similarly is low in quartz and also in sulfide content

The portal of the crosscut to the northeast vein is at an altitude of 3,060 meters and about 200 meters north of the principal adit on the main vein The crosscut is 170 meters long and bears north; the drift follows the vein for a few meters to the northwest and 65 meters to the southeast At the intersection of the crosscut and drift, the vein strikes N 35° W and dips 65° NE To the southeast it curves southward and hooks to N 10° E strike and 85° SE dip at the face of the working The vein is nearly barren of sulfides

About 0 5 kilometer west of the Buena Fe mine are a group of abandoned workings on the south side of Quebrada Huapulahuran Most are cut in quartzite that strikes N. 70° W. and dips 40° SW One of the veins, 0 5 meter wide and containing only quartz and pyrite, was opened by several adits over a vertical extent of 30 meters The vein strikes N 45° W and dips 75°–85° SW The workings in this area may be one or more of the mines mentioned by Velarde

#### ATAHUALPA MINE

On the north side of Quebrada Huapulahuran. about opposite the abandoned workings, are several adits, one of which was being operated in 1947 by Sr Gastelmendi The southernmost adit, at an altitude of 3,210 meters and 110 meters long, is known as the Atahualpa mine It follows a vein striking N 25°–30° W and dipping 55°–70° SW , 75 meters from the portal the strike changes to N. 50–55° W. The vein, only 10–15 centimeters wide, occupies a shear zone 35 centimeters wide At the end of the working, a short lens as much as 35 centimeters wide consisting of quartz and sulfides, was being stoped at the time of our examination About 30 meters north of the portal and at an altitude of 3,230 meters is a caved adit on the same vein

Thirty meters N 30° W of the main Atahualpa adit and at the same altitude is an adit known as the Progresso prospect The working is 110 meters long and bears N 40° W Three barren shear zones, striking N 40–50° W. and dipping 40°–80° SW , are exposed in the adit At its end is a narrow pyritized shear zone containing small amounts of galena and pyrite The mineralized structure is vertical and strikes N. 10° E.

### SANTA RITA MINE

The Santa Rita mine is an adit at an altitude of 3,280 meters, about 130 meters north of the Atahualpa adit The working is stoped and caved 20 meters from the portal Within the accessible part of the drift, the vein strikes N 40° W and dips 15°–20° SW , it is only from 10–20 centimeters wide This deposit was mentioned by Velarde (p. 63).

### ANIMUS AND SOCAVONERA PROSPECTS AND SANTA ROSA MINE

About 1 kilometer north of the Atahualpa deposit, just south of a trail from Pueblo Libre and near the crest of the spur between Quebrada Huapulahuran and the valley to the north, are two caved adits and other small workings, known as the Animus prospect The altitude is about 3,200 meters Only pyrite and quartz were seen on the dumps About 250 meters to the northeast and at an altitude of 3,000 meters is a flooded adit trending S 65° W This working is the Socavonera prospect The dump is large but is principally shale, together with small amounts of pyrite and quartz

A short distance to the west and from 30 to 50 meters higher are six caved adits that are said to be the Santa Rosa mine. Only pyrite and quartz are left on the dumps

Still another prospect or abandoned mine is about 1 kilometer to the east, several hundred meters west of the junction of Quebrada Huapalahuran and the quebrada on the north side of the spur. Its workings also are inaccessible.

### SANTA DAMILIA PROSPECT

The Santa Damilia prospect is higher on the same spur, at an altitude of 3,800 meters and 6 kilometers west-southwest of Pueblo Libre, and is just south of the trail from that hamlet (pl 1, loc. 41). Quartzite, striking N 40° W and dipping 60° SW , is cut by a vein with a strike of N 65°–70° E and a dip of 70° SE. The vein was mined from an open stope 30 meters long and as much as 1 meter wide Unmined parts of the vein consist of quartz only 10 centimeters wide Pyrite and enargite occur in the quartz now seen on the dump. Evidently all ore was removed from the one shoot located on this vein

#### RAYOS-X PROSPECT

The tributary valley south of Quebrada Huapulahuran locally is known as Quebrada Pacchac Several prospects are in quartzite and shale just west of the granite stock occurring in this area (pl. 1, loc 42)

The Rayos-X prospect is just north of the stream and at an altitude of 3,570 meters. The contact with granite is 50 meters east of the mouth of the largest working. Sandstone, quartzite, and carbonaceous shale in the area strike N 25° W. and dip 55° SW. Several veins and unmineralized shear zones, with northwest strikes, are opened by small workings Sulfides of lead, zinc, and copper were not visible in any exposures

Along the stream, the most easterly working is a short trench and adit on a vein striking N 45° W. and dipping 75°–80° NE The sheared and altered zone pinches and swells to widths of 1 meter. Only pyrite and small amounts of quartz occur in the vein. Fifteen meters to the northeast and higher on the slope, a vein strikes N 25° W and dips 55° SW It contains quartz and pyrite in widths from 5 to 25 centimeters Ten meters west of the lower vein is the mouth of a cut 20 meters long, the largest working of the prospect It follows a shear zone from 1 to 2 meters wide which strikes N. 55°–60° W. and dips 80° NE The degree of mineralization seems to be slight An adit 17 meters long from the back of the cut leads to a vein striking N. 15° W and dipping 65° NE.; it contains 5 centimeters of quartz and pyrite. Seven meters west of the mouth of the cut, several small adits follow a shear zone striking N 50° W. and dipping 70°–75° NE All these veins seem to be nearly barren.

Another prospect, about 250 meters north of the stream and also at an altitude of 3,570 meters, is about 10 meters west of the granite contact A short incline bearing west cuts quartzite and shale but no vein minerals were found in the workings

Close to the contact with granite, carbonaceous shale locally contains pockets of graphite which have been prospected by means of several small pits

#### CERRO CHAQUICOCHA MINE

A small deposit containing galena, sphalerite, and some chalcopyrite in a gangue of carbonate, pyrite, and altered volcanic wall rock is on the west side of a small knoll on the ridge forming the divide of the Cordillera Negra, about 1.5 kilometers north-northeast of Cerro Chaquicocha (pl 1, loc 43). The deposit is about 13 kilometers west of the town of Yungay, and may be reached by a little-used trail extending from the head of Quebrada Chanahuasi, south of Pueblo Libre, to the Colquipocro mine Its altitude is 4,650 meters

The vein is vertical and strikes north Branching veins strike northeast and northwest and dip 45°–85°. The veins are only weakly mineralized and all are narrow The country rock is trachytic flow breccia which has been epidotized and which is strongly propylitized close to the main vein A pit 2 meters long and an adit 5 meters long have been cut on the deposit The exposures indicate very small quantities of recoverable minerals

### CERRO CHACAY PROSPECTS

Several prospects are along the Pueblo Libre-Colquipocro trail, about 1 kilometer east of the pass at Cerro Chacay and 8 kilometers west of Pueblo Libre (pl 1, loc 44) The prospects along and above the trail are at an altitude of 3,900 meters Only sedimentary rocks crop out in the area, and consist of shale and quartzite lying just above the upper limestone of the lower unit of Steinmann's Barremian sequence. Prevailing dips are 55°–65° W. and SW , and the beds are broken by many small faults

The prospect below the trail consists of an inclined adit bearing S 75° E. and about 6 meters long It follows a weak shear zone about 1 meter wide which strikes N. 75° W. and dips 40°–80° SW A quartz vein from 2 to 20 centimeters wide containing small amounts of pyrite and galena, occurs along the footwall Just above the incline and on the trail, a short adit follows a vein striking N 15° W and dipping 75° NE The vein consists principally of about 40 centimeters of silicified wall rock but this pinches out in a short raise near the face of the working

To the southeast of the incline and in a gully above the trail, a caved adit bears S 60° W Some pyrite and quartz are on the dump. Several meters north of the portal, two faults strike N 35°–40° E. and dip N 75°–80° NW , no ore minerals were seen in the outcrops

It is probable that no ore shoots occur in the area

### COLQUIPOCRO MINE

The Colquipocro mine, on the south side of Quebrada Cajabamba (or Quebrada Chorilloran), is 18 kilometers southwest of Carás and about 9 kilometers west of the crest of the Cordillera Negra (pl 1, loc. 45). The nearest settlement is Cajabamba, in the quebrada 4 kilometers east of the mine, formerly the site of beneficiation plants processing ore from the deposits Trails from Carás, Pueblo Libre, and Pamparomas, a hamlet 7 kilometers to the northwest, lead to the mine Workings on the veins range in altitude from 3,750 to 4,200 meters.

The mine probably has been one of the major sources of silver ore in the Cordillera Negra In 1868, Raimondi (1873, pp 112–113 and 493–496) found the deposits being worked by many independent operators At that time native silver, silver sulfides, and pyrargyrite were abundant. Velarde (1908, p. 61) stated that in the first decade of this century ore contained between 8 and 20 kilograms of silver per ton The L J. Rosenshein interests worked the deposits in the 1930's and another concern was mining on a small scale in 1947. Most of the larger ore bodies have been mined, and present production comes from small blocks having a much lower silver content than was mined in the past

Volcanic rocks, principally andesite flows, predominate in the vicinity of the deposit In the north end of the area massive rocks which may be intrusive, are in the andesite range of composition, grading in part toward rhyodacite where small amounts of quartz are present. Along the east edge of the massive block, the rock is fine-grained and brecciated, but near the portal of the Toro vein, it is coarsely porphyritic Both the layered and massive rocks are altered along veins Much is strongly propylitized and part is silicified and sericitized

In 1947, proustite was the chief ore mineral. Most of it is associated with calcite, and in addition some pyrite and small amounts of galena, sphalerite, and quartz occur in the veins. Raimondi and Velarde also reported the presence of tetrahedrite, chalcopyrite, chalcocite, pyrargyrite, and native silver, as well as other silver sulfide minerals which evidently were removed during later mining operations

Most veins dip steeply and strike north-northwest They occupy an area 1,200 meters long and 900 meters wide (fig 14) The Toro vein, the longest, is traceable for 900 meters and averages 1 meter in width It is sinuous, with an overall strike of N 20° W and a steep northeast dip The principal adit is at its north end, at an altitude of 3,750 meters Near its south end it is opened by a crosscut at an altitude of 4,100 meters Ninety meters west of the Toro is the Descubridor, which strikes N 40° W. and dips 60° NE The vein is from 1 to 2 meters wide The Balcón vein, 130 meters west of the Toro, strikes N 20° W and dips 80° SW. The Animas vein is 280 meters west of the Toro. Its strike is N 15°–20° W and it dips 80°–90° SW Of these western veins, only the Descubridor is cut in the crosscut at 4,100 meters altitude, but several smaller veins also are exposed in this working

Smaller veins occur east of the Toro The crosscut at 3,800 meters altitude provides access to a vein striking N. 35° E and dipping 60°–90° SE. A cross vein strikes N 20° W and dips 65° NE. The adit at the east edge of the area, at an altitude of 3,900 meters, is accessible for only 40 meters, so the vein in this area was not seen The upper adit east of the Toro vein, at an altitude of 4,000 meters, follows branching veins striking N 10° W. and N 30° W.

Raimondi and Velarde mentioned the Toro, Animas, and Balcón veins, and also listed the Pozos Ricos, San Antonio, Rosario, and Jardín Most of the latter probably are the veins east of the Toro vein

Although silver ore will permit continued mining on a small scale, base-metal content of the veins is low.

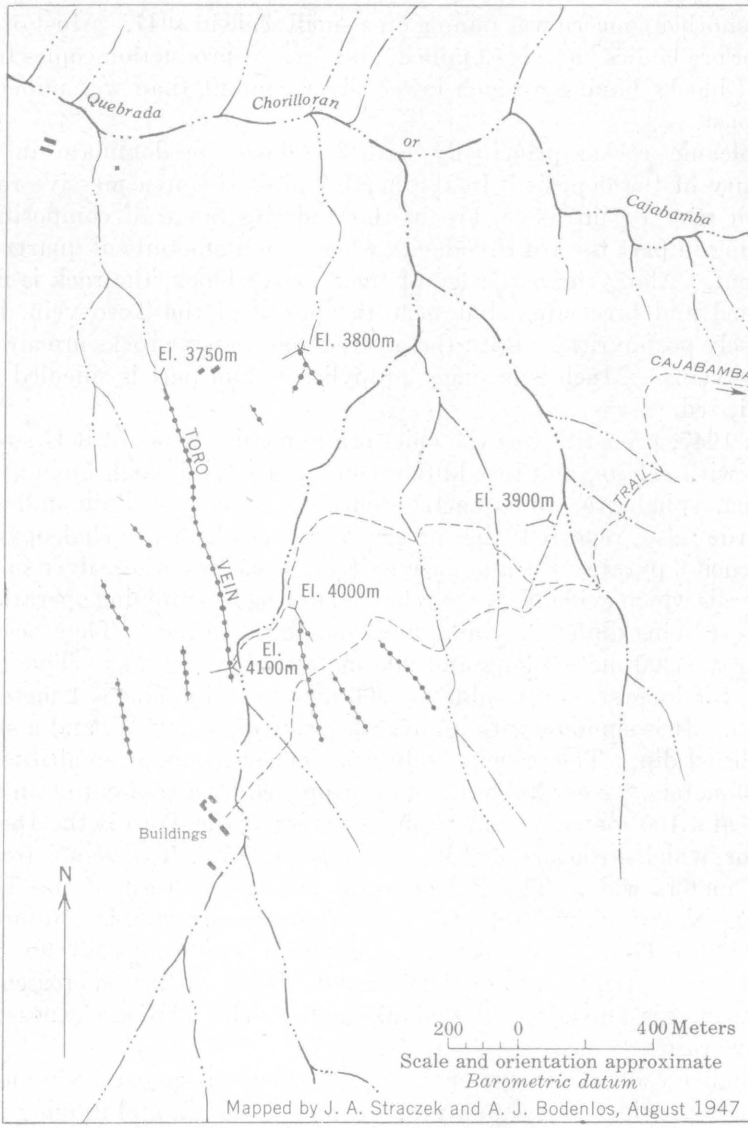


FIGURE 14.—Sketch map of veins, Colquipocro deposit.

## CHACUOPAMPA MINE

The Chacuopampa mine, at an altitude of 4,500 meters, is near the north end of the Cerro Aquilpampa ridge (pl. 1, loc. 46). The area is 14 kilometers southwest of Carás and 5 kilometers east of Colquipocro, and is accessible by trail from Cajabamba and Colquipocro. It is owned by Máximo Kam, of Chimbote, and is said to have been worked in 1941 and 1942.

Dark gray limestone with some interbedded shale, of middle Cretaceous age, underlies the area. The sedimentary rock strikes N. 5° E. and dips 55° W. Several dark, fine-grained, monzonite porphyry sills form prominent outcrops near the deposit The largest, 10 meters in width and several hundred meters in length, is just west of the vein, and smaller ones, from 1 to 2 meters in width, are in a zone from 10 to 20 meters east of the vein.

The vein which follows a bedding-plane fault is as much as 40 centimeters wide and contains galena, chalcopyrite, enargite, quartz, and calcite, as well as angular breccia fragments of limestone and shale. The minerals are banded, calcite and vuggy comb quartz occurring along the walls of fissures.

The deposit is opened by a trench 55 meters long. At its north end, an adit cuts under the surface working It is said to be 30 meters long but in 1947 was flooded. About 45 meters to the north is an exploratory pit in unmineralized limestone It appears that the one ore shoot in the vein was mined out above the adit level.

### PROSPECT ON CERRO AQUILPAMPA

A prospect about 2 kilometers south of the Chacuopampa mine is high on the southeast flank of a peak of the Cerro Aquilpampa ridge (pl 1, loc 47) The area may be reached by a secondary trail extending from Cajabamba on the north to the trail crossing the Cordillera about 2 kilometers to the south The altitude of the prospect pit on the deposit is 4,650 meters

Gray limestone in this area strikes N 25° W. and dips 45° SW It is intruded by sills and by a plug of fine-grained rhyolite. The prospect pit is on a vein striking east, dipping 85° S , and transecting the east contact of the plug. Only small amounts of pyrite were seen in the vein

### CAPALO MINE

The Capalo mine, at the south end of the Cerro Aquilpampa ridge, is 200 meters north of a major trail crossing the range from Yungay (pl 1, loc 47). The area is 18 kilometers west of Yungay and 8 kilometers southeast of Colquipocro. The altitude of the south pit is about 4,600 meters

Country rock in the area consists of a sequence of alternating beds of sandstone, shale, and limestone, which strikes N. 20° W. and dips 50° SW Strongly altered rock along part of the vein may be an intrusive sill

The vein occupies a bedding-plane fault It pinches and swells and small sulfide-bearing ore shoots are as much as 40 centimeters wide Minerals in the vein are galena, sphalerite, pyrite, quartz, and calcite; sheared and bleached shale and sandstone also form part of the gangue A chip sample across a lens 35 centimeters wide shows 638 grams of silver per ton, 9 5 percent lead, and 8 5 percent zinc (analysis 1622, table 3)

The southeastern working is a pit 4 meters long and a short drift Several meters to the north are an inclined shaft and other pits At one point the sulfide-bearing zone is from 5 to 10 centimeters wide A crosscut adit 35 meters to the east and 10 meters lower in altitude is 49 meters long and bears N 81° W To the southeast of the crosscut, the drift was stoped upward and walled off The drift to the northwest is 15 meters long, and was stoped downward by means of a small winze, now flooded Shear-plane walls are short and irregular and lenses of ore are small The vein pinches out at the northwest end of the drift

Reserves in the mine are judged to be small, but the assay indicates the ore is relatively high-grade

### PROSPECTS ON CERRO ANANPUNTA

On the south slope of Cerro Ananpunta, the ridge south of the Yungay trail, are two prospects, one about 1 kilometer due south of the Capalo mine, and the other about 0 5 kilometer northeast of the first (pl 1, loc 48) The deposits are about 9 kilometers southeast of Colquipocro and may be reached by branch trails

The southwest deposit, at an altitude of 4,550 meters, is near the crest of the ridge, within a few meters of a trachyte plug Beds of shale in which the vein occurs strike N 10° W and dip 60° SW The vein is parallel in strike but dips 50° SW. The shear zone is as much as 30 centimeters wide but only a few centimeters of this consists of sulfides The comparatively small deposit is opened by a drift 22 meters long

The northeast deposit is at an altitude of 4,500 meters Sandstone and shale there strike N 5° W and dip 60° W The vein strikes N. 55° E and dips 80° NW It is as much as 50 centimeters wide but contains only small amounts of quartz and pyrite The deposit is opened by a crosscut 20 meters long and bearing N 55° W , and by a drift about 8 meters in length.

### SANTA ROSA MINE

Workings of the Santa Rosa mine are downslope from the southwest Cerro Ananpunta prospect, in a valley locally known as Quebrada Tranca The area is 19 kilometers west-southwest of Yungay and between 9 and 10 kilometers southeast of Colquipocro (pl 1, loc 49) Two groups of workings are 700 meters apart and between them is a prospect on another small vein The workings are among the most extensive in the area southeast of Colquipocro, but were dormant in 1947.

Sedimentary rocks in this area consist of impure quartzite and shale, as well as a few beds of limestone They strike just east or west of north and dip 75°–80° W.

Three groups of workings are on the southern deposit The southernmost is a shaft cut on an unmineralized altered dike, which is about 1 meter wide and which strikes N 45° E About 100 meters to the north and at an altitude of about 4,300 meters is the main adit. The second adit is 50 meters northwest of the main adit Two small veins were mined from these and from connecting surface stopes and shafts. Minerals in the veins include pyrite, pyrrhotite, galena, and sphalerite, and clay gouge provides part of the gangue

The southeast adit is 50 meters long and bears N 18° W , parallel to the bedding of impure quartzite, and provides access to a vein striking N 75°–80° E and dipping 65° NW Southwest of the crosscut the vein, which is as much as 60 centimeters wide, was stoped upwards; at places a band of solid sulfide 15 centimeters wide remains on the hanging wall In the short drift northeast of the crosscut, the vein contains only clay gouge From the surface 15 meters above, pits and open stopes connect with the drift and evidently were cut in small lenses which were mined out The largest lens seems to have been about 15 meters long

The northwest adit is 16 meters long and bears N 7° E , reaching a vein striking N. 70° E and dipping 80° NW A stope on the vein connects with a shaft on the surface 10 meters above, the ore shoot seems to have been 30 centimeters wide and several meters long.

About 300 meters north of the south workings and in a tributary gully is an inaccessible adit bearing N 50° E Only bleached shale and small amounts of pyrite are on the dump The shear zone at the portal parallels the adit and dips 75° NW

The northern deposit is at an altitude of about 4,400 meters and just above a fork in the quebrada Thin-bedded shale and impure quartzite in the area strike N 15° E and dip 70° NW The vein, about 50 centimeters wide, strikes N 50°–55° E and dips 70°–75° NW The principal working is an opencut 50 meters in length. At its northeast end is an inclined shaft and 10 meters beyond its lower end is a crosscut driven below the surface working. Ore stockpiled on the dump has a large content of sulfides but also contains some crystalline vuggy quartz In order of their abundance, the sulfides in the ore are pyrite, dark sphalerite, galena, arsenopyrite, and silver sulfide minerals A grab sample from the stockpile assays 573 grams silver per ton, 3 4 percent lead, and 5 4 percent zinc (analysis 1623, table 3) The ore shoot seems to be mined out above the lower crosscut

### INGENIO MINE

The Ingenio mine, at an altitude of 3,900 meters, is at the junction of Quebrada Tranca and a main tributary valley of Quebrada Pishac, about 1 kilometer south of the south Santa Rosa workings The country rock is flaggy limestone of middle Cretaceous age, which strikes N 20° W. and dips 80° SW. The only working is a surface cut and a caved adit, driven parallel to the strike of the limestone Several tons of mined material consist principally of pyrite together with small amounts of galena and dark sphalerite In the walls of the cut the limestone is slightly altered and pyritized. A small mill or furnace, now in ruins, is near the working

The nature and size of the vein and ore shoots could not be determined from present exposures

On the southeast side of the larger tributary valley and 200 meters upstream from the Ingenio mine is an inaccessible adit on a vein in quartzite The adit follows the bedding which strikes N 30° W and dips 80° SW. Only small amounts of minerals are on the dump Another fault, 20 meters east of the adit, strikes N 40° E and dips 85° NW.; it is barren of vein minerals.

### PIEDRA IMÁN MINE

The Piedra Imán mine, owned by Losilo Ramírez, is 16 kilometers west-southwest of Yungay, in the headwaters of the northeast tributary of Quebrada Pishac and on the southwest side of the ridge known as Cerros de Hueco (pl 1, loc 50) The area is just west of the crest of the ridge and at an altitude of 4,550 meters It is within 1 kilometer of the trail from Yungay The deposit is said to have been worked as recently as 1940

The sedimentary rocks in this vicinity are limestone, limy shale, and a few beds of thin, impure quartzite They are folded in a north-plunging anticline, and at the deposit strike northwest and dip both northeast and southwest Southeast of the deposit they are intruded by the large granitic stock underlying Cerro Chaquicocha At the deposit small irregular masses of trachyandesite crop out and nearby is a dike of probable dioritic composition Limestone fringing the trachyandesite masses has been irregularly dolomitized and silicated, containing much coarse-grained actinolite and some garnet and quartz All igneous masses in the mine area are altered and also contain some actinolite

Piedra Imán is a small replacement and fissure-filling deposit The altered country rock is fissured along planes striking N 70° W and dipping steeply northeast Mineralization was most intense along these fractures, one of which contains a vein as much as 50 centimeters wide Disseminated sulfides form irregular, low-grade masses both in metamorphosed sedimentary rock and in altered trachyandesite (fig 15) Minerals are chiefly pyrite and pyrrhotite and some galena, sphalerite, quartz, and calcite The mineralized area measures only 6 by 13 meters In 1947 the shaft to the stope was caved

A patch of about 10 square meters contains sulfides in another block of silicated limestone 50 meters to the northwest

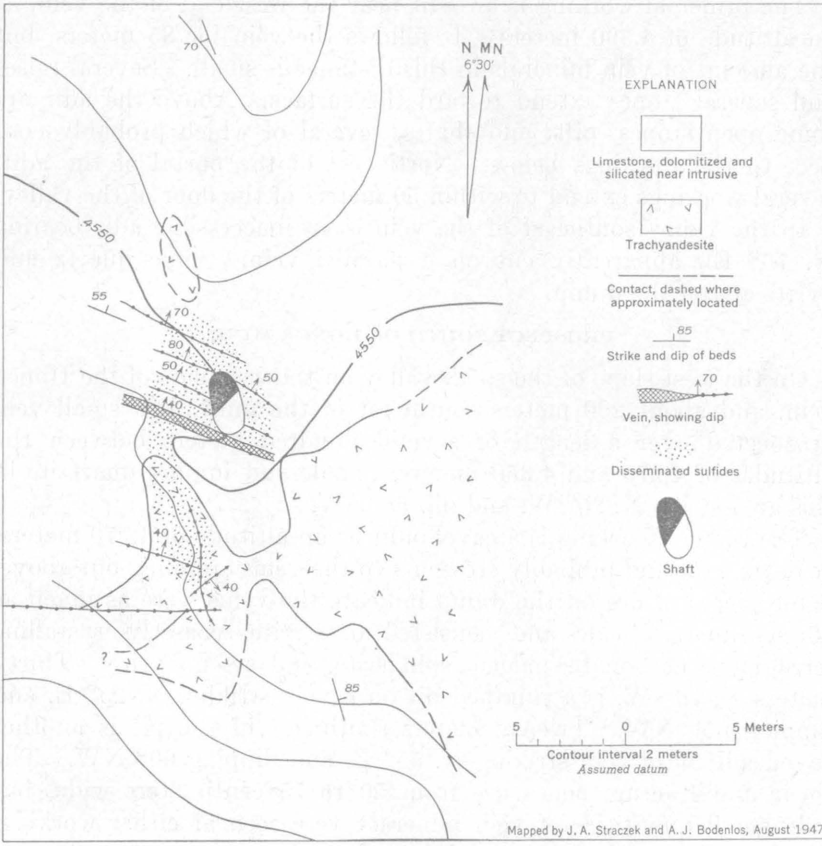


FIGURE 15.—Geologic sketch map, Piedra Imán deposit.

## HONCA PROSPECT

The Honca prospect is between Piedra Imán and Ingenio, and is 17 kilometers west-southwest of Yungay (pl. 1, loc. 51). The vein crosses a ridge between two sharply incised valleys which join a few hundred meters below the mineralized zone. A secondary trail from the Yungay trail affords access. Workings range from 4,350 to 4,420 meters in altitude. The deposit has been thoroughly prospected but sulfides are scarce; the mine seems to have been abandoned for some time.

Quartzite and shale on the west limb of a large anticline strike from N. 10° W. to N. 20° E. and dip 35°–55° W. The vein strikes N. 65°–80° E., swinging to N. 20° E. at its northeast end, and it dips 55°–70° NW. The vein is thin, generally from 10 to 15 centimeters wide and occupies a shear zone about 1 meter wide. Throughout most of the workings only quartz and pyrite were seen, but on several dumps some calcite and sphalerite occur with these minerals. The vein is traceable several hundred meters.

The principal working is an adit near the west end of the vein, at an altitude of 4,390 meters It follows the vein for 85 meters, but the amount of vein minerals in this distance is small Several raises and several stopes extend toward the surface Above the adit are some open stopes, pits, and shafts, several of which probably connect to the workings below Northwest of the portal of the adit, several workings extend to within 50 meters of the floor of the valley

In the valley southeast of the vein is an inaccessible adit bearing N 75° E, apparently cut on a parallel vein Some quartz and pyrite are on the dump

### PROSPECT SOUTH OF HONCA MINE

On the west slope of the small valley on the west side of the Honca vein, and about 200 meters southwest of the mine, is a small vein prospected over a length of several hundred meters between the altitudes of 4,270 and 4,350 meters Shale and impure quartzite in this area strike N. 20° W and dip 55° SW

The eastern working is a caved adit at an altitude of 4,270 meters It bears west and probably crosscuts to the veins cropping out above Some pieces of ore on the dump indicate the veins were as much as 35 centimeters wide and consisted of pyrite, coarsely-crystalline ferruginous carbonate, galena, sphalerite, and arsenopyrite Thirty meters N 70° W is a slumped pit on a vein striking N 25° E and dipping 65° NW Twenty meters southwest of the pit is another caved adit on a vein striking N 55° E and dipping 60° NW The shear and fracture zones are from 50 to 75 centimeters wide, but only small quantities of vein minerals were seen at either working

Several hundred meters to the southwest are a group of pits and inaccessible underground workings cut on a vein striking N 50° E The structure dips 50° NW lower on the slope and 70° NW. in the upper workings Very little ore was seen in the few exposures on this vein.

Ore seems to have been comparatively scarce in these prospects

### RUMICHACA MINE

The Rumichaca mine is low on the north side of a valley locally known as Quebrada San Bernaldo, a northeast tributary of Quebrada Pishac just southeast of the quebrada in which the Ingenio deposit occurs The area may be reached by a branch of the Yungay trail that descends the Quebrada Pishac and by a spur trail ascending Quebrada San Bernaldo The mine is 18 kilometers west-southwest of Yungay, and the lower adit is at an altitude of 3,930 meters (pl 1, loc 52).

A small mass of light-gray fine-grained andesite intrudes vertically dipping shale and interbedded sandstone which strike N 60° W

The vein is in the intrusive, strikes N 70°–85° E , and dips 30°–50° NW. It contains vuggy comb-quartz, pyrite, galena, and sphalerite; altered wall rock is pyritized The lower adit is a crosscut bearing N 15° E. The upper adit, 7 meters higher, bears N 15° W At the end of a crosscut 25 meters long, the working drifts along the vein for about the same distance The inner 16 meters is stoped downward for 20 meters Narrower parts of the vein, left in pillars, are 15 centimeters wide

The deposit is said to have been worked from 1941 to 1943; probably the ore shoot was mined out during this time We could not determine from exposures whether additional bodies of ore occur in the vein

### ANCUSHTRANCA PROSPECT

The Ancushtranca prospect is in a quebrada of the same name that is the south fork of Quebrada San Bernaldo On the Huarás quadrangle map, the valley is erroneously shown as a tributary of Quebrada Pishac. The deposit, at an altitude of 4,400 meters, is 16 kilometers west-southwest of Yungay and may be reached by descending the valley from the Yungay trail (pl 1, loc 53) The workings are in a narrow and rugged part of the valley and low on its north wall

Massive andesite lava flows and agglomerate of the upper group of the volcanic sequence form the country rock At the deposit the andesite is epidotized and chloritized

A group of irregular short fractures, striking north, northwest, and northeast and dipping 25°–85°, break the andesite in an area 6 by 3 meters. The main fracture is vertical and strikes N. 55° E. All but it are truncated above by a horizontal fracture and the various smaller fractures are complexly terminated at their intersections. Along this group of fractures, quartz and sulfides, principally sphalerite, fill openings and also replace altered andesite

The deposit was worked for several months in 1935, during which period a surface cut and an irregular room 3 by 3 meters were mined A small tonnage of ore remains in the locality but owing to heavy surface cover of talus, the extent of sulfide minerals could not be determined Because most ore occurs at intersections of weak fissures, it is not likely that large ore bodies are present.

### CERRO PUTACA PROSPECT

The Cerro Putaca prospect is on the southeast flank of the peak, about 5 kilometers northeast of Colquipocro and 15 kilometers west-southwest of Carás. Its location on the index map is approximate because the topography is generalized in an area of rugged terrane (pl 12, loc 54). It is on the south side of a lake in a glaciated valley, at an altitude of 4,600 meters Access is difficult, but the prospect may be reached on foot by ascending the valley from Quebrada Cajabamba.

Country rock is fine-grained porphyritic andesite The vein strikes N 50° W., dips 55° NE , and is opened by an adit 16 meters long The fracture zone is as much as 1.5 meters wide but the zone of altered volcanic rock is only 15 centimeters wide No vein minerals were seen in the working and only silicified rock containing pyrite was on the dump. Possibly the vein was prospected for silver.

## THE NORTHERN AREA

The northern area contains the fewest mineral localities of the three divisions, and it seems to have been the least actively mined Only one large deposit, Patara, occurs in this part of the range; it evidently was energetically worked in the last half of the 19th century but has been dormant for years The only deposits being worked in 1947 were the Portachón, by Sr Henrique Chaves, and the Diomedes, by Sr. Pedro Villar

### CERRO PALTAC PROSPECTS

Two groups of prospects are on the north slope of Cerro Paltac and in the south tributaries of Quebrada Cashcarana The area is 4 kilometers south-southwest of the hamlet of Ancoracra and 6 kilometers west-northwest of the village of Huata (pl 1, loc. 55) The prospects are just south of the Huata-Pamparomas trail and also may be reached from Villa Sucre in the Santa Valley via trails passing through Ancoracra The altitude of the prospects is about 4,500 meters

The prospects are in granodiorite and quartz diorite near the south margin of the apophysis of the Cordillera Blanca Batholith The western group consists of three small workings, in which only iron oxides were seen in sericitized wall rock The western of these is a pit on a vein striking N 80° E and dipping 80° SE , and which consists of an altered and silicified zone 1 meter in width A short incline 20 meters to the east is on a vein parallel in strike and dipping 60°–70° SE The wall rock is sheared and altered for a width of 30 centimeters Thirty meters to the north-northeast is a pit at the contact between the intrusive and the volcanic rocks The vein explored in this area strikes N 85° E to N 85° W. and dips 70°–85° N , and consists of silicified and altered rock 20 centimeters wide in a fracture zone 1 5 meters wide

The eastern group of prospects is less than 1 kilometer east-northeast of the western and in the adjacent valley Three inclined shafts, each about 4 meters deep, are cut in a distance of 22 meters They are opened on a zone of sheared and altered granodiorite which strikes N 65° E and dips 80° SE Although the zone of deformation is as much as 3 meters in width, sericite and limonite occur along fissures and in maximum widths of 25 centimeters.

### CERROS CULEBRILLA MINE

Abandoned workings on the southwest flank of Cerros Culebrilla, 4 kilometers north of Ancoracra and 8 kilometers northwest of Villa Sucre, occur between the altitudes of 4,220 and 4,555 meters (pl. 1 loc 56) They may be reached by a trail near the crest of Cerros Culebrilla either from Villa Sucre or from Huailas or by ascending the valley above Ancoracra The veins seem to be almost barren, but Raimondi (1873, p 104 and 453) stated that some deposits in this area contain argentiferous galena Several workings on the veins may have been gold prospects.

Volcanic rocks underlie the area; the sequence include interbedded andesite and rhyolite flows and quartz-bearing tuff, of various colors and coarseness of texture. The beds strike N. 0°–65° W. and dip 15° NE.–E Small andesite dikes, from several centimeters to 4 meters in width, intrude the bedded rocks

The workings along a zone bearing east and 660 meters long, expose a group of short, steeply-dipping veins, most of which strike east-northeast. Pyrite, specularite, quartz, iron and manganese oxides, and copper salts are the only minerals seen in the veins or on the dumps Volcanic and dike rocks are sheared and altered along the veins.

At the west end of the area are two short veins opened by adits at 4,220, 4,250, and 4,280 meters altitude (fig 16) The lower vein, 20 to 40 centimeters wide, strikes N 70°–80° E and dips 65°–70° SE. It contains only small amounts of quartz and pyrite. Some pyrite also occurs along small fissures in the crosscut at the end of the adit The upper adits and a surface stope are on a vein parallel in strike and dipping 75°–90° SE Quartz lenses are larger than in the vein below, but pyrite is present in only small amounts In places the sheared and altered zone along the vein is as much as 1 meter wide The adit at 4,250 meters altitude is caved at its portal; evidently the vein was stoped upward The vein in the adit at 4,280 meters altitude is stoped downward in part for at least 8 meters In the upper working the vein follows a dike.

About 70 meters northeast of the upper portal are two small prospects, the lower an undercut 2 meters long and the upper a short surface cut at 4,325 meters altitude These cuts follow slightly mineralized fractures parallel to joints which strike N. 50° E. The veins contain some quartz, pyrite, iron and manganese oxides, and copper salts

A vein 200 meters east of the small prospects strikes N 40°–70° E and dips 60°–90° SE It is opened at 4,450 meters altitude by an adit and a stope extending to the surface. The altered zone is as much as 3 meters wide, but only specularite and pyrite were seen in the adit.

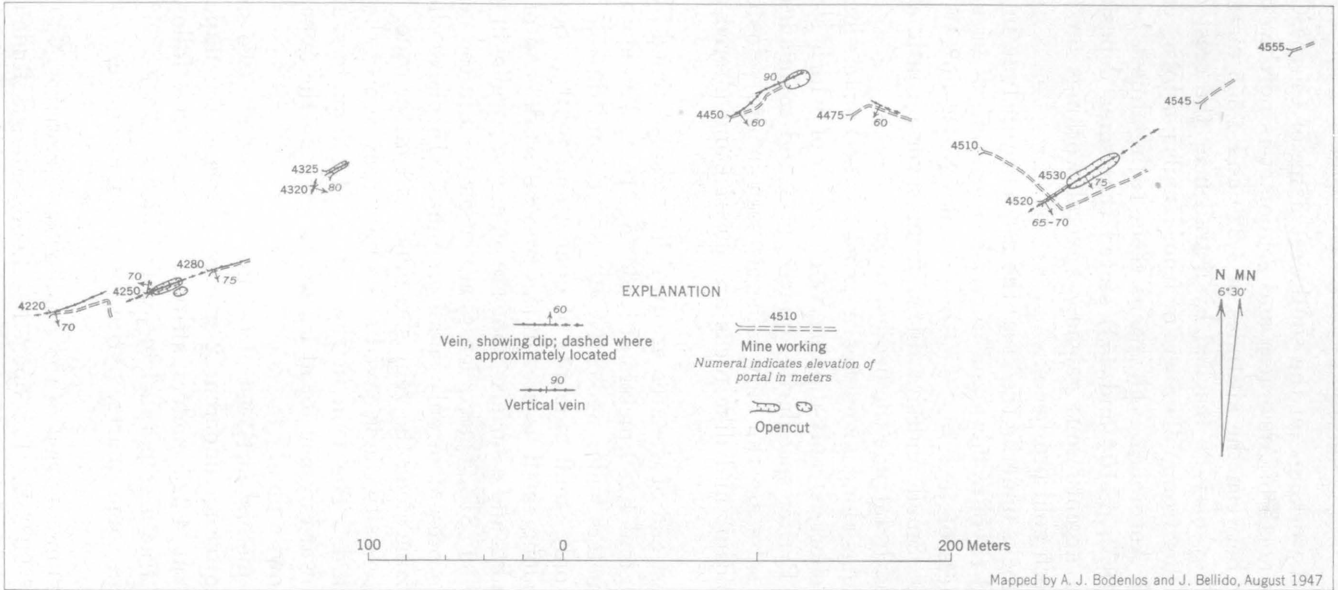


FIGURE 16.—Sketch map of veins and workings, Cerros Culebrilla mine.

The working is caved at the beginning of the stope. Another adit 60 meters to the east is in a shear and breccia zone, as much as 1 meter wide, which strikes N 70° W. and dips 60° SW It contains only specularite in altered wall rock

The eastern vein is 110 meters northeast of the portal at 4,475 meters and is followed for at least 60 meters by adits at 4,510 and 4,520 meters and by an open stope above The vein strikes N 65° E and dips 65°–75° SE In the lower adit only quartz and specularite occur on the vein, which is 25 centimeters wide and is bordered by a moderately altered zone 1 5 meters wide Three short underhand stopes are cut downward from the working. The upper adit and surface stope show an altered zone 2 0 meters wide, but no ore was seen.

An incline and a drift were opened on the northeast extension of the vein, at altitudes of 4,545 and 4,555 meters, but the rock is not even altered in this area

These deposits are essentially barren of ore minerals

#### QUEBRADA ANCUSH PROSPECTS

Several prospects are near the head of Quebrada Ancush, the valley just east of Quebrada Pariasca The workings are 5 kilometers north-northwest of Ancoracra and extend from 4,300 to 4,430 meters in altitude (pl 1, loc 57). A trail from Ancoracra leading across the range passes the area Raimondi (1873, p 453) stated that several gold mines and prospects were in this vicinity The workings have been abandoned for some time

Fine-grained and porphyritic rhyolite flows underlie the area Veins in these volcanic rocks contain only quartz, pyrite, and limonite

The east prospect, at an altitude of 4,300 meters, is about 50 meters east of the floor of the quebrada, and consists of three pits in a distance of 15 meters The prospected vein strikes N. 25° W and dips 75° SW Quartz and pyrite occur in a zone as much as 1 meter wide, in part as a boxwork in shattered and altered rhyolite.

On the west side of the quebrada and several hundred meters north-west of the east prospect is a trench and an incline at an altitude of 4,400 meters For a distance of 40 meters, these follow a vein striking N. 70°–85° E and dipping 75° SE At places the vein is slightly pyritized for a width of 70 centimeters and some quartz is on the dump

The northeast end of the upper prospect lies 60 meters northwest of the mouth of the trench and consists of a group of trenches extending southwest for a distance of 60 meters, beyond which is a trench bearing west for 20 meters The trenches obliquely cross a group of short en echelon veins striking N 50°–60° E. and dipping 75°–90° SE The widest of the veins is 30 centimeters and contains quartz and pyrite.

### PORTACHÓN MINES AND PROSPECTS

Just west of the crest of the Cordillera Negra, a group of deposits occur around the uppermost lake at the head of Quebrada Flere, one of the upper tributaries of the Río Nepeña drainage system The lake, Laguna Cuillorcocha, is at an altitude of 4,600 meters The areas is known as the Portachón district and may be reached by trail from Huailas, 8 kilometers to the northeast, and from Villa Sucre, 12 kilometers to the east-southeast (pl 1, loc 58) In 1868, Raimondi (1873, p. 103) found a number of abandoned workings in this vicinity. In 1947, one deposit was being operated by Sr. Henrique Chaves.

Flat-lying volcanic rocks, principally andesite flows, form the country rock of the area On the southwest side of the lake is a small tonalite plug. Along most veins, the volcanic rocks are strongly altered, principally propylitized and sericitized Minerals on the veins include galena, sphalerite, chalcopyrite, argentite, pyrite, and quartz, as well as some epidote associated with the quartz. The few ore shoots seen were small, most veins consisting entirely of quartz and pyrite

The mine of Sr. Chaves is on the west side of the lake The lower pit is close to the lake shore and the upper pit is 8 meters higher and 30 meters from the shore. In the lower, the vein strikes N. 50° E , and dips 60° SE. Sulfides of lead, zinc, copper, and silver occur in a band 10 to 15 centimeters wide, in an altered and pyritized zone 1 meter wide. The small lens was being mined in 1947. The lens had been mined out of the upper pit, which is 8 meters long, 4 meters deep, and as much as 1 5 meters wide. The vein lies in a zone 50 meters wide of thin veins containing only quartz and pyrite, most of which strike N. 70°–80° E and dip steeply southeast.

About 400 meters south of the Chaves mine, a breccia zone 5 meters wide contains small amounts of quartz and pyrite. It is opened by an undercut 3 meters in length which bears S 80° E

Northeast of the lake, on the projection of the vein at the Chaves mine, a mineralized fault strikes N 50°–55° E. and dips 60° SE , and is intersected by a fault striking N 20° E. and dipping 5°–10° SE Both contain quartz and pyrite several centimeters in width Another fault 10 meters to the north strikes N. 75° E. and dips 65° SE., and contains quartz and pyrite over a width of 35 centimeters in a fracture zone 1 meter wide.

About 75 meters north of these workings, an inaccessible adit has been cut on a vein striking N. 45° E and dipping steeply southeast Although the walls of the vein have been altered for a width of 3 meters, quartz and pyrite occur only in small amounts The vein can be traced across the ridge to the northeast About 150 meters west-northwest of the caved adit is another adit on a comparable vein striking N. 35° E. and as much as 1 meter in width.

Quartz-pyrite veins also occur 250 meters east-northeast of the east end of the lake A vein 1 meter wide strikes north for 30 meters and then breaks into a group striking N 70°–85° E The northeast-striking veins occupy a zone 30 meters in width

Despite the number of veins in the Portachón area, base-metal sulfides seem to be comparatively scarce

### RUMICRUZ PROSPECTS

Two small workings are near the head of Quebrada Rumicruz, a valley trending northeast toward the town of Huailas. The area is 6 kilometers southwest of the town, with which it is connected by trail, and about 4,500 meters in altitude (pl 1, loc 59). Other than one small stope, the workings seem to have been only prospects and were dormant in 1947.

Fine-grained gray andesite flows, one of which contains subangular cobbles of quartzite, form the country rock In the northeast part of the area they strike N. 30° W and dip 30° SW The rocks are chloritized and epidotized along the veins

The southwest prospect is a pit and short undercut on a vein striking N 85°–90° W. and dipping 45° S ; the vein is traceable about 100 meters to the west At the pit, the vein consists of pyrite and thin veinlets of comb quartz, together with small amounts of chalcopyrite Although pyritized and chloritized rock extends several meters into the footwall, the vein itself is at most 80 centimeters wide and contains only low-grade ore. Two parallel but unmineralized faults occur at distances of 5 and 30 meters south of the vein

The northeast prospect, 15 meters lower in altitude and 125 meters N. 40° E of the upper vein, is an adit 15 meters in length on a vein striking N. 80°–90° E and dipping 20°–30° S On the surface the vein locally strikes N. 75° W The ore consists of small quantities of quartz and chalcopyrite in altered and pyritized andesite Some actinolite occurs in mineralized rock along the vein The width of the vein is 50 centimeters, and its tenor of ore is low The vein is stoped 4 meters up and 3 meters down for a length of 11 meters

Visible parts of the veins are not minable.

### DIOMEDES MINE AND PROSPECTS

The Diomedes mine and prospects are in a south tributary of Quebrada Rumicruz and about 3 kilometers south of Huailas. It may be reached by the trail which ascends from the town to Cerros Culebrillas or by a secondary trail ascending the valley from Quebrada Rumicruz (pl 1, loc. 60). The Diomedes mine was worked in 1946 and 1947 by Sr Pedro Villar.

The Diomedes mine is in an east fork of the tributary valley and at an altitude of 3,600 meters Beds of greenish gray tuff form the country rock The vein strikes N. 45° E and dips 40°–60° SE. It contains vuggy and coarsely granular quartz, galena, argentite, calcite, and gouge, as well as iron and manganese oxides and azurite and malachite Ore occurs in short lenses as much as 25 centimeters wide, along a shear zone with a maximum width of 80 centimeters. The main adit is 35 meters in length It has been stoped down for 3 meters at a point 5 meters from the portal and also at a point 30 meters from the portal An overhand stope 5 meters long and 3 meters high begins 28 meters from the portal An adit bearing S 75° E and 4 meters in length, which may have been the beginning of a crosscut to the vein is located 25 meters S 75° W. of the portal and 15 meters lower in altitude

About 0 5 kilometer to the south and at an altitude of 3,500 meters is an adit 5 meters long, bearing east-northeast. The vein explored by the adit strikes N 80° E and dips 70° SE at the portal, swinging to N 55° W strike and 55° SW dip at the face. It consists of a maximum of 10 centimeters of iron oxides in a shear zone 75 centimeters wide A cross fault just beyond the portal cuts the vein, the fault strikes N. 10° W and dips 55° NE , and is dropped 20 centimeters on the west side Country rocks consist of coarse tuff and agglomerate.

A pit and small shaft on a shear zone striking N. 25° E and dipping 45° SE is 50 meters south and 20 meters lower in altitude The zone is unmineralized

Ore shoots seem to be very small in the Diomedes area

### CERRO MARIAUCRO MINES AND DEPOSITS

Three deposits have been prospected and mined in Cerro Mariaucro, the ridge on the northwest side of Quebrada Rumicruz. Workings are at altitudes between 3,635 and 3,750 meters. Trails connect the area to Huailas, 3 kilometers to the northeast (pl. 1, loc 61) Operations seem to have been long abandoned. The area in which the deposits occur locally is known as Yanamarca.

The northeast end of the ridge is underlain by folded sedimentary rocks of Cretaceous age Unconformably over the folded rocks are low-dipping volcanic rocks, consisting of a thick formation of agglomerate wedging out to the southeast, and overlying andesite flows. The veins are in the volcanic rocks

The deposit on the northwest side of the ridge is opened by an adit at 3,650 meters altitude The adit consists of a crosscut 45 meters in length, bearing S 6° W. and drifts totaling 45 meters in length The vein strikes N 70°–75° E except at its southwest end where it turns to N. 30° E , and dips 70°–85° SE It contains galena, pyrite, quartz, calcite, limonite, and malachite Sulfide minerals occur in a band only a few centimeters wide, although sheared and altered wall rock forms a zone as wide as 1 5 meters at one point Mined ore shoots were no more than 4 meters in length; unmined parts of the vein contain only small amounts of low-grade galena ore.

West of the crosscut the vein, containing only gouge, is opened for a length of 20 meters by an incline, the back of which is a low-dipping shear plane striking N. 20° W. and dipping 35° SW East of the crosscut, the drift follows the mineralized segment of the vein for 25 meters, and extends along a barren shear zone striking N 50° E and dipping 70° SE for an additional 10 meters At the crosscut the vein is stoped upward 20 meters for a length of 4 meters, and just to the northeast is a winze of about the same length Several meters beyond the winze is an overhand stope 2 meters long and 8 meters high Clearly, the small ore shoots have been mined out

South of the ridge crest are a group of pits, most of which are grassed over The lowest is at an altitude of 3,700 meters, and they extend N. 65° E. for a distance of nearly 200 meters In one short adit, a vein containing only limonite and gouge strikes east and dips 75° S

Lower on the southeast slope is the third group of workings The uppermost, at an altitude of 3,650 meters, is along one of the main trails ascending the ridge The working consists of an adit 12 meters in length opened on a vein striking N 40° E and dipping 75° SE Only quartz, pyrite, limonite, and malachite are in the vein which is from 10 to 20 centimeters wide Sulfide content at most is 2 percent

About 50 meters to the east and 5 meters lower in altitude is an adit 25 meters in length following a vein striking N 25° E. and dipping 75° NW. The altered wall rock and gouge are as much as 0 25 meter in width Some malachite is seen on the dump but copper sulfides are sparse in the vein A second adit on the vein, a working 10 meters below, is 50 meters in length Some calcite and chalcopyrite, as well as quartz and gouge, form a vein of about 25 centimeters wide Copper content is estimated to be only 1 or 2 percent

Little ore seems to be available in the deposits on the southeast side of the ridge.

### CERRO PATARA MINES

The Cerro Patara mines are just west of the crest of the Cordillera Negra, 13 kilometers northwest of Huailas and 8 kilometers east-southeast of Macate (pl 1, loc 62) A trail between the two towns passes through the deposit area The vein system is in the headwaters of Río Tres Cruces, the eastern part in a glaciated basin west of the ridge forming the divide of the range, the western part on the west flank of a ridge which includes the peak Cerro Patara (fig 3) Two lakes dammed by moraines are in the eastern basin, the lower at an altitude of 4,400 meters. A number of small deposits, not shown on fig. 3, occur on the east flank of the ridge forming the divide of the range. Workings on the principal veins extend from 4,090 to 4,710 meters in altitude

The deposits were not being worked in 1947, and the accounts of Velarde (1908, p. 60) and Miller and Singewald (1919, p 451) indicate that they have not been actively worked during the last 50 years. In contrast, Raimondi (1873, pp 109 and 455–487) found them being actively exploited by many miners in 1868. All workings at that time were surface cuts, and evidently secondarily-enriched silver ore of high tenor was available. Raimondi commented that nearly the entire population of Macate was engaged in some phase of mining at Patara and that fortunes were made on the basis of finding one rich pocket. He noted that the deposits also had been mined during the Spanish Colonial period and possibly even earlier. At some time between 1868 and 1947, underground mining was practiced and several large stopes were opened. Presumably argentiferous galena was the ore sought.

At present there is little likelihood of finding high grade ore without exploration at depth In 1947 construction of a road from Huailas to Chimbote was begun by the Santa Corporation to facilitate installation of a power line across the range When this road is completed, access to the deposits will be much more convenient, and possibly some lower grade argentiferous galena and sphalerite remaining in pillars and at the edge of mined lenses may then be worth mining.

Beds of massive welded tuff underlie most of the Cerro Patara area, extending from the Río Tres Cruces on the west to just east of the ridge along the divide of the range The volcanic rocks are folded, forming a syncline plunging north East of the divide, they rest on a sedimentary sequence of shale, impure sandstone, and a few beds of limestone At one point, a thin group of tuff beds occurs between the sedimentary rocks and the welded tuff.

In the eastern part of the main vein area, the welded tuffs are intruded by small plugs and dikes of gabbro. Several small rhyolite dikes were seen in the sedimentary rocks

The vein system is one of the largest in the Cordillera Negra The longest vein is traceable for nearly 3 kilometers, and vein minerals can be traced eastward across the divide another one-half kilometer. As may be seen on fig 3, the veins strike from east to northeast and in most places dip steeply north to northwest; they are sinuous and branching structure. Vein 7 feathers vertically (fig. 17). At a few places the veins are slightly displaced by small premineral cross faults and dikes

The veins contain mostly quartz and pyrite associated with smaller amounts of galena, sphalerite, chalcopyrite, arsenopyrite, calcite, and rhodochrosite. These minerals occur as fissure fillings, in part banded (pl 7, *B*), but quartz and pyrite also replace sheared and altered wall rock Some parts of veins are silicified in zones as wide as 10 meters. The welded tuffs are sericitized and kaolinized and the gabbros are propylitized near veins

In addition to the minerals listed above, Raimondi (1874, p. 457) and Velarde (1908, p 60) mentioned the presence of argentiferous tetrahedrite, pyrargyrite, native silver, cerussite, anglesite, and various oxides of iron, manganese, antimony, and silver.

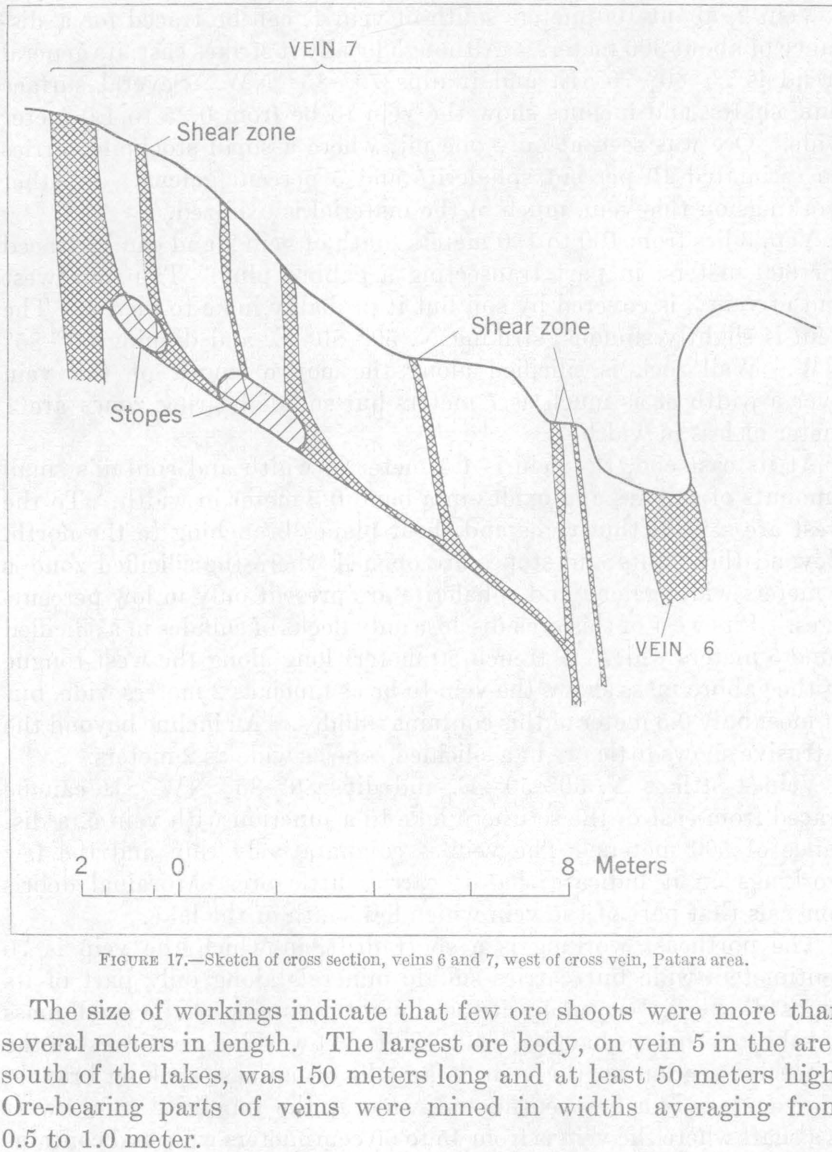


FIGURE 17.—Sketch of cross section, veins 6 and 7, west of cross vein, Patara area.

The size of workings indicate that few ore shoots were more than several meters in length. The largest ore body, on vein 5 in the area south of the lakes, was 150 meters long and at least 50 meters high. Ore-bearing parts of veins were mined in widths averaging from 0.5 to 1.0 meter.

The veins are numbered on fig. 3 to facilitate reference in the following descriptions.

### PATARA MINE

The workings in the east basin contain the Patara mine. The northernmost vein, vein 1 just south of the lower lake, is traceable only 100 meters. It strikes N. 65° E. and dips 70°–80° NW. In one pit a silicified and altered zone is 2 meters wide. Narrow sulfide-bearing parts of the vein contain quartz, pyrite, galena, and sphalerite. A crosscut driven from the north does not reach the vein.

Vein 2, about 100 meters south of vein 1, can be traced for a distance of about 300 meters. Although locally it strikes east, its general trend is N. 60°–70° E. and it dips 70°–85° NW. Several surface pits, shafts, and inclines show the vein to be from 0.25 to 1.0 meter wide. Ore was seen at only one pit, where a small stockpile carries an estimated 10 percent sphalerite and 5 percent galena. In other workings on this vein, much of the material is oxidized.

Vein 3 lies from 100 to 150 meters south of vein 2 and can be traced for 600 meters, in part transecting a gabbro plug. The southwest end of vein 3 is covered by soil but it probably links to vein 4. The vein is slightly sinuous, striking N. 50°–80° E. and dipping 50°–85° NW. Wall rock is silicified along the entire length of the vein over a width of as much as 7 meters but sulfide-bearing zones are 1 meter or less in width.

At its east end, the vein is 1.5 meter in width and contains small amounts of sulfides and oxides in a band 0.5 meter in width. To the west are several thin veins and shear planes branching to the north. Beyond these, pits and stopes are opened where the silicified zone is 7 meters wide; galena and sphalerite are present only in low percentages. Pits west of this area disclose only flecks of sulfides in a silicified zone 5 meters wide. A trench 50 meters long along the west tongue of the gabbro mass shows the vein to be as much as 2 meters wide, but at most only 0.5 meter of this contains sulfides. An incline beyond the intrusive shows little ore in a silicified zone as wide as 2 meters.

Vein 4 strikes N. 30°–50° E. and dips 80°–85° NW. It can be traced from east of the southern lake to a junction with vein 5, a distance of 500 meters. The vein is comparatively thin and the few workings on it indicate that it carries little ore. Morainal debris conceals that part of the vein which lies south of the lake.

The northeast working is a short drift, in which the vein is 70 centimeters wide but carries sulfide minerals along only part of its exposed extent. Arsenopyrite occurs in the gangue, and a small mass of gabbro forms the hanging wall. The next working, southwest of the concealed section on the vein, is an adit on an east-striking branch; the vein is only a few centimeters wide at the junction. Southwest is a shaft where the vein is from 45 to 60 centimeters wide and contains small amounts of sulfides. Between the shaft and the adit are several thin east-striking veins.

The main part of vein 5 is arcuate, striking northeast to east-northeast and dipping 55°–85° NW., and traceable for a distance of 500 meters from the junction with vein 4 on the southwest to a crosscutting dike on the northeast. About 100 meters east of the dike, a slightly offset extension continues east-northeast for at least another 400 meters.

The lower working on the eastern extension consists of a pit and a stope, sulfides have been mined out of a narrow zone. About 40 meters to the northeast, silicified wall rock widens to 9 meters and the zone contains thin veinlets of sulfides The wide part feathers out eastward, but the vein continues to the adit at 4,710 meters altitude Quartz and iron oxides, as much as 0.8 meters wide, remain in the working, one lens containing pyrite, galena, sphalerite, and carbonate minerals occurs where a footwall shear plane branches east from the main structure A chip sample taken from this lens across a width of 45 centimeters assays 73 grams silver per ton, 2 9 percent lead, and 13 6 percent zinc (assay 1624, table 3)

The east end of the main part of vein 5 is interrupted by a gabbro dike and is slightly offset to the south on the east side of the intrusive Several meters west of the dike an incline exposes small amounts of galena and sphalerite West is a pit and shaft, where the vein is from 1 0 to 1 5 meters wide at the surface, but pinches to 0 5 meter a short distance below the surface Several meters beyond is a shaft and stope connecting to the main workings on the vein The vein is from 1 0 to 1.5 meters wide, strikes nearly east, and dips 85° N About 150 meters to the west is a short crosscut, the main adit to the Patara mine The main ore body was stoped up from this level to the surface for a length of about 150 meters, and a winze about 50 meters west of the crosscut apparently reached ore at lower levels The vein was from 0 2 to 1 0 meter wide where stoped, and little ore remains in the working. At the surface, widths of stopes are 0 5 to 1 0 meter, the vein there strikes N 55° E and dips 80°–85° NW From the west end of the workings, the vein curves southwest toward the junction with vein 4

Vein 6, the northeast end of which is about 150 meters south of vein 5, can be traced for about 250 meters It is arcuate in shape, strikes northeast, and dips steeply northwest The vein nearly merges with vein 7 at its southwest end The width reaches 1 meter only in places and it is sparsely mineralized. Shafts have been opened at the northeast end and near a cross vein

Vein 7, still farther south, can be traced for 250 meters, along which trenches and workings are many. Along its eastern part it strikes east and dips 80°–85° N. It is from 0 5 to 1 0 meter in width, but does not contain significant amounts of base-metal sulfides Near its west end it is intersected by a slightly mineralized cross vein striking N. 30° W and dipping 50°–70° SW., which displaces the vein 1 meter to the north on the west Beyond the cross vein, vein 7 swings in strike to N. 45° E and flattens in dip to 45° NW. The flatter segment ramifies vertically and at several branches, small flat-lying lenses of ore were found (fig 17).

Vein 45, formed by the junction of veins 4 and 5, extends from just east of the crest of the Patara ridge down the west slope nearly to Río Tres Cruces, a distance of 1,500 meters. The vein strikes east and dips 60°–85° N. except at one point where it dips 80° S. The west end curves northwest and possibly abuts against vein 13. Several short veins branch from vein 45 and one crosses without displacement. The upper or eastern workings are known as the San Antonio mine, the central, as the San Pedro mine, and the western, as the Misionera mine. The vein is covered between San Antonio and San Pedro, but the vein, being the strongest in the area, probably is continuous between exposures. In places sheared and altered rock forms a zone 50 meters wide along the vein.

At the junction of the veins 4 and 5, vein 45 is 8 meters wide, containing quartz and some carbonate. In several prospect pits, sulfide minerals are sparse or absent.

#### SAN ANTONIO MINE

The upper adits of the San Antonio mine are at an altitude of 4,590 meters. The vein zone is 21 meters wide and consists of sheared and brecciated volcanic rock. The hanging wall strikes N. 70° E. and dips 70° NW. The adit at this point is caved. The adit on the footwall is inclined downward 15° and follows the vein 85 meters, then steepens to 35° over another 30 meters. Some quartz is seen at places within the working, but the bulk of the rock is unmineralized. Some manganiferous carbonate is on the dump. Fifty meters to the west the vein splits into two segments, the northern one is only 1 meter wide. Adits on both segments are caved.

About 100 meters west of the upper workings are two adits, of which the northern one is caved. On the dump of the southern adit is a small amount of quartz-carbonate rock containing some galena. The southern branch of the vein strikes N. 70° E., dips 80° SE. and is 1 meter wide. The branches of the vein are about 50 meters apart in this area.

#### SAN PEDRO MINE

Many workings on vein 45 and on branch veins 8 to 12 inclusive, comprise the San Pedro mine. In this area vein 45 has several splits. The branch veins strike northeast and vein 8 crosses vein 45. Most sulfide minerals occur on the branch veins.

Several stopes on vein 8 are from 0.7 to 1.0 meter wide. Above, vein 9 seems to be offset but may be on the continuation of vein 8. Here the vein is from 2.0 to 2.5 meters wide and from the size of stopes it is judged that considerable amounts of ore were mined, however, only quartz-pyrite rock with some carbonate was seen on the dumps. South of vein 9, an adit was cut on vein 10. The vein can be traced only a few meters and it is from 0.5 to 0.7 meter wide. Fragments of vein material on the dump consists of dark gray quartz with small amounts of carbonate and specks of galena and sphalerite

About 100 meters west of the intersection of vein 8 with vein 45, a drift opens a branch vein striking N 50° E and dipping 75° NW Although the vein is 1 4 meters in width at the portal, it thins to 0 5 meter within the working Abundant pyrite and some galena and sphalerite occur on the vein In trenches and outcrops 30 meters west of the adit, the north split of vein 45 is from 1 to 2 meters wide

The junction of vein 11 with vein 45 is 100 meters west of the portal on the north branch A short drift on vein 11 shows a maximum width of 0 6 meter On the dump, ore is of low grade, consisting chiefly of quartz and pyrite with only small percentages of galena and sphalerite Upslope from this working are a series of pits and adits cut on the apparent extension of the vein They follow the vein for a distance of 200 meters, over which it has a maximum width of 1 meter Carbonate containing pyrite and some galena and sphalerite occur on several dumps

About 150 meters west of the junction of veins 45 and 11 is an adit 100 meters in length on vein 45 At 70 meters from the portal is the junction with vein 12 which consists of two segments, about 3 meters distant from each other and each 0 6 meter in width The eastern segment is considerably stoped Mostly gouge and altered volcanic rock occur along vein 45.

### MISIONERA MINE

The Misionera mine is near the west end of vein 45, and consists of many old adits and stopes extending over a distance of 200 meters. The vein strikes N. 80° W. and dips 40°–60° NE , and is from 2 to 3 meters wide in this area Quartz and manganiferous carbonate contain lenses from 0 5 to 1 0 meter in width of sphalerite and galena Near the west end of the main adit, pillars left in one stope contain as much as 75 percent sphalerite in a width of 1 meter Substantial amounts of sphalerite and small amounts of galena were left on dumps. The ore body is one of the richest in the Cerro Patara region

Several hundred meters northeast of the Misionera mine, vein 13 has been extensively prospected.

### MINES AND PROSPECTS EAST OF THE DIVIDE

All mines and prospects on the east flank of the ridge forming the divide are small Less than ten mineral occurrences were seen, containing the same minerals found along the veins west of the ridge. Although several veins are moderately wide, sulfide-bearing bands are narrow and short The southern veins, in sedimentary rocks, strike northwest to north, and the northern veins, in welded tuff, strike west to west-northwest Only one deposit contains chalcopyrite and galena of moderately good grade but ore shoots are small

### QUEBRADA MANTO ALTO MINES AND PROSPECTS

A group of small copper mines and prospects lies in a valley locally known as Quebrada Manto Alto, an area 15 kilometers northwest of Huailas and 4 kilometers north of Cerro Patara (pl 1, loc 63) The valley is flanked to the south by Cerro Huacacuy and to the north by Cerro Callhuash, and it drains into the Río Santa 3 kilometers northwest of the Mayucayán station on the railroad (fig 18) The area may be reached by trail from Patara Another trail extends westward from the Río Santa at the mouth of Río Tambo, passes near the area, then continues northward through the hamlet of Callhuash and returns to the Río Santa near the El Chorro station No mining or prospecting was done on the deposits in 1947

The area is underlain by a sequence of sedimentary rocks of Cretaceous age Most are beds of impure sandstone or quartzite and interbedded with them is some limestone, shale, and at least one thin coal seam The clastic rocks correspond to those of the lower

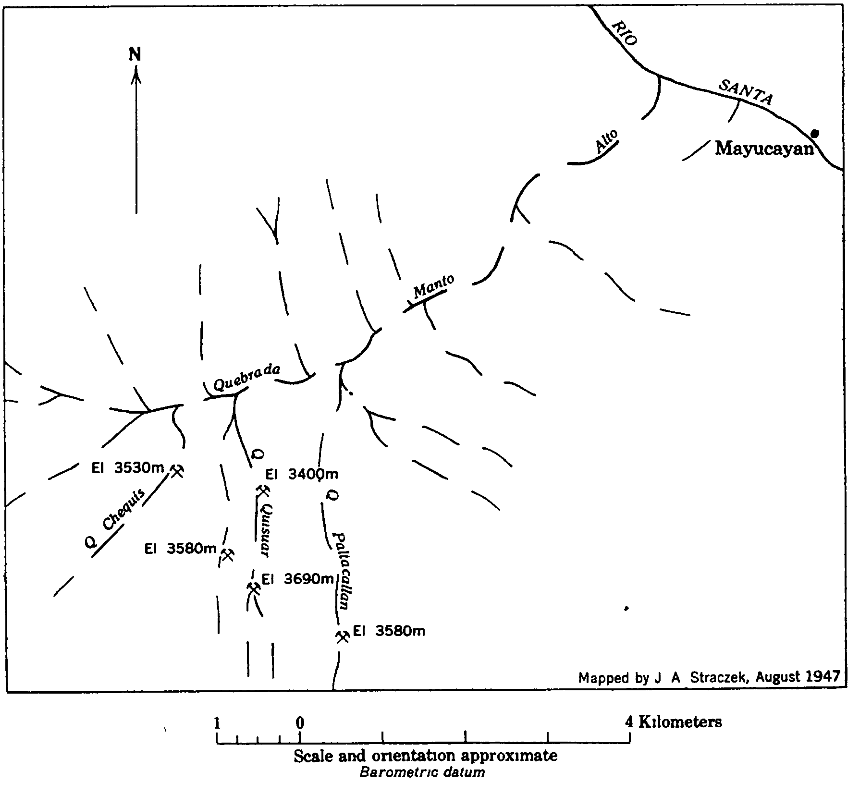


FIGURE 18 —Index map of mines and prospects, Quebrada Manto Alto

Neocomian sequence of Steinmann Bedding generally strikes north and dips steeply west. A small mass of porphyritic rhyolite is on the north flank of Quebrada Manto Alto

The deposits consist largely of secondary copper minerals and in places contain small amounts of pyrite and comb quartz Malachite and chrysocolla are most abundant, and azurite, chalcocite, and cuprite are seen in small amounts A few grains of chalcopyrite occur locally, the mineral probably was the source of the more common secondary minerals The minerals occupy thin veinlets in bedding planes, joints, and faults, at most 10 centimeters and generally 1 centimeter or less in width The copper content of most zones containing such veinlets is less than 1 percent, too low to be mined on a small scale, and deposits are too small to be worth mining on a large scale using mechanized equipment

The northwestern deposit is in a tributary valley locally known as Quebrada Chequis, about 1 kilometer south of its junction with Quebrada Manto Alto It is owned by Srs Brasaña and Alvino Mendesaba Three adits explore the veins, the eastern of which is at an altitude of 3,530 meters In the vicinity of the veins, sandstones and shales strike N 5° W to N 5° E and dip 50°–60° W

The eastern adit, 14 meters in length, is opened on a vertical fault striking N 25°–30° E Seven meters from the portal it joins a fault striking N 60° W and dipping 60° NE Along each is a vein as wide as 10 centimeters containing chrysocolla Some malachite and chalcocite also are in the more westerly-striking fault

About 25 meters to the west, two adits, one 5 meters vertically above the other, explore copper showings along a thin coal seam which strikes N 5° W The lower adit, 82 meters long, reaches the seam 20 meters from the portal A number of thin fractures on the footwall of the seam, nearly parallel in strike but dipping 40°–45° E , contain chrysocolla, malachite, azurite, and cuprite. Most of these minerals are in the middle of the working, near a mineralized cross fault striking N 75° W and dipping 85° NE. In the upper adit, which does not reach the cross fault, only very small amounts of copper minerals are seen The maximum width of veins containing copper minerals is 5 centimeters, found on the cross fault in the lower level

In the west branch of the valley east of Quebrada Chaquis, several small showings of copper occur 2 kilometers south of Quebrada Manto Alto The one adit in the area is at an altitude of 3,580 meters

The adit is 7 meters long and bears N 70° E , opening on a zone stained by copper minerals along joints and bedding planes in sandstone. The largest veinlet is 1 5 centimeters in width and 0 5 meter in length. A pit 5 meters north of the portal exposes a lens as much as 20 centimeters thick but only 1 meter long, containing malachite. The vein in which it occurs strikes N 85° E and dips 35° S. Other small fissures containing malachite are from 2 to 5 centimeters wide. A pit 50 meters to the east follows a fracture striking N. 85° W. and dipping 55° N. Chrysocolla on the hanging wall impregnates sandstone in an area 3 meters square.

Two mineralized areas occur in Quebrada Quisuar, the east branch of the valley described above. The lower area is 1.2 kilometer south of Quebrada Manto Alto. The north adit is at an altitude of 3,370 meters, and bears S. 25° E. It is inaccessible and the dump is barren. The second adit is 50 meters south and at an altitude of 3,400 meters cut along sandstone bedding striking N. 10° W. and dipping 75° SW. Ten meters vertically above is an upper adit bearing S. 10° W., also along bedding. Ten meters from its portal a fault zone strikes N. 65°–70° W. and dips 55°–65° SW. A parallel fault is 2 meters beyond. Both contain from 5 to 10 centimeters of chrysocolla, and have been partly stoped. Bedding planes dipping 45° NW. also contain veinlets of copper minerals. Several tons of rock on the dump contain less than 1 percent copper.

The upper mineralized area is 2.5 kilometers south of Quebrada Manto Alto. Three pits and one adit explore a small area, the lowest working is an altitude of 3,700 meters. The northwest pit exposes sandstone striking north and dipping 55° W., cut by joints striking N. 40° W. and dipping northeast. Bedding planes and joints contain thin films of malachite, azurite, and chrysocolla. A pit 20 meters south, on the west side of the floor of the valley, discloses a vein 1 meter wide containing iron oxides and copper stain. The vein follows bedding which strikes N. 15° W. An adit 5 meters south bears S. 80° W. and is 19 meters long. In the first 10 meters, veinlets of malachite occur in bedding planes and joints. The third pit, 15 meters east, on the east side of the valley, shows a similar degree of mineralization.

Copper stain continues to 50 meters north of this area where two additional pits expose similar copper minerals.

The largest workings are at the Paltacallan mine, in the eastern tributary valley of the area. The mine is about 3.5 kilometers south of Quebrada Manto Alto and workings range from 3,500 to 3,600 meters in altitude. The major workings are east of the valley floor and consist of three adits. The upper, at an altitude of 3,580 meters and open only 12 meters to a filled section, bears south and follows bedding in massive sandstone. Some pyrite and copper sulfides are on the dump, but only copper stain was seen in the working. Three meters below is a drift 47 meters in length, bearing S. 5° W. Vertical faults striking N. 20°–75° W. occur 12, 13, 30, and 47 meters from the portal. All are barren and contain only white clay, but sandstone is pyritized near each structure. The fault 13 meters south of the portal crops out on the surface east of the working, where it contains a thin band of iron oxide.

Fifteen meters northeast of the lower adit is another working consisting of a crosscut bearing N 70° E for a distance of 14 meters and then N 50° E for another 30 meters A barren vertical fault striking N 75° W is seen at the face Five meters from the portal, a drift to the south follows bedding striking N. 15° W and dipping 55° SW. Considerable copper stain is seen on the walls of this drift and some also in the crosscut. Some white comb quartz and pyrite is on the dump

About 75 meters southwest of the mine are two adits following the bedding in sandstone which here strikes N. 15° W. and dips 70° SW. The eastern adit is filled, but copper stain is abundant at the portal The second adit, 9 meters to the west, follows bedding south for 20 meters and connects to the eastern Several rooms have been cut but no minerals are visible in the walls.

On the west side of the quebrada, 200 meters north and at an altitude of 3,500 meters, is an adit 20 meters in length. Sandstone here strikes N. 15° W. and dips 75° SW. It is cut by a vertical fault striking N 80° W. and 30 centimeters wide Some chrysocolla and copper carbonates occur along the fault and adjoining fractures.

The Milagro prospect is 250 meters N 60° W of the main workings. Sandstone in this area strikes N. 5° E. and dips 60°–65° W. The drift at this deposit, 17 meters in length, follows two bending planes about 1 meter apart. Each contains 10–15 centimeters of disseminated pyrite and chalcocite. A fault striking N 55°–60° W and dipping 55° SW. crosses the veins 7 meters from the portal

Several other workings about on the same level are found on the trail to the north They are similarly mineralized and have low tenor of ore

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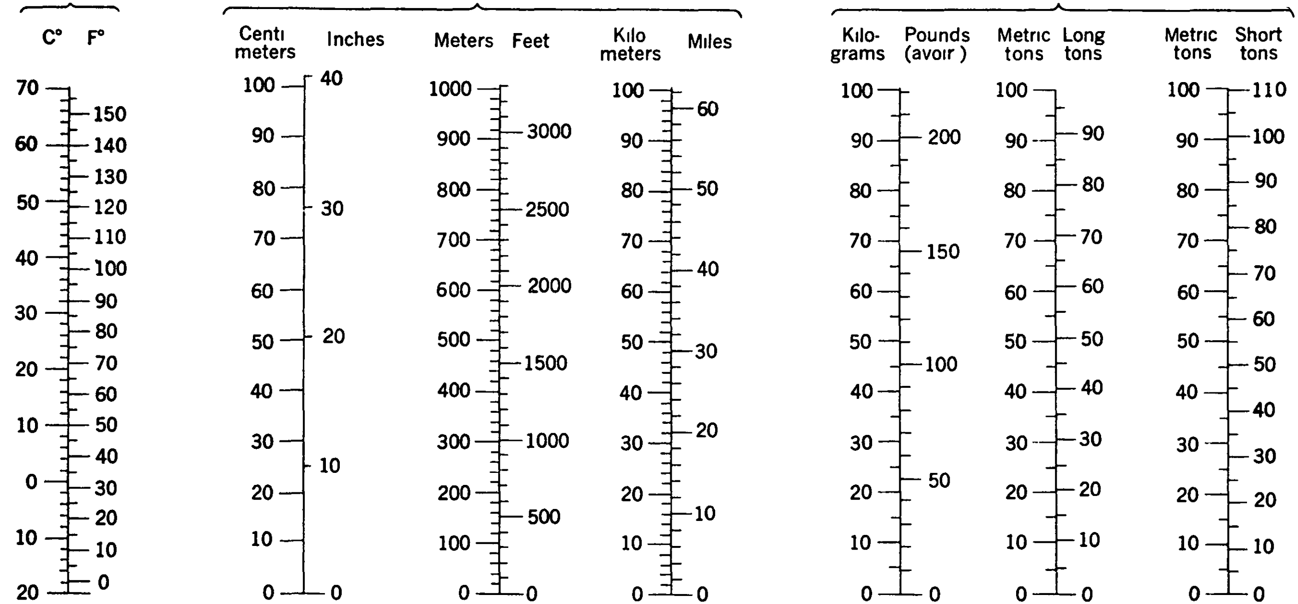
# METRIC EQUIVALENTS

TEMPERATURE — LINEAR MEASURE — WEIGHTS




1 cm = 0.3937 inch
1 inch = 2.5400 cm

1 meter = 3.2808 ft
1 ft = 0.3048 meter
1 sq. meter = 1.20 sq. yd.
1 hectare = 2.47 acres
1 cu. meter = 1.31 cu. yd.

1 km = 0.6214 mile
1 mile = 1.6093 km

1 kg = 2.2046 lb
1 lb = 0.4536 kg

1 metric ton = 0.9842 long ton
1 metric ton = 1.1023 short tons
1 metric ton = 2205 lb
1 long ton = 1.0161 metric tons
1 short ton = 0.9072 metric ton

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