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MINERAL RESOURCES OF THE SOUTHERN HALF OF ZONE III

SANTANDER, NORTE DE SANTANDER, AND BOYACA, COLOMBIA

by

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U. S. Geological Survey

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ABSTRACT

The areas covered by this report lies in the eastern Cordillera of the Colombian Andes in the region around Bucaramanga. This part of the eastern Cordillera consists of a structurally complex core of metamorphic and igneous rocks of Precambrian to Mesozoic age, flanked to east and west by faulted and folded sedimentary strata of late Paleozoic to Tertiary age. Infaulted blocks of sedimentary rocks are locally present in the massif. Unconsolidated deposits of Quaternary age, primarily terraced alluvium, are locally extensive in valleys on the flanks of the range. The crystalline central core of the range is called the Santander massif. In it are located the principal gold deposits and scattered deposits of copper, lead, zinc, and fluorite. The sedimentary rocks flanking the massif contain significant deposits of phosphate rock and gypsum, as well as other nonmetallic industrial minerals such as limestone, barite, glass sand, and coal. A belt of lead-zinc prospects in carbonate and sandstone beds of Cretaceous age on the east side of the range warrants further investigation.

Gold and silver are the only important metallic minerals that have been produced in the Santander massif. Mining dates back to colonial and possibly to pre-colonial times and continues on a small scale at present. The California and Vetas district was the main area of investigation of metallic minerals during the present project. Results of geochemical sampling of stream sediments and assays of vein material indicate that the main potential of the area is in gold with lesser potentials in copper, lead, zinc, and silver. Mineralization of the district is probably younger than Early Cretaceous.

Although no copper minerals have been mined elsewhere in the massif, small amounts of copper minerals in various rocks in scattered areas is revealed by green and blue stains of copper carbonates and sulfates. Deposits of greatest areal extent are in arkosic conglomeratic beds of the Girón Formation. These are being explored and sampled at the present time (1969). A little lead has been mined and smelted in the past but operations were on a very small scale and of short duration. Small amounts of lead, zinc, and copper minerals accompany dolomite replacement of Cretaceous limestone in a few scattered places, and several promising prospects are being investigated by means of trenches and drilling. One magnetite and several hematite prospects were examined but none offers any potential for economic development.

Thick beds of gypsum in Lower Cretaceous limestone on Mesa de Los Santos, south of Bucaramanga are being quarried from outcrops for use in cement manufacture. The deposit was discovered shortly before the present project began, and although its extent beneath overlying strata is not yet determined by drilling, it appears to be in a small evaporite basin of about three kilometers in radius. Reserves of gypsum are large, but future development will have to be by underground mining.

Outcrops of Cretaceous limestone of high purity are widespread and are more than adequate to meet all demands, which at present are for cement and calcined lime, road construction material, and to a small extent for agricultural lime and polished decorative stone. Upper Paleozoic limestone of the Diamante Formation crops out in a few places; it has been used near Bucaramanga for cement manufacture.

Marble is present in several localities of the Santander massif in Lower Paleozoic and Devonian rocks. Impurities, fractures, and solution cavities render most of it unsuitable for decorative purposes, but selected parts are used in floor tile and terrazo. Recrystallized limestone of the Diamante Formation in the same area, usually referred to as marble, is of uniform high purity throughout a thick and uninterrupted section, and offers a good source of limestone raw material. A little is now used for agricultural lime. The potential of this resource has not been fully evaluated.

Dolomite zones are present in the recrystallized limestone of the Diamante Formation and in Lower Cretaceous limestone of the Rosa Blanca Formation in the area where gypsum is now being quarried from the same section. Potentials of these dolomites have not been evaluated.

Large deposits of phosphate rock are the most important resource discovered during the present project. They are in the Upper Cretaceous sedimentary rocks, mostly in the La Luna Formation. Exploration and evaluation are continuing. Although the potential phosphate rock resources may ultimately supply much of Colombia's growing need for agricultural fertilizers, much remains to be done before a new industry can be established to convert the raw material into marketable form.

Coal beds are being mined on a small scale in several localities in uppermost Cretaceous and Paleocene rocks. Most of the coal is used for fuel in brick and lime kilns of the area and ranges in grade from subbituminous to semianthracite. Thinness of beds, structural complexities, and transportation costs are major obstacles to development on a larger scale.

Asphaltite occurs in scattered lenticular bodies as fracture fillings in Upper Cretaceous rocks of the La Luna Formation. A few of the larger bodies have been mined by underground methods as a source of fuel for brick and lime kilns, but these are not numerous enough to constitute a large or dependable energy source.

White quartz sand suitable for glass making is recovered from shallow pits in low Quaternary terraces in the Magdalena Valley. The railroad from Bucaramanga to Puerto Wilches on Rio Magdalena extends through the area and provides convenient transportation to the main markets in other parts of the country. Large veins of almost pure quartz that crop out in an area of the Santander massif near Berlin are a potential source of silica for industrial use.

Barite has been dug from outcrops of veins in various places, but none has developed into a sustained underground mining operation. Most of the deposits have been found in Lower Cretaceous limestone in the mesa area south of Bucaramanga. Other deposits now being mined are in limestone and dolomite of the Diamante Formation. There is continuing demand for barite by the oil industry for use in drilling fluids.

Fluorite veins in the pink Pescadero granite have been small sources of this mineral in two localities. Only surface pits have been used in mining, and potential for subsurface development is not known.

Low quality sandy clays are used extensively for making ordinary bricks and tiles for construction. Better quality clays are present in the Giron Formation, but there has been little use made of them.

Sand and gravel used in Bucaramanga are mostly screened from poorly sorted stream deposits around the base of the Bucaramanga terrace. Better sorted and more abundant deposits beyond the foothills to the west are not within economic transportation distance.

INTRODUCTION

The area of this report, comprising 7,500 sq km in northeastern Colombia, is principally in the Department of Santander, but includes parts of the Departments of Norte de Santander and Boyaca (fig. 1). It is the south half of an area designated as Zone III by the Colombian Inventario Minero Nacional (IMN), the predecessor of the Instituto Nacional para Investigaciones Geológicos-Minero (Ingeominas). Zone III is one of four areas in Colombia selected for mapping and field investigations because 1) the areas were considered likely to contain potential mineral resources; 2) they had not been previously systematically investigated; and 3) they were amenable to surface exploration. Identification and evaluation of mineral deposits encountered during the investigation could be expected to encourage further exploration and development for production. The work has been conducted by the Inventario Minero Nacional, an agency established under the Ministry of Mines and Petroleum of the Colombian Government to work in collaboration with the U. S. Geological Survey (USGS). The work was financed by the Colombian Government and the Agency for International Development, U. S. Department of State.

This report summarizes results of investigations made in the southern half of Zone III between October 1965 and September 1968. The area covered includes parts of the following quadrangles of the Colombian grid system: H-12, H-13, I-12, and I-13 (fig. 2). For geographic and geological features mentioned in the text, the reader is

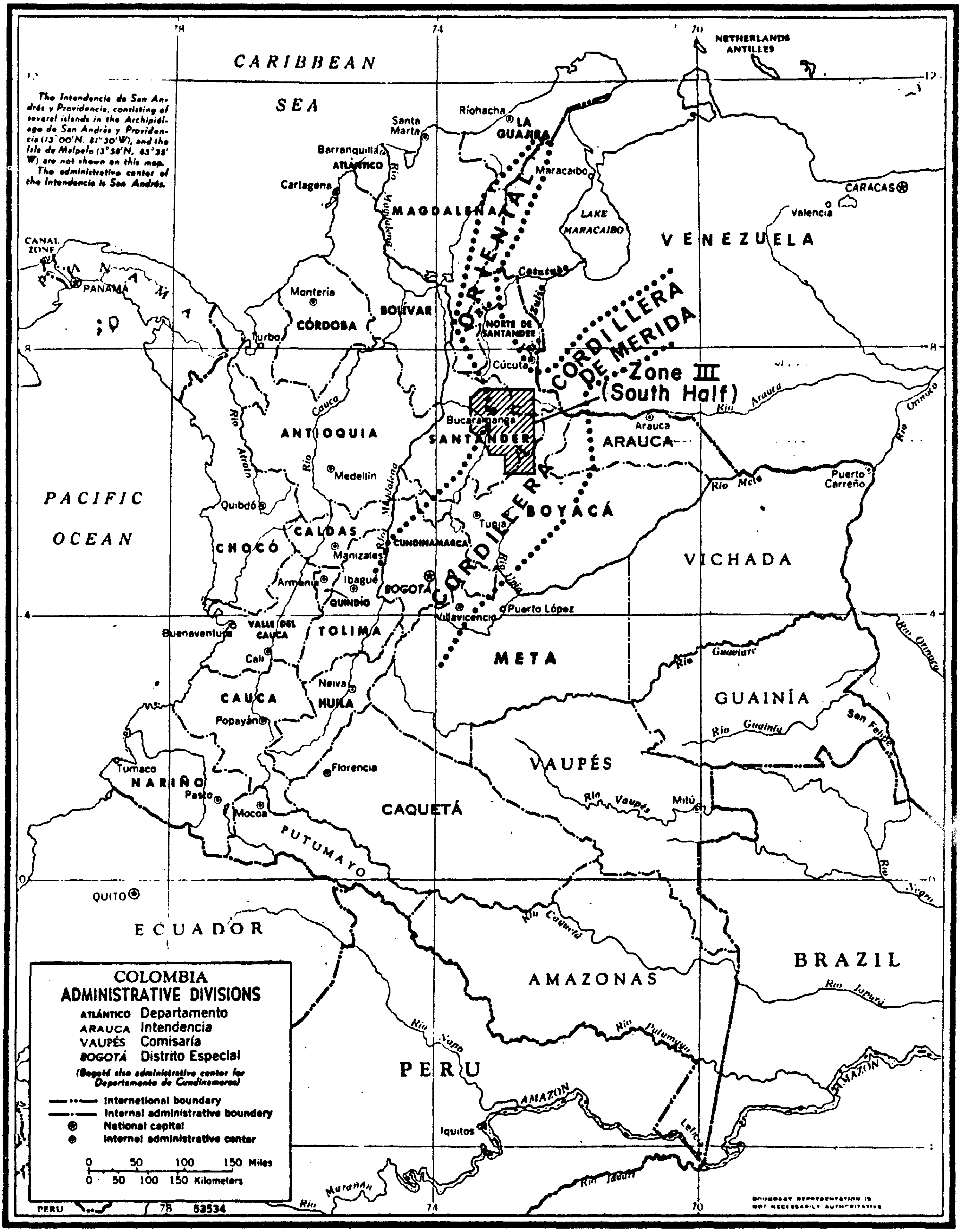

FIGURE 1. Index map showing the area of the southern half of Zone III of the Inventario Minero Nacional, Colombia.

referred to the published geologic maps of these quadrangles (Ward and others, 1969, 1970a, 1970b).

Geography

Most of the southern half of Zone III is in the Eastern Cordillera of the Andes in northeast Colombia (fig. 1). This section of the Cordillera contains an uplifted crystalline core here referred to as the Santander massif. The massif lies just northwest of where the Cordillera changes trend from northeast to northwest, and where the Cordillera branches into the northward-trending arc of the Serrania de Perija, which forms the boundary between Venezuela and Colombia and the northeastward-trending Cordillera de Merida of west-central Venezuela.

The massif forms a three-way divide between the Río Magdalena drainage to the Carribean Sea on the west, the Río Zulia-Río Catatumbo drainage into Lake Maracaibo and the Caribbean Sea on the northeast, and the Río Arauca drainage to Rio Orínoco and the Atlantic Ocean on the east. The principal rivers draining into the Magdalena are Río Chicamocha and Río Suarez which combine to form the Río Sogamoso.

Topography

The southern half of Zone III can be divided into several topographic regions. One is the massif proper which comprises the main high range centered on a line approximately through Morro Nevado and Páramo de Almorzadero at altitudes from 3,000 to 4,500 meters, and slopes to east and to the west as far as the break in slope at the Bucaramanga

Front. Another is the somewhat lower drainage basin of Río Chicamocha to the south and southeast, between Onzaga and Cepita, with summit altitudes of 2,000 to 2,600 meters. Another region includes the mesas which extend from Bucaramanga south to the limit of the zone and which border the main high range and the Chicamocha basin on the west. Altitudes of the mesas range from 2,250 meters in the south to 1,300 meters in the north. They are from north to south, the Mesa de Ruitoque, Mesa de Los Santos, and the Mesa de Barichara. Bucaramanga lies on a terrace at 1,000 meters altitude at the north of the region of the mesas. A third region, at altitudes of 1,000 to 1,400 meters includes the plateaus west and northwest of Bucaramanga and west of the region of the mesas, and the ridges and valleys west of the plateaus that drop down to the fourth region, the piedmont and the Magdalena Valley, east of San Vicente and Vanegas, at 100 to 150 meters altitude.

Local relief in the high upland (paramo) is about 200 meters, but in places is as much as 1,000 meters. Local relief in the area of Rio Chicamocha basin is as much as 2,500 meters, and on the flanks of the massif elsewhere local relief is as much as 2,000 meters. In the area of mesas and ridges and valleys, local relief is as much as 1,200 meters.

Climate and vegetation

At any given altitude the temperature changes little with the season. The range in diurnal temperatures varies only slightly from cloudy to sunny seasons. Mean annual temperatures at altitudes lower than

Bucaramanga (at 1,000 meters) range from 25° to 27°C and at Bucaramanga range from 21° to 23°C. In the high paramo at altitudes of 3,200 to 3,500 meters, mean annual temperatures are 7° to 10°C. At elevations near 4,000 meters or higher, subfreezing temperatures are sometimes reached during clear nights of the dry season.

Rainfall varies seasonally and in total amount from place to place. In the Bucaramanga area total annual rainfall is about 1,000 to 1,500 mm. The lower course of the Río Chicamocha lies in a partial rain shadow, and annual rainfall is about 500-1,000 mm. On the higher flanks of the range and in the southern part of the zone, annual rainfall is about 1,500 to 2,000 mm. The largest amount of rain throughout most of the Zone falls in two seasons with maxima in May and October. Little rain normally falls during December, January, and February. The paramo is quite cloudy during most of the year. Precipitation is sometimes in the form of snow. However, no records are available for this area.

In the canyon of Río Chicamocha the vegetation is sparse and xerophytic, the soil less deep. The barrenness of much of the Chicamocha drainage area east and southeast of Pescadero is due in part to high permeability of the granite-derived soil. South of the Chicamocha basin at higher elevations, there is more rain and the forest cover increases. The extreme southern part of the Zone is heavily wooded and accessibility and exposures are poor. The southeastern part, north and south of Málaga, is relatively open farming country with only little forest.

The slopes of the Cordillera vary from heavily wooded to cleared, with many small farms. Cloud forest is now largely limited to the less accessible areas above 2,500 meters. This once continuous stretch of forest between the treeless paramo at about 3,100 meters and the cultivated lower slopes has been breached by man at many places, usually in the areas of major roads. More forest remains on the west slope of the range than on the east slope within the Zone except in the headwaters of Río Cucutilla in northern H-13.

Slopes are steep and streams are usually choked with vegetation. Some stream courses have many outcrops, others are filled with rubble. The heads of the streams and the smaller streams flow over many cascades and waterfalls.

Deep weathering is characteristic at intermediate and low altitudes; the greatest depth of weathering is on hillslopes and spurs at elevations of 1,500 to 2,500 meters. Somewhat fresher rock is exposed on lower slopes.

The country above the tree line (about 3,100 meters) is relatively open. Outcrops are fairly abundant, especially in the more dissected parts and where glaciation has scoured off weathered rock.

Culture

Bucaramanga, with a population of about 230,000 (1964), is the largest city in the Zone and is the center for industry, trade, and transportation. Regularly scheduled airline service is available to other cities of Colombia and to some smaller towns in Santander and Norte de Santander.

Good roads connect Bucaramanga with Bogota, the cities of the Caribbean coast, and Venezuela to the northeast. A branch line of the Ferrocarriles Nacional de Colombia connects Bucaramanga with the main Bogota to Santa Marta line in the Magdalena Valley.

Pamplona in Norte de Santander, an educational center of about 20,000 people, is the next largest city in the southern half of Zone III. Numerous smaller towns of less than 7,000 people are scattered throughout the Zone, mainly near Bucaramanga and to the southeast along the upper reaches of Río Chicamocha and its tributaries. Most of the population is rural. The most thinly populated sector is the high paramo above 3,200 meters and the zone of cloud forest below this, down to about 2,800 meters. The bulk of population lives at altitudes below 2,500 meters.

Potatoes and onions are the principal crops in the high paramo; some attention is recently being given to raising sheep. On the mountain slopes at lower altitudes, fique is raised for rope, twine, and bags, and at slightly lower altitudes, coffee. Fruits and vegetables of many kinds for the local market are raised at intermediate and lower altitudes throughout the zone. Corn, yucca, legumes, and wheat are staple food crops widely grown. Pineapple is cultivated in the plateau country west of Bucaramanga and much is shipped to other areas. Sugar cane is a big industry in the local piedmont south of Bucaramanga and in the broader valleys at suitable lower altitudes elsewhere in the Zone. Tobacco is also a major crop, and manufacture of cigarettes and cigars is an important industry. The dairy industry is scattered in small farms and ranches throughout the Zone. Beef cattle are raised chiefly in the lower altitudes, particularly in the piedmont of the Magdalena Valley.

The southern half of Zone III is relatively well served by roads (fig. 2). Most of the area between the roads is accessible only by mule, horse, or foot. No place in the Zone is more than a day's ride or walk from a road. The right-of-way of the Ferrocarriles Nacionales provides some access to the Lebrija gorge and part of the Magdalena Valley.

The area south and west of Bucaramanga is open country, readily accessible except for some of the steeper canyon walls of Ríos Chicamocha, Suarez, and Sogamoso and their tributaries. However, further north, west, and northwest, the slopes are extensively covered with brush and forest. Farms are mainly on the ridges. Río Lebrija and its tributaries have cut canyons into this country with slopes covered in part by landslide debris and forest. Gorges are difficultly accessible. Toward the Magdalena Valley farms alternate with forest and the climate is hot and humid.

Methods of work

Systematic regional geologic mapping in support of the program of mineral resource evaluation was accomplished by assigning geologists to study individual quadrangles 10 by 15 kilometers. Geologic data were compiled on preliminary topographic bases prepared by the Instituto Geografic Agustin Codazzi, Bogota, at a scale of 1:25,000 and a contour interval of 50 meters or 25 meters. Field mapping was expedited by use of aerial photographs at a scale of 1:60,000.

Localities of minerals or rocks of possible economic value encountered during the mapping were noted and briefly checked during mapping. Detailed investigations and evaluations were made at the completion of the mapping phase of the program. This work usually consisted of detailed sketch mapping and sampling, and the measurement of stratigraphic sections if warranted. Mineral investigations in the California and Vetas gold mining areas were made by a special team who worked continuously throughout the duration of the project. Preliminary quantitative geochemical sampling was done in the California area and at two lead-zinc prospects in the south and southeast parts of the Zone. No geophysical work was done although a geophysical advisor visited several of the sites and offered recommendations. No drilling was done under the IMN program, but a Japanese company concomitantly carried out a small drilling program at La Baja near California under a contract not connected with the Inventario. Phosphate investigations were initiated by IMN after the early realization of the amount and significance of the phosphate resources in Colombia.

Previous work

The gold mining area of California and Vetas has been known and worked at least since the 16th century, and was apparently worked by Indians in pre-Colombian times. An entertaining as well as scholarly summary of the literature on the gold region in Santander prior to the 20th century has been made by Vicente Restrepo (1937). Mention is made of the mines, but with little detail, by Modesto Bargallo (1955) in his book on mines and mining in Spanish America during the Colonial epoch.

Recent literature on economic deposits in the Zone is not particularly extensive. Many of the reports are general or summary reports such as those by Singewald (1950) and Wokittel (1957) in which data on mineral localities are summarized from a variety of secondary sources. Radelli (1961) in a theoretical paper related epochs of mineralization with plutonic events over the entire Colombian Andes.

A number of reports, such as that by G. Botero (1945), describe brief investigations of individual mines or prospects. More intensive studies have been limited to the gold mining area of California and Vetas (Wokittel, 1954; Nelson, 1955; Pagnacco, 1962; Arce, 1951; Bueno, 1955a, 1955b; Champtier de Ribes and Alvarez, 1961). Reports on nonmetallic minerals in Santander have been made by Martinez (1962, 1964) on lime, gypsum, and barite deposits; and by Jimeno and Yepes (1963) on gypsum deposits near Los Santos. A survey of phosphate deposits of Colombia by Cathcart and Zambrano (1967), with reference to the deposits within the map area has been recently published.

The areas of sedimentary rocks in and flanking the Magdalena Valley have been studied intensively by geologists of oil companies holding concessions in the region. Although not published, results from their work have been incorporated in the geologic maps of Colombia (Servicio Geologico Nacional, 1944, 1962).

Locations

Locations referred to in the text are made in one of two ways, depending mainly on the size of the place. General locations are given with reference to towns or prominent topographic features that can be readily located by reference to geologic quadrangle maps or to figure 2.

Where more precise locations are felt to be necessary, reference is made to the topographic maps at 1:25,000 scale of the Instituto Geografico de Colombia Agustin Codazzi. These maps are identified by circled Arabic numbers, Roman numerals, and capital letters on figure 2. The maps, called planchitas, are 10 kilometers from north to south and 15 kilometers from east to west. They are partitioned by a grid into 1 kilometer squares. North-south coordinates of the grid are lettered from A to J from north to south, and east-west coordinates are numbered from 1 to 15 from west to east. A position within a square kilometer of the grid can be further fixed by indicating the quadrant where it is located, NW, NE, SW, SE. Thus a location would be given as planchita 110 III-C, J-13NW. Names of streams, farms, and ranches are used when accurately known, but experience has shown that these are not always accurately located or named on the planchitas.

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REGIONAL GEOLOGY

The crystalline rocks of the Santander massif are predominantly metasedimentary and meta-igneous rocks intruded by large plutons and batholiths that range in composition from diorite to granite. On the flanks of the massif and in structural basins within it are sedimentary strata. Radiometric age determinations indicate that the oldest rocks of the Santander massif are of Precambrian age and include high-grade gneiss, schist, and migmatite of the Bucaramanga Gneiss. These rocks were probably part of the Precambrian Guayana Shield. Low- to medium-grade metamorphic rocks of Late Precambrian to Ordovician age include phyllite, schist, metasiltstone, metasandstone, and marble of the Silgara Formation, a geosynclinal series of considerable extent in the Cordillera Oriental and possibly the Cordillea de Merida of Venezuela. In the high- and medium-grade metamorphic rocks of the central core of the massif metamorphosed plutonic rocks (orthogneiss) ranging from granite to tonalite probably represent rocks of two ages, Precambrian and Ordovician to Early Devonian. The younger orthogneiss and the Silgara Formation are overlain by Middle Devonian beds of the Floresta Formation which show a generally low but varying degree of metamorphism. Phyllites and argillites are common; less common marble and other calcareous beds are fossiliferous. Except for recrystallization in limestone of the Permian-Carboniferous Diamante Formation, sedimentary rocks younger than Devonian are unmetamorphosed.

The effects of Precambrian regional dynamo-thermal metamorphism and plutonism on Precambrian geosynclinal deposits reached the upper amphibolite facies in gneiss of the Bucaramanga Gneiss. Geosynclinal deposits of the Silgara Formation were subjected to similar conditions in Late Ordovician and Early Silurian time but reached only the greenschist or lower amphibolite facies. Metamorphosed plutonic igneous rocks (orthogneisses) generally show a concordance of foliation and lineation with rocks of the adjacent Silgara Formation and Bucaramanga Gneiss as well as similarities in grade of metamorphism. Regional dynamo-thermal metamorphism in Late Permian and Triassic time reached low grade in the Floresta Formation, and caused recrystallization of limestone of the Diamante Formation. The Bucaramanga Gneiss and Silgara Formation show evidence of retrogressive metamorphism, with high activity of potassium and water, but whether this occurred at the time the Floresta was metamorphosed or later is not clear.

Batholiths, plutons, and stocks of nonmetamorphosed igneous rocks in the Santander massif range from diorite to granite. Radiometric age dates indicate that most of them belong to a single plutonic interval and these are referred to as the Santander Plutonic Group. Rock ages in the group are Jurassic and Jurassic-Triassic. Two suites of this group are pink granite and quartz monzonite, and gray quartz monzonite and granodiorite. Contact relations indicate that the pink and more granitic rocks are younger than the gray and more mafic rocks, but radiometric age data are in conflict with this. Undated plutonic rocks that are not clearly related to the group are assigned to relatively older or younger age positions.

Rhyolite west of Bucaramanga fault forms a small pluton in one locality and as an intrusive sheet with granophyre and intrusive breccias in Triassic sedimentary rocks in another locality. The age is unknown but probably is younger than the Santander Plutonic Group.

Dikes that are common in the batholiths, plutons, and adjacent rocks are felsic, mafic, and lamprophyric in composition, and most appear to be genetically related to the larger igneous bodies, whereas rarer dikes of dacite porphyry, basalt, and diabase are not related. Dacite porphyry is the only igneous rock that intrudes rocks of Cretaceous age. Basalt and diabase dikes are widely scattered and have been found nearly as high as the Jurassic-Cretaceous boundary. Gold-quartz mineralization occurred in the metamorphic and igneous rocks of the California-Vetas district late in or after the Mesozoic plutonic interval. Fluorite-galena veins are in or near the Mesozoic plutonic rocks.

With the uplift that accompanied emplacement of batholiths in Latest Triassic and Jurassic time, erosion of the roof rocks furnished fine-grained redbeds and conglomerates of the Jordan Formation of Jurassic age; erosion of the batholiths and the Jordan Formation as well provided the coarse-grained and conglomeratic arkosic sediments of the Giron Formation of Jurassic age in thick accumulations off the flanks of the uplift. Sandstone and arkose of the Girón Formation locally contain sparse secondary copper minerals. This period of continental accumulation was followed by Cretaceous marine invasion and sedimentation. In the Magdalena Valley area, Early Cretaceous sedimentation began with quartz sands of the Tambor Formation and continued with fossiliferous limestone of the Rosa Blanca Formation, black shale of the Paja Formation, fossiliferous limestone, glauconitic sandstone, and black shale of the Tablazo Formation, and still more black shale of the Simiti Formation. In Late Cretaceous time, calcareous black shale, chert and phosphatic beds in the upper part of the La Luna Formation were deposited during the time of most widespread marine transgression. Thereafter gray shale, limonitic beds, and coal beds of the Umir Formation accumulated as marine conditions were gradually succeeded by continental deposition in latest Cretaceous. Lead-zinc deposits are found in the Lower Cretaceous sequence, primarily in carbonate beds.

Cretaceous deposits over the area were mostly uniform in character if not in thickness, and remnants of these rocks that have escaped erosion in the massif are similar to the Cretaceous rocks of the Magdalena Valley to the west and the Marcaibo Basin to the east.

In the Magdalena Valley area continental conditions prevailed through the Tertiary. The Paleocene Lisama Formation, consisting of coal beds, was followed in the Eocene by thick conglomeratic sandstone of the La Paz Formation and sandstone, siltstone, and shale of the Esmeraldas Formation; in the Oligocene by shale of the Mugrosa Formation and shale with coarse conglomeratic sandstone of the Colorado Formation; in the Miocene by even coarser and thicker sediments of the Real Group; and in the Pliocene and Pleistocene by the Mesa Group. Most of the section of Tertiary rocks in the Colombian part of the Maracaibo Basin is similar in origin and lithology, but the beds are thinner than those in the Magdalena Valley. These rocks were eroded or were never deposited in the area that is now the highest part of the massif.

Alpine glaciers formed on the Santander massif during the Pleistocene, and widespread terraces in the lower valleys may date from that period. Uplift of the massif is probably at or near its highest elevation at the present time; streams are eroding the flanks of the massif at a high rate, aided by action of deep weathering and landslides.

The Bucaramanga fault, a major fault of regional extent, trends north-northwestward across the area through Bucaramanga and apparently extends on to the north coast as the Santa Marta fault defining the western boundary of the Santa Marta Mountains. The present investigations indicate a long and complex history for the Bucaramanga fault, associated with earlier lateral displacement and uplift of the Santander massif to the east that continues to the present time.

West of the Bucaramanga fault are three areas with rather distinct structural character:

1) A wedge-shaped, down-faulted block tilted slightly westward between the Bucaramanga and Suarez faults is mostly an area of mesas capped by basal Cretaceous sandstone. At the thin north end of the wedge Quaternary gravels and mudflows accumulated in the fault-formed basin and now form the dissected terrace on which Bucaramange, the main city of the region, is located.

2) A plateau belt bordering the mesas west of the Suarez fault is formed mostly by dissected strata, undulating to steeply dipping of the thick Giron Formation.

3) West of the plateau area all sedimentary rocks from Jurassic to Tertiary plunge westward into the deep trough of the Nuevo Mundo syncline. This narrow syncline is on the deeper eastern side of the geosynclinal area of the Magdalena Valley basin. It is mostly separated from the shallower part of the geosyncline to the west by the north-trending La Salina fault where Upper Cretaceous rocks on the east side are in contact with Oligocene and Miocene rocks on the west.

In the high country that extends south and east of the metamorphic and igneous rocks of the Santander massif, two north-trending structural basins are separated by the regional Servita fault. The western basin contains sedimentary rocks ranging from Devonian to Upper Cretaceous and is complexly faulted. Rocks of the eastern basin range from Lower Cretaceous to Eocene and have undergone compressional folding that was more intense toward the west.

Many faults were mapped to the east and west of the Bucaramanga fault, and many more are indicated by lineaments on aerial photographs. Most have trends within a range of north-northeast to north-northwest, mostly parallel to the trend of structure. Only a few major faults cut across this trend. On the east and west flanks of the Santander massif, belts of sedimentary rocks, including mostly Cretaceous formations, have escaped erosion on the downthrown sides of long faults. On the east flank the downthrown sides are on the west, and on the west flank the downthrown sides are on the east, which suggests either more active uplift of the flank areas or collapse of the central area relative to the flanks.

METALLIC MINERAL RESOURCES

Historically the only significant exploitation of metallic mineral deposits in the Santander massif has been in the area near California and Vetas where gold and silver have been mined since pre-Colombian times. Placer gold deposits, probably derived from the district, have been worked along Río de Oro and Río Surata near Girón and Bucaramanga. Small deposits of base metals, primarily lead, have been worked in a few places in the massif, but these workings have been abandoned. The IMN in its minerals resources survey has outlined large areas in the massif within which small amounts of copper, lead, and zinc minerals are found. These areas are scheduled for future detailed exploration in order to determine their potential. Significant amounts of metals other than those mentioned above have not been found by the Inventario during the initial phase of the program.

Detailed studies of the California and Vetas mining district were undertaken to evaluate potential gold resources of the known producing area and to determine the potential for other metallic resources.

Locations of deposits of metallic minerals are shown in figure 2.

Gold and silver

California and Vetas mining district

Geography.--The California and Vetas mining district is about 40 kilometers northeast of Bucaramanga near the municipality of California. The district occupies an area of about 50 kilometers square along Río La Baja and Río Vetas (fig. 3) in the headwaters of Río Suratá. Access to the districts is by road from Bucaramanga to Suratá to California, a distance of about 50 kilometers, and by road from Bucaramanga to Berlín via the Bucaramanga to Pamplona highway and thence northward by a spur road to Vetas, a total distance of about 85 kilometers. California, on the west edge of the district, and Vetas at the southeast edge of the district, are connected only by mule trail. California lies at an altitude of 2,000 meters and is the lowest point in the district. Vetas lies near timberline at an altitude of 3,200 meters. The adjacent high country to the north, northeast, and east of the district is above timberline, at altitudes ranging from 3,800 to 4,000 meters. The climate is cool and wet, with a relatively dry season from December to March. Río Vetas and Río La Baja lie in deep V-shaped steep-sided valleys. Gradients on short tributary streams are as much as 600 meters per kilometer. The lower courses of larger tributaries such as Quebrada Mongora are about 150 meters per kilometer. Local relief ranges from 600 to 1,400 meters; maximum relief in the district is about 2,000 meters.

Population is sparse and is scattered in small farms most of which are below timberline. Much of the land between farms is covered by scrub growth. The only remaining patch of thick rain forest is in the valley of Quebrada Mongora. Slopes in some areas are extensively scarred and gullied by ancient workings and sluiceways. A prominent example is the slope above and northeast of Vetas.

History.--The history of gold mining in the Departments of North and South Santander is told in several accounts, the most detailed being that of Vicente Restrepo (1937). A more recent and briefer summary is that of R. Wokittel (1954). The district was possibly a source of gold for Indians in pre-Colombian times (Duarte, 1966, p.12). Placer gold deposits in Río de Oro near Girón and Bucaramanga were worked about 1550, soon after settlement in the region about 1550, and shortly thereafter gravels in Rio Surata were worked. In 1555, following the founding of Pamplona, gold was discovered near Vetas, and a gold rush resulted. An amusing account of the discovery of the gold, told by R. P. Enrique Rochereau is translated from a pamphlet celebrating the 400th anniversary of California in 1951:

> "After traversing the dark rocks which enclose the pass of Santurban the traveler immediately encounters a vast plain, a countryside both bleak and grand. Innumerable rivulets carry off gold over a land black and sterile. The lonely frailijon and other plants of the Andean high plains grow sparsely in the midst of rocks and auriferous sand. The scattered traces of ancient mines are reminders of the millions of unfortunate Indians, numbed by the cold and oppressed by the heavy yoke of slavery, who tore away from this frigid land a part of its gold.
>
> I was there from the year 1550 to 1555.
>
> Some gentlemen from the city, dressed in hunting attire and mounted on spirited horses were riding over this high plain (páramo) which at that time was unnamed. After having spent half the day pursuing the graceful white deer which abound in these regions, and whose phantoms jump and disappear on the bare crests, the horsemen overwhelmed by thirst and exhaustion looked for a stream and sat down on the banks of a crystalline brooklet to prepare a frugal lunch. They had hardly begun when one of them observed a man in poor and ragged attire laboriously climbing up the slope towards them. "Hellow, my fellow," one of the caballeros said to him. "What fortune brings you to these deserts?" Somewhat intimidated by the aspect of the rich gentlemen who addressed him, the poor man hesitated a moment, and with an extremely strong accent said to them: "My apologies for accompanying you. A few weeks ago I left the homeland to look for something with which to relieve my poverty. I have a wife and children whom I left in the most frightful misery. Luck would have it that I should come to Pamplona and today upon seeing your party, I thought that you were going to look for gold and I followed you." "And you came to look for gold with knapsacks?", answered one of the caballeros, laughing heartily at the simplicity of the man. "It would have been better if you had brought a few animals to carry the load, which I believe will be rather heavy." "I will hardly be content with what the knapsacks will hold," replied the man in all seriousness. "Well then, friend," one

of them said to him, "the effort that you have expended in reaching here has not been lost. There above, on the summit, is sufficient gold to fill several knapsacks such as yours. Up then, and be careful that you don't break any ribs in returning with the load."

The stranger did not suspect that the men wanted to take advantage of his simpleness, and with great pain and difficulty he climbed upward through the brushwood. Finally he reached the summit. Exhausted and despairing now of finding anything in these bare rocks, he dropped on the barren ground. Below, near the stream, he saw the merry companions begin to mount their beasts; the sound of their peals of laughter rose mockingly to him. He wanted to get up and follow them, fearing to stay alone in this strange, cold, barren place. To help himself stand up, he grabbed a plant, but the weight of his body tore out the roots and left him with the plant in his hand.

Oh, surprise! There, in the black earth clinging to the roots something yellow is shining, and another--. It is gold! Weakly, the man recognizes one, two--twenty nuggets. His trembling fingers pull apart the turf; gold is everywhere. Now he thinks no more of going. He fills his knapsacks with the precious dust, millions of flakes of which sparkle in the sunlight. And when, after painful work, he finally lifts his load onto his tired shoulders and prepares to return to the lowlands, he takes another glance at the companions who are looking up at him in astonishment, now knowing what is happening. He does not hesitate to take his turn at the fun.

"God will reward your honors," he says to them upon arriving at their sides. "I have already enough in my knapsack to relieve the household."

"What! Is the man crazy?" said one of the caballeros. Hardly had he pronounced these words when the stranger put a nugget of the precious metal in his hand.

Speechless and with wide-open eyes, the merry companions looked at one another. Meanwhile the man returned the nuggets to the knapsacks and giving the men a mocking smile, he left, heading for Pamplona.

A few minutes afterwards the Governor and his hunting companions also returned at a gallop toward the city. The paramo was the "Paramo Rico," and soon gold-mad Pamplona was to be called "Pamplonilla La Loca."

Restrepo recounts briefly the same story. The district was an important producer of gold from colonial times until about 1644. The mines were abandoned and rejuvenated periodically until 1886 when the government opened the district to development by private companies. Since then numerous small companies have operated some of the mines in rudimentary fashion. Two mining companies with foreign backing did considerable development work in certain parts of the district after independence. An English company, the Colombian Mining Association, operated from 1824 until the middle of the late 1800's. In the early 1900's a French company, the Francia Gold and Silver Company, operated for a short time. Both companies set up relatively large plants and equipment, the remains of which can still be seen in the district. The periodic abandonment of the enterprises has been attributed to various causes, such as exhaustion of easily minable ore amenable to simple mining and processing methods available; insufficient hydraulic potential for large-scale development; political strife; improper management; legal problems connected with title to mining properties; and technical processing difficulties in treatment of the ore. The possibility of mining copper in the La Baja area has been investigated but no studies as yet have gone beyond the exploratory stage.

Some figures for gold and silver production in recent years are available for the district. In the 9 years between 1945 and 1953 gold production averaged about 100,400 grams of gold per year (8,366 grams per month) and 68,700 grams of silver per year (Wokittel, 1954, p. 6). In the 9 months in 1966, an average of 15,844 grams of gold were produced per month (Duarte, 1966, p. 14), 75 percent of which came from near Vetas.

The following description of mining and methods used in the past is taken from Duarte (1966, p. 14-15): Early mining was done in shallow open pits and trenches following the exposed oxidized parts of the veins. Water from high mountain lakes and artificial ponds was sluiced down over the workings, washing off the soil and permitting exposure of new veins. The trenches were tortuous and narrow because only the gold-bearing vein material was mined. Deeper workings were prohibited by the lack of iron implements, explosives, illumination, and methods of ventilation. Rocks showing traces of gold were milled in primitive stone mills or by hand in stone mortars using pestles of quartz. Wooden gold pans and mercury were the only means of concentration and recovery of gold. This work was necessarily carried on in isolated small operations. Later, primitive iron stamp mills, wheel-driven by mules or water power, were utilized. The system of cyanidation was introduced with favorable results.

In 1906 the Francia Gold and Silver Company set up a plant to crush and mill the ore and process it for shipment abroad. The milled fine material was roasted in a reverbatory furnace in order to remove sulfur and volatiles. Then the roasted and partially oxidized material was mixed with lime. This material was then roasted in an electric furnace powered by a hydroelectric plant generated by a 200-meter head of water. A slag of silica and iron was removed, and the remaining matte of copper, gold, and silver was exported to Europe without further separation.

Geologic setting.--The country rock in the California and Vetas district is a complex of metamorphic rocks of pre-Devonian age and igneous rocks of Mesozoic age (figs. 4,5). Pelitic, semi-pelitic, and arenaceous paragneis and hornblende-bearing gneiss of the Bucaramanga gneiss predominate in the Vetas and northern part of the Río La Baja areas. Much of this gneiss is migmatitic. Trends of these rocks are north and northeast in the Vetas area and north to northwest in the Río La Baja area. A large mass of fine- to medium-grained tonalite and diorite (tonalita) extends into the southwest part of the district from the south, and terminates northeast of California. Near the junction of Río Vetas and Río La Baja is a mass of mafic-poor, fine- to medium-grained, locally porphyritic, granite and quartz monzonite (cuarzo monzonita porfiritica). Smaller masses crop out in the eastern part of the California area and in the Vetas area. Dikes of this rock and dikes and small masses of fine-grained biotite quartz monzonite (cuarzo monzonita de La Corcova) are relatively abundant in the gneisses in the La Baja area and somewhat less abundant in the Vetas area. The youngest dikes are a light-gray dacite porphyry prominent near California. Sedimentary rocks of Cretaceous age overlie the igneous and metamorphic rocks unconformably west of California beyond the area of hydrothermal alteration and veins. However, the dacite porphyry dikes are known to be younger than Lower Cretaceous beds and are affected apparently by hydrothermal alteration and mineralization. The mineralization thus is probably younger than Early Cretaceous.

Altered and silicified rock is abundant immediately east of California. Iron sulfate stain is prominent on exposed rock surfaces along Río La Baja and the lower part of Río Vetas. In places in the La Baja area malachite coatings are prominent on the faces of old workings. Such copper stain is absent in the Vetas area. Mafic-poor quartz monzonite, aplite, and porphyry near California and dikes in other places are commonly laced with small fractures filled with quartz containing pyrite or, rarely, other sulfides. In places silicate minerals have filled areas between fractures. The monzonite and porphyry appear to be particularly susceptible to fracturing and silicification throughout the district. However, fracturing, silicification, and sulfide mineralization have also altered, but less prominently in the gneiss in the Upper La Baja area and in the Vetas area. The alteration is less pervasive in the Vetas area and more apt to be confined to narrow discrete zones.

Scattered exposures of altered rock can be seen along Río Vetas toward Vetas, but apparently the alteration is not widespread in that area. A few prospect pits and mines not mapped have been reported on the slopes south of Río Vetas. The high land to the south, called Paramo Rico, has been the source of placer gold in Colonial times, but no old pits or mines were observed there.

Quartz veins and an extensive silicified zone in which the original structures of the metamorphic rocks are preserved crop out on the ridge between Quebradas Paez and El Pozo, but no sulfide mineralization is associated with them. A swarm of quartz veins cuts porphyritic biotite quartz monzonite on the ridge between El Volcan mine and Vetas, but this swarm also does not appear to contain sulfides. Both of these quartz masses are interpreted as being a different age of quartz than that in the adjacent mineralized zones. The mineralization in the district is not restricted to particular rock types.

The exact locations and the numbers of faults in the district have not been carefully mapped out and are not known with certainty. The large regional faults in the area trend north to northeast. A major fault, the Cucutilla fault, extends into the La Baja area from the northeast along Quebrada Romeral (fig. 4). This fault may have had some control on the sulfide and gold mineralization. The exact traces of the extension of this fault into the district are not clear. The valley of Río La Baja may be controlled by a branch of this fault. A west-southwest trending fault along which rocks have been chloritized projects from east of the district toward the Volcan mine near Vetas (fig. 5). This may possibly be part of a system that controls mineralization in the Río Vetas area. The valleys of Quebrada El Salado and the stretch of Río Vetas north of Vetas may be controlled by this or parallel faults.

Because the major faults of the region have northerly to northeast trends, it is not unreasonable to interpret the veins in the Río La Baja area as tensional features in a northeast-trending shear system.

Near Vetas the strike of veins is north to north-northwest, and the veins near El Volcan strike north-northeast to northeast. A different set of faults has been mineralized here and a different stress field may be operative. The veins are in groups in the Río La Baja area; the main groups are near La Baja-El Cuatro, La Angostura, and El Silencio (fig. 4). The La Angostura group probably extends to the area around La Alta. The two major vein groups, that near La Baja-El Cuatro and that in the La Angostura-La Alta area, are each about 250 to 300 meters wide and about 1 kilometer in length. The pattern of veins suggests that individual veins may actually be continuous with others on strike and that they probably intersect with veins that have not heretofore been recognized.

Description of mines and prospects.--The distribution of the mines and prospects in the California and Vetas district is shown in figure 3. Those mines currently being worked are largely accessible. Many of the old mines are wholly or in part inaccessible because of caving and landsliding. The La Francia mine on Quebrada La Plata and a number of smaller stopes around it were almost completely closed by landslides and were not studied by our group. Mapped mines are shown on figures 4 and 5. Where several levels are present the higher are shown superimposed on the lower.

Mineralized veins in the district are generally vertical to steeply dipping. Veins in the La Baja area individually strike about east, but are arranged in en echelon fashion in a northeast direction, the axis roughly parallel to Río La Baja. In the district as a whole, mineralization consists primarily of silicification and sulfide replacement, predominantly pyrite, in and adjacent to closely to widely spaced fractures and shears. Evidence for repeated shearing, brecciation, replacement, and recrystallization is widely seen. Several generations of quartz and sulfides are present. Ore shoots and sulfide-bearing veins, usually steeply dipping, follow narrow shear zones and fractures in the silicified and altered host rock. Sulfide concentrations tend to be lenticular. Narrow seams of gouge are common along many of the veins.

In both the California and Vetas areas the most abundant sulfide is pyrite. In the Vetas area sulfides other than pyrite are rare. The gold in the district is typically associated with the pyrite. In the zone from La Baja to Quebrada Angostura, chalcopyrite is locally abundant, with lesser amounts of covellite and bornite. Sphalerite, galena, and rare molybdenite are present locally in the San Celestino, La Catalina, and La Mascota mines. Some tetrahedrite, probably the principal bearer of silver, is present in the mines in the San Celestino area. Chalcopyrite and the other sulfides are scarce in the mines in upper Quebrada Paez and near La Alta. Uraninite, meta-autunite, and zeunerite occur in mines in the San Celestino area. Uraninite forms finely disseminated grains in quartz. This quartz appears to be the youngest quartz.

In the host rock, adjacent to mineralized fractures, feldspars are kaolinized; mafic minerals are leached, or at a greater distance from the mineralized zones, altered to chlorite. Pyritization and silicification are most prominent in the relatively mafic poor granite, aplite, and porphyry in the California area and in aplite dikes in the surrounding gneisses. However, the mineralization is locally just as intense if not as widespread and prominent in the gneisses.

Geochemical sampling of stream sediments

Purpose.--Stream sediment samples were collected by the Inventario Minero Nacional in 1967 at 69 sites on smaller streams in the California and Vetas mining district; these were analysed semiquantitatively for a wide range of trace elements in order to obtain reconnaissance information on the kind, distribution, and relative amounts of metallic elements present in addition to gold and silver that might prove to be of potential economic value in the district. The sampling was also intended to give, if possible, an indication of the distribution of the known principal product gold, and to show the extent and trend of anomalous concentrations of metallic minerals. Because of the high relief and rainfall in the area, it was not certain what sort of results would be obtained from the sampling program. Systematically useful quantitative results were not expected because of the presence of active and abandoned mines in some stream drainage basins and the absence of mines in others. Results from localities of isolated and unsystematic anomalous amounts would be viewed skeptically because of the possibility of contamination in the district during the long history of settlement and mining.

Procedure.--Two types of samples were collected from each locality. One was a panned concentrate of sand-sized material from the stream bed; the other was mud. An attempt was made to pan a uniform quantity of raw material. Cobbles and pebbles were removed by hand during the panning. No attempt was made to screen the material for fear of contamination by the screening material available. The resulting sample, nevertheless, was of fairly uniform sand-sized material. The amount of material differed greatly among the different samples. Panning and sampling was done by local panners using wooden gold pans. Sampling was under the direction of Jaime Galvis V.

The sample of mud was collected from banks and beds of streams and submitted without screening or sorting. Some variation in grain size among the different samples resulted, and a few samples contained appreciable sand.

Samples were collected without regard to the presence or absence of active or inactive mines upstream. In fact, an attempt was made to collect a sample below mines and prospects in order to see what elements were coming from them. Sampling upstream from mines and prospects was not as complete as desired, primarily because of accessibility or adverse stream conditions. Some streams are so steep and rock-bound with numerous waterfalls that some difficulty was encountered in finding accessible localities where sand, let alone mud, was suitable for sampling. This was particularly true for the upper reaches of the streams.

About 50 grams of sample when available were submitted for analysis. Some samples contained less, and some much less than 50 grams. A few samples were lost. The samples were submitted to the U. S. Geological Survey in Washington, D. C., for analysis. The heavy-mineral concentrates were analyzed for 62 elements by standard six-step spectrographic analysis. The mud samples were analyzed first for equivalent uranium (eU), which is a measurement of gross radioactivity in the sample from whatever source, and then analyzed for gold by combination fire assay and atomic absorption technique (Huffman and others, 1967).

The weights of the samples of panned concentrate before splitting into the 50-gram lots for submission for analysis unfortunately are not available so an estimate of quantity of metals in the original sample can not be made. The amount of concentration might be from 3,000 times to 4 times.

Results.--Histograms of the results of spectrographic analyses of trace elements in heavy-mineral concentrates, and fire assay and atomic absorption determinations for gold, and results of equivalent uranium determinations (eU) on samples of mud are shown in figure 6. Histograms of spectrographic analyses are shown only for those trace elements present in detectable amounts. Limits of detection are shown in table 1. Elements detected in the present study are underlined; other elements listed in table 1 but not plotted on figure 6 if present are in amounts below the limit of detection. Ir, Os, Rh, and Ru were not looked for because Pd and Pt were not found.

Most of the histograms shown in figure 6 show normal distribution, or indicate that the elements are present in amounts below the limits of detection. Histograms showing marked skewness or spread beyond the mode indicate metals that are considered to be present in significantly anomalous amounts; they are Au, Ag, Cu, Pb, and Zn. Values above which these metals are considered anomalous are Au, 0.6, Ag, 1, Cu, 300, Pb, 100, and Zn, 300. The histograms for Ba, Mo, Sn, W, and Eu and possibly Pr have shapes and amounts that indicate the presence of anomalous amounts of these metals, but the anomalies and amounts are low. Compared with the amounts of the other metals such as Cu, Pb, and Zn, the amounts of Mo, Sn, W, and Pr do not appear to be high enough to indicate that these elements are present in economically significant amounts. These elements are indicator elements that normally may be expected in association with metallic mineralization, but generally not in economically recoverable amounts. The high amounts of Ba, Mo, Sn, and W commonly are found below mines where amounts of the other metals are high, otherwise they would doubtless be undetectable in the sampling.

Table 1.--Approximate visual lower limits of determination in parts per million for trace elements analyzed by the 6-step spectrographic method of the Denver Laboratory of the U.S. Geological Survey, 1967.

Element	ppm	Element	ppm	Element	ppm
Mn	1	In	10	Sr	5
		Ir	50	Sm	100
Ag	0.5	La	30	Ta	200
As	1,000	Li	50	Tb	300
*Au	20	Lu	30	Te	2,000
B	20				
Ba	1.5	Mo	3	Th	200
		Nb	10	Tl	50
Be	1	Nd	70	Tm	20
Bi	10	Ni	5	U	500
Cd	20	Os	50	V	7
Ce	150				
Co	3	Pb	10	W	100
		Pd	1	Y	10
Cr	1	Pr	100	Yb	1
Cu	1	Pt	30	Zn	200
Dy	50	Re	30	Zr	10
Er	50				
Eu	100	Rh	2		
		Ru	10		
Ga	5	Sb	150		
Gd	50	Sc	5		
Ge	10	Sn	10		
Hf	100				
Ho	20				

NOTE: Some combinations of elements affect the limits of determination. Approximate values are given. In unusually favorable materials concentrations somewhat lower than the values given may be detected. In unfavorable materials the given limits of determination may not be attained for some of the elements.

Elements underlined are those detected in the samples submitted from the California-Vetas district, and except for Bismuth plotted on figure 6.

* .02 by fire assay and atomic absorption technique.

The mode for Zr seems to be unusually high, but the granitic and metamorphic host rocks both contain zircon as a common accessory mineral. An anomalous amount of equivalent uranium is recorded from only one site.

The histograms shown in figure 6 indicate that Au, Ag, Cu, Pb, and Zn are the only metallic elements present in significantly anomalous amounts. With the exception of gold, amounts of these elements are not particularly high in panned concentrates even from below mines.

The data for gold in mud and silver, copper, and lead in panned concentrates have been plotted graphically in figures 7 and 8. The samples have been arranged in order of increasing amounts of copper. Amounts of gold, lead, and silver have been plotted accordingly. Amounts of gold and other significant elements in the panned concentrate are shown in parts per million in table 2. The locations of the samples are shown on figure 9.

The graphs in figures 7 and 8 indicate a crude correlation in amounts of elements at any one locality. The most obvious relationship is that where one element is high, one or more of the others is apt to be high. High amounts usually indicate the presence of a mine upstream. Amounts of copper and lead, and by inference zinc, appear to be somewhat more systematically related to each other than to silver and gold. Amounts of gold are high in both the mud samples and the panned concentrate. The mode for gold from mud is 0.02 to 0.05 ppm, which appears to be a rather high background for gold. The mode is well above the modes of gold in non-mineralized or weakly mineralized areas, as determined by Fischer and Fisher (1968, p. 2), for example. The amounts of gold in the mud are true values

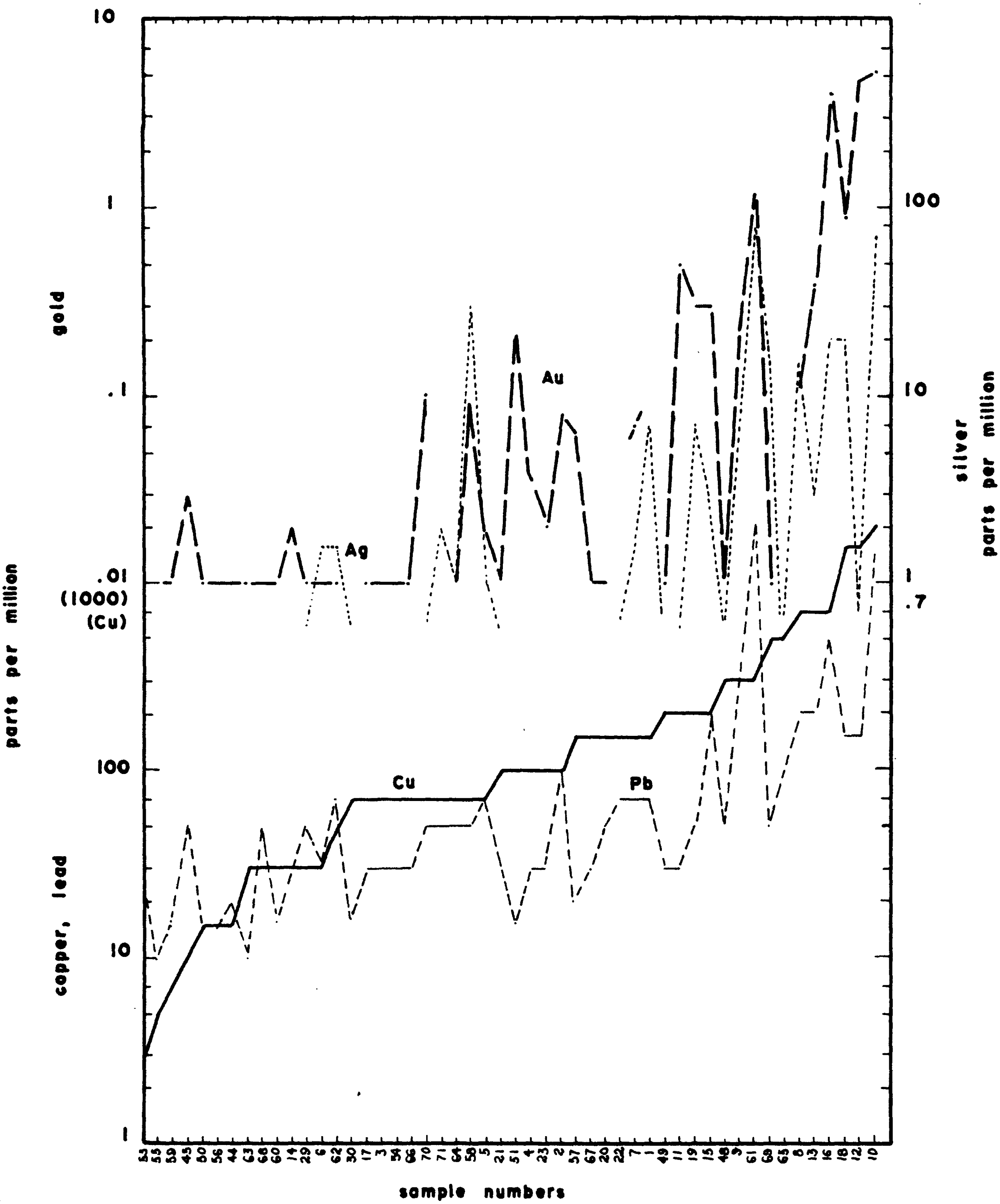

FIGURE 7 : Amounts of Au, Ag, Cu, and Pb in stream sediment samples from La Baja area, Department of Santander. Samples arranged in order of increasing Cu content. Sample localities shown on Figure 9

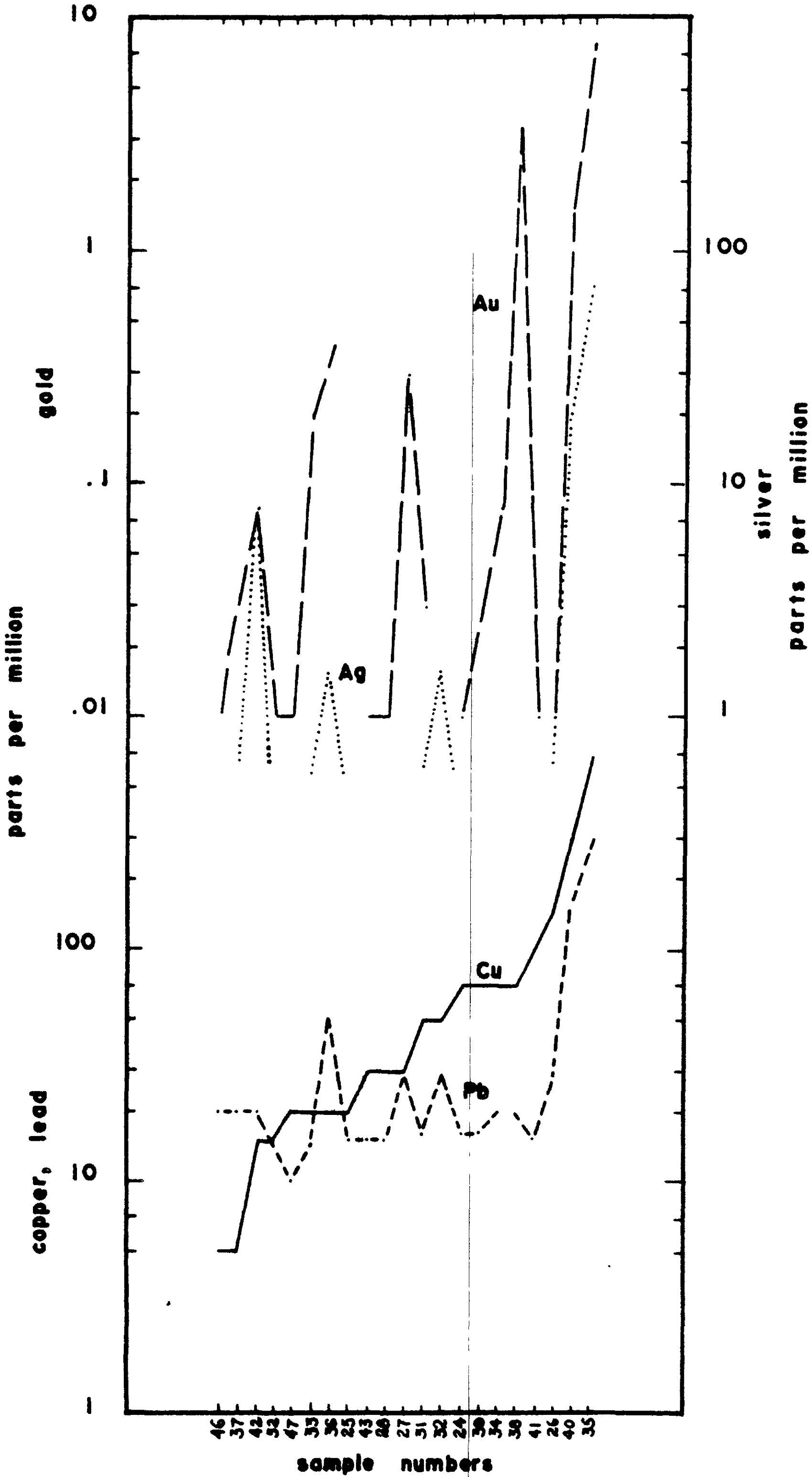

FIGURE 8 : Amounts of Au, Ag, Cu, and Pb in stream sediment samples from Vetas area, Department of Santander. Samples arranged in order of increasing Cu content. Sample localities shown on Figure 9.

Table 2.--Samples of heavy-mineral concentrate from stream sediment, California and Vetas district, containing anomalous amounts of selected elements.

/Spectrographic analyses by J. L. Finley and G. W. Sears, Jr., U. S. Geological Survey. Sample locations shown on figure 9./

* eU determination on sample of mud by John Gardner, U. S. Geological Survey.

No.	Zn	Mo	W	Other	Comment
		Parts per million			
		La Baja area			
1		15	100	Sn 15	Below mine
8			150		Below mine
10	700	15		U .012 percent*	Below mine
11		5			
12		30			
13		20			
15			500		Below mine
16		5			Below mine
17			100		
18		15		Ba 50,000	Below mine
19		7			
20		7			
21		7			
45	300			Sn 30	
48	1,500				
49		7			
61	7,000			Ba 7,000	Below mine
		Vetas area			
26		10			
32				Sn 20	
35	700	7			Below mine
38				Sn 20	
40	500	15			Below mine
41		20			
43		5			

because there has been no concentration of these samples. Amounts of gold in the panned concentrate that are greater than the threshold of detection by spectrographic means, 20 ppm, are appreciably higher than for the mud samples from the same locality, but there is no consistent factor among the results at each site that would indicate the degree of concentration in the panned samples, assuming that both mud and sand had the same amount of gold originally. Probably the mud and the sand carry different amounts of gold because of the form and habit of the gold in the source vein material. Most of the gold is fine and carried in pyrite. Free gold is rarely seen, but its presence is indicated in some places along an ore shoot by a bright yellow clay. Even so, the largest mass of solid gold ever mined in Colombia is from the Pie de Gallo mine (locality 6, fig. 7). This mass was reported to weigh about 65 kilograms (Restrepo, 1937).

Samples containing high amounts of molybdenum and tungsten also contain high amounts of gold or high amounts of copper, lead, and zinc. Samples with high amounts of tin also tend to contain high amounts of gold. Samples with high amounts of silver generally also contain high amounts of gold, but the ratios of gold to silver are not uniform. A better correlation exists between lead, silver, and gold than between copper and the other metals (figs. 7 and 8). The high amounts of gold and silver at locality 58 are unaccompanied by anomalous amounts of copper and lead. A similar relationship exists in several places in the Vetas area, as at locality 33. The high amount of gold in heavy mineral concentrate at locality 45 is accompanied by anomalous amounts of zinc and tin (table 2) but low amounts of copper. Further sampling in this stream is warranted to see if the anomalies are real or are possibly due to contamination or error. As far as is known, this stream drains an area of unmineralized sedimentary rock. The high percentage of barium at locality 18 is unexplained, but the locality is below several operating mines. An anomalous amount of equivalent uranium (eU) was measured only at locality 10. This site is markedly north of localities 1 and 6 of figure 7 where radioactive minerals have been previously identified. (Pagnacco, 1962, for example.)

The amounts of gold indicated on the histograms have been plotted in three groups on figure 9 to allow for analytical error and for clarity of presentation. The first group, <.02 to .05 ppm, comprises samples containing modal and near modal amounts of gold. The second group comprises samples containing above modal amounts, >.06 to .5 ppm. The third group comprises samples that are clearly anomalous, >.6 ppm.

The lower limit of detection of gold for some samples was raised from <.02 ppm to as much as <.08 ppm, because of inadequate amounts of sample for the fire assay-atomic absorption analyses. Most such samples are plotted on figure 16 as if they contained the minimum amount, <.02 ppm. At a few locations the mud samples are missing and amounts are inferred from the amount of gold and silver in the heavy mineral concentrate.

Similarly, amounts of copper in panned heavy-mineral concentrate are grouped in threes to allow for analytical spread, and contours at 30, 100, 300, and 1,000 ppm copper are shown on figure 9. Areas of high copper are approximately those areas high in lead and zinc, and the distribution of anomalous copper can be considered as approximately representative of that for lead and probably zinc. The mode of copper in the samples is 70 ppm. The contours at 30 and 100 ppm enclose an area in which modal and sub-modal amounts of copper are present in the samples. Samples outside the 30 ppm contour contain much less than modal amounts of copper. Samples between the 100 and 300 ppm contain amounts of copper above modal amounts but which are not necessarily anomalous. Samples within the 300 ppm and 1,000 ppm contours contain anomalous amounts of copper. These areas contain most of the active and inactive mines.

The map, figure 9, shows two belts of anomalous amounts of gold: one extends northeast along Río La Baja; the other trends east or east-northeast along and south of Río Vetas. The La Baja zone is fairly well defined and the anomalous amount of gold at locality 58 suggests that the area of anomalous amounts of gold extends further to the northeast, into the northeast-flowing Quebrada Romeral drainage. However, the convergence of samples with low gold content toward this locality indicates that the area of anomalous gold does not extend northeastward. Samples with maximum values in gold are clustered in the area of intersection of Quebrada Angostura and Quebrada Paez and scattered to the southwest. The areas of samples containing anomalous amounts of copper occur in two nodes superimposed on the belts of anomalous amounts of gold and coincide approximately with the areas of maximum amounts of gold. A line through the centers of the two nodes coincides with the trend of the area of anomalous amounts of gold. The area containing anomalous amounts of copper is smaller than that containing anomalous amounts of gold.

The zone containing anomalous amounts of gold along Río Vetas is less well defined than that along Río La Baja for control is lacking to the south and east. Field evidence suggests that the anomaly does not extend very far to the east, but may extend southwestward toward the Páramo Rico area. The area containing anomalous amounts of copper in the Vetas zone is smaller than that containing anomalous amounts of gold, and is smaller than the area of the anomalous amounts of copper in the La Baja area. This agrees with field observations that alteration is less widespread, and copper, lead, and zinc-bearing minerals are much less evident in the Vetas area. No sampling was done south and east of Vetas. The contours as drawn here are based on lack of mines and manifestations of mineralization in rock at the surface.

The differences that might exist between amounts of metals in stream sediments below active mines and the amounts of metals in stream sediments below possible mineral-rich locations where there has been no mining activity is not known. Under existing topographic and climatic conditions, the amounts of metals in stream sediments might be no higher than background even where unexploited metaliferous rock exists. The evidence is conflicting. Where amounts of gold are above the mode, from .06 to .5 ppm, generally some modern or ancient mining has taken place. Samples from the streams draining Páramo Los Puentes east of Río La Baja and north of Río Vetas contain minimum amounts of gold and the rocks at the surface do not appear to be mineralized, nor has there been mining. However, anomalous amounts of metals that might be expected in the samples below the old abandoned workings in the Quebrada La Plata drainage, samples 24, 25, and 28, did not show up in the analyses. On the other hand, relatively large amounts of gold were obtained in panned concentrate (table 2) at locality 45 where there has been no previous indication of mineralization or mining activity. This suggests that anomalous amounts of gold, at least, would have been found in the sampling program if the mineralization were there. On the whole, the anomalies shown in figure 9 are located in the areas of mining activity, both ancient and modern. In both the La Baja and Vetas zones, samples containing the largest amounts of gold are in the northeast and east parts of the zone respectively. These are the areas of greatest mining activity at the present time.

Summary.--The results of geochemical sampling of stream sediments in the California and Vetas mining district indicate that gold is the metal of primary economic interest. Copper, lead, zinc, and silver are of subordinate interest. Minor amounts of molybdenum, tungsten, and tin are present in a few samples. Other metals are not of economic importance. An anomalous amount of radioactivity was recorded only at one locality in the California-La Baja zone and this was low.

Two zones containing anomalous amounts of metals are present. One trends northeast roughly parallel to Río La Baja northeast of California; the other, less well-defined, trends approximately east along and south of Río Vetas. Greatest anomalous amounts of copper, lead, and zinc are recorded in the La Baja zone. The greatest concentrations of metals are in the area of intersection of Quebrada Angostura and Quebrada Paez in the La Baja zone and north and northeast of Vetas in the Vetas zone. These are the areas of most of the active present-day mining. On the whole, the distribution of anomalies of gold and other metals coincides with the areas of known mineralization and the areas of active or formerly active mining.

Mine investigations

Accessible adits in the California and Vetas areas were mapped and sampled during the course of the Inventario program. About 590 channel samples were taken from roof or back at intervals of 10 meters along drifts, and at faces of drifts or crosscuts on both vein material and adjacent wall rock. The channel samples were of different lengths, most of them being about a meter long. These samples were assayed for gold and silver and also analyzed for copper, lead, and zinc in laboratories of the Ministry of Mines and Petroleum, Medellín.

For reports of the analyses and exact locations of the samples, the reader is referred to Appendix A of this report. These data are summarized in figures 10 and 11 on which are shown the mapped mines and the samples containing significant amounts of gold, copper, lead, and zinc. Only samples in which gold is greater than 5 grams per ton (5 ppm), or which contain greater than 1 percent copper, 2.5 percent lead, and 3.5 percent zinc are shown. Mines are identified on figures 10 and 11 by letter and number keyed to data and detailed maps in Appendix A.

Sites of samples containing 5 grams per ton (5 ppm) or more are fairly well scattered throughout the La Baja and La Alta area. Samples containing over 20 grams per ton are fairly common and samples containing over 50 grams per ton are found in several mines. Samples containing high values in copper, lead, and zinc are restricted largely to the zone from La Baja to the La Angostura area. Few samples contain over 500 grams per ton silver and these are from the San Celestino (AG, AF) and La Catalina (W) mines.

Amounts of copper are high in some samples from the mines near La Baja and in the El Cuatro (C), and La Mascota (J) mines. However, only a few samples contain over 5 percent copper. Amounts of lead are high in samples from the San Celestino and La Mascota mines, whereas amounts of zinc are high only in samples from the San Celestino and La Catalina mines. A few samples contain as much as 13 percent lead and 38 percent zinc. Most samples contain less than 5 percent lead or zinc.

In the Vetas area only the samples from the El Volcan mine contain much gold. No samples contain significant amounts of copper, lead, or zinc. About 90,000 tons of tailings of sand-size material and smaller are present at the El Volcan mine mill site. The sand fraction contains 18 grams per ton of gold and 38 grams per ton of silver. The mud fraction contains 26 grams per ton of gold and 44 grams per ton of silver. A map and results of core sampling on the tailings is given in Appendix A.

On the basis of diamond drilling and sampling, the Nippon mining company has estimated ore reserves in the San Celestino and San Antonio mine areas (The report of prospection of the California Mines, July, 1967, Nippon Mining Company, Ltd.: Report in the files of the Servicio Geologico Nacional, Bogotá). They estimate gold reserves in the San Celestino and San Antonio mines to be about 46,000 tons with tenor of

12 grams per ton. They estimate reserves of about 40,400 tons of copper ore with a grade of 1.24 percent copper in the San Antonio mine. Other mines in this area had lower tenors and tonnages. They found the amounts of uranium to be noneconomic. Drill cores revealed decreasing amounts of uranium with depth.

About 70 randomly selected samples from the La Baja area were analyzed spectrographically by six-step semiquantitative spectrographic analysis for 62 elements by laboratories of the U.S. Geological Survey, Denver, Colo., to check the trace-element content and to cross-check the results of assays and analyses done in the laboratories of the Ministry of Mines and Petroleum, Medellín. Gold analyses were made by fire assay-atomic absorption technique. Results on gold and silver from the two laboratories are consistent.

The results of spectrographic analyses of the 70 samples support the conclusions drawn from the results of the stream sampling program and are in accordance with the observed mineralogy of the mines. Metallic elements other than gold, copper, silver, lead, and zinc are lacking or are present in insufficient amounts to be of economic interest. No samples from the Vetas area were submitted for spectrographic analysis.

Amounts of a few of the elements are sufficient to be of interest in a few places. Arsenic and antimony are relatively high in rare samples indicating the presence of arsenide and antimonide minerals. These high values coincide with high amounts of lead and zinc and with observed high relative abundance of sphalerite, galena, and tetrahedrite. Two samples from the San Antonio mine contain 3,000 and 7,000 parts per million molybdenum, respectively. Highest amounts of molybdenum in samples from other mines are 100 ppm in two samples from the La Mascota and La Catalina mines. In most of the samples it was not detectable or in amounts less than 50 ppm.

Tungsten occurs in amounts up to 700 ppm in samples from the Mascota mine area and 100 to 500 ppm in samples from some of the mines in the La Baja area where lead and zinc are high. A sample from the Porvenir mine (A-8) near El Cuatro contained 1,500 ppm tungsten. Uranium was recorded spectrographically in samples from the San Celestino mine (AF) (2,000 ppm), San Antonio (T) (1,000, 700 ppm), and Begonia (V) (3,000 ppm), mines. No samples contained anomalous amounts of tin.

Conclusions

Results of reconnaissance sampling and mapping program in the California and Vetas district indicate that gold is the principal commodity of the district and that amounts of copper, lead, silver, and zinc are too small to be more than by-products of gold production. No new surface exposures of gold mineralization were discovered during the investigations and the results indicate that the district does not extend much beyond the present area containing the workings. The Río La Baja area is more promising than the Vetas area.

Samples containing high values in gold are distributed along Río La Baja over a fairly long belt from La Baja to La Alta, a distance of 3.3 kilometers. The two larger vein swarms have areas of about 0.5 and 0.3 square kilometer. Individual veins are quite likely more continuous one into another than is indicated from mapping of known drifts. The existence of probable extensions of known veins with others along strike and probable intersections of veins could be profitably tested by a well-planned drilling program.

It is clear from the size of the area of each vein swarm that exploration and development would require a larger operation with greater mining capabilities than presently exist with the small individual hand operations. Because of the generally fine particle size of the gold and its usual fixation in pyrite, the present primitive processing methods entail appreciable loss.

Future potential of the California and Vetas district hinges largely on an increase in the price of gold and on the possibility of the smaller concessions coming under the control of a large well-financed mining company that has the means to establish mine and recovery plants that are adequate for a large operation.

Amounts of silver, copper, lead, and zinc are too small to be more than by-products of gold production; even then, they could become by-products only by exploitation on a large scale with installation of a modern flotation plant.

Under the present relatively primitive small-scale operations the district could continue indefinitely as a producer of gold, but always as a very low volume, inefficient operation with considerable loss in unrecovered gold and by product metals.

Copper

The description of the mineral commodities in this and following sections is exclusive of the California-Vetas district (Copper mineralization in the California-Vetas district was given in the preceding section). For locations of copper deposits, refer to figure 2.

No commercial copper deposits are known in the report area, and none of the occurrences of copper minerals reported here appears to have much prospective potential except possibly those at Cañada El Tuto and Caño Jascajal. Because of the lateral extent of the copper mineralization in the outcrops of the Girón beds at these localities, sampling and more detailed investigations appear justified.

Tembladal Mine

Copper mineralization is included in the description of the Tembladal mine on page 55.

Cerro El Cacho

110 II-C, G-15 NW, Municipality of Pamplona, North Santander. Fractured quartz monzonite with disseminated copper minerals crops out about 3 kilometers east of the Pamplona-Chitagá highway on the north side of the trail to Cerro El Cacho. The minerals include covellite, very small amounts of native copper, and malachite. The mineralization extends over an area of about 800 square meters.

Pozo Negro

110 III-D, F-15, SW, Municipality of Silos, North Santander. From Campamento on the road southeast of Silos, a trail leads to the prospect which is on the north side of Río Caraba about 500 meters upstream from its junction with Río Angosturas (or Quebrada Pajaritos). In a small pit in sericitic graphitic schist are exposed two small quartz veins 4 and 5 centimeters wide (strike N. 55° E., dip 72° NW) that contain pyrite, chalcopyrite, and secondary malachite, calcite, and limonite. Malachite bloom is also present in small amounts about 30 meters farther upstream. The prospect is near the contact of the schist with dioritic orthogneiss.

Cañada El Tuto

121 I-B, G-8 SE, Municipality of Silos, North Santander. At a distance of 3.2 kilometers N. 30° E. from El Portillo on the Berlín-Baraya road, coarse arkosic beds of the Girón Formation (strike N. 62° W., dip 32° NE) on the northwestern slope of Cañada El Tuto are stained green with malachite that is apparently derived from oxidation of disseminated fine grains of copper sulfides. In the largest of four exposures over approximately 300 meters of the Girón section at this locality, the mineralization extends for a distance of 136 meters along strike in a bed 5.4 meters thick.

Caño Jascajal

121-I-D, A-10 SE, Municipality of Silos, North Santander. This locality is on the east side of Caño Jascajal at a distance of 4.8 kilometers S. 73° E. from El Portillo on the Berlín-Baraya road. Disseminated fine grains of copper sulfides are probably the minerals from which malachite is derived in a 70-centimeter-thick bed of gray, arkosic, locally conglomeratic sandstone and in the underlying 50-centimeter-thick bed of sandy, slightly calcareous, dark-gray siltstone (strike N. 10° W.?, dip 45° NE?). These beds are in the Girón Formation, and the mineralization can be traced for approximately 250 meters along the strike.

About 200 meters upstream to the south from the occurrence described above, a bed of arkosic conglomerate (strike N. 32° E., dip vertical) 1.2 meters thick has malachite bloom of which the lateral extent was not determined. A little galena is also present.

Alpargateral

121 II-A, F-1 NE, Municipality of Chitagá, North Santander. This deposit is in fractured siltstones of the Jordan Formation at the top of a high ridge about 500 meters northwest of the trail that extends from Hacienda Burgua southwestward past Alpargateral to El Portillo on the Berlín-Baraya road. Chalcocite, covellite, and quartz are present in small amounts in the fractures, but most of the sulfides have apparently been oxidized to malachite and azurite. The Jordán beds, which are normally a uniform reddish-brown color, are gray in the mineralized zone. The zone is two to three meters in width and is exposed at the surface over a distance of about 8 meters. It is located along a fault that trends west-northwest. A steeply inclined prospect adit has been dug into the mineralized rock to a depth of about 6 meters.

Las Castillas

136 III-B, C-7 SW, Municipality of Covarachía, Boyacá. From Covarachía the deposit is reached by road to Nogontova and El Limón, and continuing by trail to Ayuelal, El Jazmín, and Las Castillas on the south slope of Río Chicamocha. In an area about 40 by 30 meters in size, small fractures in orthogneiss contain pyrite, chalcopyrite, calcite, and quartz, with secondary malachite and azurite(?). A pit has been dug in the mineralized rock by persons searching for emeralds.

Lead-zinc

No lead or zinc deposits were being mined on a commercial scale at the time of this report (1969). Of the deposits described here, those at Hacienda La Amarilla, Montenegro, and Quebrada Cedrillal appear favorable enough to warrant further investigation by trenching and possibly by drilling. In the latter two, which are widely separated, dolomitization of the limestone as well as the lead and zinc mineralization are quite similar.

Loma El Padre

110 III-C, C-15 NE, Municipality of Tona, Santander. At a distance of 2.5 kilometers east of Berlín on the highway to Pamplona, the deposit is about 600 meters north of the highway. Along a fault that cuts mica schist and granite pegmatite, a zone up to 20 centimeters wide has incrustations of yellowish-green crystals of pyromorphite, a secondary lead phosphate mineral, lining small cavities in soft, limonitic rock of the fault zone. A trench has been dug along the strike of the fault for a distance of about 8 meters to depths up to 4 meters. A sample from the pile of excavated mineralized rock assayed 25.6 percent lead, 1 gram of gold per ton, and 26.5 grams of silver per ton.

Tembladal Mine

110 III-C, C-8 NE, Municipality of Tona, Santander. The mine (inactive) is 5 kilometers west of Berlín in Quebrada Tembladales, north of the trail to Tembladales and Tona. Galena, fluorite, quartz, and minor amounts of pyrite, chalcopyrite, and sphalerite are present in a brecciated fault zone that trends E. to N. 75° E. in the Tambor Formation. The mineralized zone is about 2 meters wide where it has been mined in an open cut along the bed of the quebrada for a distance of about 15 meters. It can be traced about 50 meters farther upstream where it narrows to less than 1 meter and where only fluorite is evident.

A ball mill and wilfley table (capacity of 8 tons per day) were used to process the ore, but the small size of the mine cut and small pile of mill tailings indicate that operations have been of only short duration. Only small ore reserves are indicated, probably not more than 1,000 tons containing sulfides and 3,000-4,000 tons containing fluorite. A grab sample from the ore pile analyzed 3.38 percent lead, 0.77 percent copper, 0.24 percent zinc, 6 grams of gold, and 47.6 grams of silver per ton. No attempt has been made to evaluate the fluorite in this deposit.

Hacienda La Amarilla

110 IV-C, C-6, C-7, Municipality of Chitagá, North Santander. From the highway 5.5 kilometers north of Chitagá, a trail crosses Río Chitagá at Puente Bolívar and extends to Hacienda La Amarilla and beyond to Bábega. In an area of approximately 1 square kilometer on the north slope of Río Caraba, galena mineralization has been found in two outcrops of the basal sandstone of the Tibú Formation and in limestone of the Mercedes Formation. The galena, with quartz, fills small fractures up to 15 centimeters long and 2 centimeters wide. Outcrops are few in the area and the mineralization in the limestone is better represented in pebbles and boulders on the slopes below the outcrop. The largest exposure of mineralization is about 1.6 meters in length by 0.9 meters in maximum width in highly fractured sandstone. Argenite may be present with the galena. The owner of the hacienda reports that analyses of the mineralized rock showed a large silver content with the lead. Ore is reported to have been taken from excavations in the vicinity of the mineralized limestone in the distant past, but the pits are now nearly filled with colluvium.

Between its basal sandstone and the overlying Mercedes Formation, the Tibú Formation contains mostly limestone which is not exposed in this area. This limestone is probably the most favorable part of the section for the occurrence of replacement-type lead-zinc mineralization, and, therefore, further investigation is needed to try to determine if exploitable deposits do occur in these beds.

Montenegro

136 II-A, E-10 NW, Municipality of Concepcíon, Santander. The The deposit is 7.5 kilometers southeast of Concepción and is accessible by trail to El Cedro and Alto Platera and continuing about two kilometers farther to the southeast toward Hacienda Montenegro. On the north side of a small stream, Cañada Caja de Agua, a mineralized zone in the Mercedes Formation has been exposed about 3 meters below the surface in a pit about 11 meters long. Steeply dipping limestone beds (strike N. 20° W., dip 80° SW) are dolomitized, with fine rhombic crystals of dolomite in a uniform crystalline texture. Abundant medium crystalline galena, sphalerite, dolomite, and calcite occur in irregular lenticular concentrations parallel to the bedding and as random concentrations and disseminated grains. The mineralized zone is 2.2 meters thick where exposed in the pit and has 20-30 centimeters of soft limonitic gossan at the top, and soft, weathered, sandy gray shales below.

Seven samples taken from lenses in the mineralized zone were submitted for analysis, but results were received from only four:

Chemical analyses of samples from Montenegro lead-zinc prospect, in percent

(Laboratorio Químico Nacional, Bogotá)

IMN Sample No.	Location in mineralized zone	Fe	Zn	Pb	Mn	Cd
13834	Base	3.35	17.25	0	0.90	0
13838	1.2 meters above base	8.35	6.25	22.50	2.24	0
13839	1.6 meters above base	3.19	56.60	0.55	1.10	0
13840	Top	12.45	37.75	0.05	2.00	0

An attempt was made to trace possible extensions of the mineralized rock along strike to the northwest and southeast by means of geochemical exploration. Eleven soil samples and four sand samples from streams were taken at distances up to 150 meters north and 110 meters south of the prospect pit. In semi-quantitative spectrographic analyses supplied by the Denver laboratories of the U.S. Geological Survey, the highest lead concentration of 100 ppm was found in a soil sample taken 25 meters northwest of the prospect pit. Others ranged up to 50 ppm; most were less than 30 ppm. No zinc was reported in any of the samples. It appears that the samples represent colluvium that is moving down from the rather steep slopes to the east rather than residual soils derived from weathering of the mineralized rock in place.

The owner of the prospect has hauled several tons of the ore by muleback to his house in Concepción. Some has been shipped to Medellín for smelting, but no continuous mining and shipping operation has been established. Although the deposit has very limited exposure thus far, the abundant lead and zinc mineralization makes it a favorable prospect for further exploration.

Quebrada Cedrillal

151 11-D, C-15 SE, Municipality of Coromoro, Santander. From Hacienda Miraflores at the end of the road southeast of Coromoro, the prospect is about 1.2 kilometers to the northeast in Quebrada Cedrillal and extend westward toward Quebrada Socavón. Dolomitized limestone of the Rosa Blanca Formation containing galena, sphalerite, chalcopyrite, and veinlets of siderite is exposed as a dip slope for a distance of about 90 meters in the bottom of southwestward-flowing Quebrada Cedrillal. The surface of the mineralized rock weathers to a conspicuous orange-brown color, probably due to the siderite content. At the upstream and downstream limits of the exposure the mineralized rock appears to pinch out as a lens between dark gray to black fossiliferous limestone and calcareous shale above and gray fossiliferous limestone below.

In a program of exploration and evaluation of this prospect, five holes were drilled into the mineralized rock in the quebrada with a portable diamond drill. These holes ranged from 2.3 to 4.3 meters in depth and penetrated 2.1 to 3.2 meters of the mineralized rock before reaching unaltered gray fossiliferous limestone below. Heavier equipment was used to drill holes east and west of the quebrada to define the extent of the mineralization in those directions. A hole 40 meters S. 88° E. of the first location in the quebrada penetrated two meters of mineralized rock starting at a depth of 8.7 meters. The hole was drilled to a total depth of 25 meters in fossiliferous limestone but did not encounter deeper mineralization. A hole 60 meters S. 87° W. of the first quebrada location penetrated the maximum thickness, from 9.3 to 20.0 meters of mineralized rock four and two intervals of 0.6 and 0.8 meter of unmineralized limestone near the middle of the zone. The hole was drilled to 31.1 meters in limestone without finding more mineralized rock. A hole 140 meters S. 82° W. of the first quebrada location penetrated mineralized rock from 12.8 to 16.8 meters but none in deeper limestone to a depth of 38.1 meters. A hole 115 meters S. 63° W. from the first quebrada location found no mineralization to a depth of 30.5 meters although the same section of rocks was drilled as at the other locations.

The information from drill holes, exposures of mineralized rock, and outcrops elsewhere indicate an elongate mineralized body extending 200-250 meters from east to west and up to 60 meters wide from north to south, with maximum thickness of about 10 meters. Dips of beds are toward the southwest and south at angles of 5° to 25°. Toward the west the body ends against an east-northeast-trending fault. Similar mineralization was found in a smaller area adjacent to this fault but on the opposite side and about 100 meters to the west of the main body, suggesting that the two mineralized areas are parts of one body displaced by lateral movement along the fault. A hole drilled to 16.8 meters near the fault in the western area penetrated only 0.6 meter of mineralized rock starting at a depth of 3.2 meters in a stratigraphic sequence similar to that in the eastern area. In a direction of N. 10° W. from this location, a second hole 18 meters away and higher in the section cored mineralized rock from the surface to a depth of 4.3 meters in a total depth of 4.6 meters. This smaller mineralized area, where beds dip 35° to 50° northward, is estimated to extend about 100 meters from east to west along the fault and to have a width of 40-50 meters from north to south.

The most abundant mineralization of galena, sphalerite, and chalcopyrite was found in cores from the hole with the thickest mineralized section near the middle of the main body. At this writing, analysis of the mineral content of the cores has not been completed, and an overall evaluation of the deposit cannot be made. Although it is apparently small, it is probably not too deep to be mined by an open pit, which would be a favorable factor in considering development.

Previous reports of Botero (1945b) and Singewald (1950) apparently refer to this deposit. Botero (1945a) mentions an attempt to develop the deposit in 1942, and this is probably the origin of the inclined adit, now caved, that is located east of Quebrada Cedrillal.

Machacuta Mine

136 IV-C, J-3 SW, Municipality of Soata, Boyacá. This abandoned mine, now covered by landslides, is two kilometers southwest of Tipacoque on the west side of Quebrada La Calera. The mine is in the Capacho Formation and west of a fault that trends northeastward along Quebrada La Calera. Ore from this mine is reported to have supplied a small lead smelting operation at Tipacoque in 1951 that was supported by Instituto Fomento Industrial. Nature of the ore, extent of the mine workings, and length of the period of operations are not known.

El Jeque

136 IV-C, H-4 NE, Municipality of Soata, Boyaca. One kilometer northeast of Tipacoque and about 200 meters north of the highway, pits that are now caved were dug in the Aguardiente Formation to explore galena mineralization. Local inhabitants say that no ore was ever recovered.

Alcohol Mine

152 II-A, B-4 NE, Municipality of Soata, Boyaca. From La Playa on the highway about 4 kilometers south of Tipacoque, this abandoned mine is about 2.5 kilometers by trail to the west. A lower adit was driven about 80 meters along a mineralized fault zone in the Aguardiente Formation. Another adit, about 25 meters above the first but not not along the fault, extends about 8 meters in from the opening, and for 30-40 meters along the bedding which dips 20° toward the southwest. Only traces of galena mineralization could be found. This mine reportedly supplied ore for the smelting operation at Tipacoque.

Iron

No iron ore is mined in the area of the report, and no potential resources were identified in any of the deposits examined and described here.

Palencia

121 I-B, A-1 N. Central, Municipality of Silos, North Santander. About 12 kilometers southeast of Berlín on the road to Baraya, the occurrence is 700 meters west of the road on the eastern slope of Cuchilla de Palencia. Thin lenticular seams of magnetite and hematite and minor amounts of quartz fill nearly vertical fractures that trend nearly due east in a roof pendant of metasedimentary rocks in quartz monzonite of the Santa Bárbara batholith. A lens of magnetite 90 centimeters thick is exposed in a prospect pit for a length of 2.5 meters, and another lens, not well-exposed, is in the bottom of the pit. In the area of mineralization, approximately 200 x 75 meters, there are perhaps 20 other seams that average about 1 centimeter in thickness. A magnetometer (hand-held) traverse across a small lens yielded a curve typical for a thin, vertical tabular body. Float boulders of magnetite

are sparsely distributed on the lower slopes. A very rough estimate indicates that about 15,000 tons of magnetite may be present in the mineralized area.

Quebrada Pajaritos

121 I-B, A-12 S. Central, Municipality of Silos, North Santander. From Santa Elena on the road south of Silos, the deposit can be reached by trail to El Hatico and from there to the school at Patacón near the deposit which is on the south slope of Quebrada Pajaritos. Specular hematite and calcite occur in lenticular bands filling fractures in highly fractured dark to light gray crystalline limestone of the Bocas Formation(?). The texture of the rock is due to recrystallization and tends to resemble the texture of marble. The best exposure of the hematite mineralization is in an overhanging outcrop of tabular form about 22 meters in length and 0.9 meter thick. Hematite content probably does not exceed 10 percent of the volume of the outcrop. Toward the west this outcrop ends at a south-trending fault. Other lesser exposures of the mineralization including siderite occur on the opposite side of this fault for a distance of more than 400 meters south of the main outcrop.

Samaria

121 II-A, F-8 NW, Municipality of Chitaga, North Santander. From Samaria on the highway 7 kilometers south of Chitagá, the deposit is about 800 meters to the east on the north side of Quebrada Churumbelero. Numerous roughly lenticular bodies of hematite up to 30 centimeters thick occur in dikes of pegmatite that intrude Bucaramanga gneiss. The lenses comprise from 10 to 20 percent of the rock by volume. The average strike and dip of the lenses is N. 54° E., 67° SE. The length of individual lenses was not determined, but the mineralization can be traced for about 200 meters along strike. The best exposure of the hematite is in an old, partly caved prospect adit.

Quebrada Aguacolorado

136 I-D, F-11 NW, Municipality of San Jose de Miranda, Santander. This deposit is 5 kilometers southwest of San Jose de Miranda and is accessible by trail from that village. It is in Quebrada Aguacolorado near its source on the southeastern slope of Alto El Laurel. In an outcrop of the Girón Formation about 3 by 5 meters in size, specular hematite occurs in three veins ranging up to 15 centimeters in thickness and also as cementing material in conglomerate.

Quebrada El Bambacho

137 III-D, G-1 NW, Municipality of San Mateo, Boyaca. From Vijagual on the road north from San Mateo to Guacamayas, the occurrence is accessible from the trail that extends northwest to Chapetón. A bed of sandy oölitic hematite about 1 meter thick is in sandstone and mottled claystone of the Paleocene Barco Formation (strike N-S, dip 15° E.). The extent of the bed had not been traced at the time of this writing. The oölite is similar to siliceous oölitic hematite in the Paz de Río area about 60 kilometers to the southwest where the upper nonsiliceous beds are mined for the steel plant at Belencito. The beds at Paz de Río are in the Concentración Formation of Miocene age.

NONMETALLIC MINERAL AND ROCK RESOURCES

Most local needs for nonmetallic building materials are supplied from local sources, and some raw materials are shipped to other areas. Aside from the most widely used construction materials such as clay for brick and tile and sand and gravel, limestone is the most widely used resource. In recent years a gypsum deposit has been discovered which supplies not only local needs but those of some other parts of the country as well. Silica sand is shipped to other places for glass manufacture. Small amounts of coal, asphaltite, and marble are mined and used locally. Small amounts of barite and fluorite are shipped to processing points elsewhere.

The largest undeveloped mineral resource is phosphate rock which has been found and studied during the course of the mapping and investigations reported here. A separate report describes this resource (Cathcart and Zambrano, 1967) and only a summary is given here.

Some of the fields that produce petroleum and natural gas in the middle Magdalena basin are within the report area, but these resources were not included in the investigations leading to this report.

Locations of the deposits and outcrops of nonmetallic minerals and rocks of economic interest are shown on figure 2.

Gypsum

Gypsum rock being produced at Mesa de Los Santos is transported by truck to cement plants in Bucaramanga and San Gil and is shipped by rail from Bucaramanga to other plants as far away as Cali. The gray to dark gray color of the mined rock appears to be due to clay and carbonaceous material, but whether this makes the gypsum unsuitable for uses other than cement manufacture has not been determined as yet.

The scarcity of gypsum deposits in Colombia and the needs of the cement industry for this material makes the orderly and economic development of this new resource of importance to the country's economy.

Gypsum in the Rosa Blanca Formation, Mesa de Los Santos

(Abridged translation of a report in Spanish by J. A. Cruz B. and R. Vargas H., Inventario Minero Nacional, August 1968. Figures 12-16 and tables 3-5 are from that report.)

The area studied is in the Municipality of Los Santos, Santander along the precipitous southwestern slope of Mesa de Los Santos in the vicinity of the confluence of Rios Suarez and Chicamocha that form Rio Sogamoso (fig. 2, 120 IV-C and 135 II-A, and fig. 12).

From Los Curos on the main highway 31 kilometers southeast of Bucaramanga a local road to the southwest climbs to the top of the mesa and extends on to the village of Los Santos, a distance of 35 kilometers. From Los Santos, other local roads to the west and northwest lead to the quarry operations at El Guayacán (18.3 km), El Diviso (12 km) and El Toro (9 km).

Early field investigations were made by R. Perea in order to find extensions of the gypsum deposit away from the three quarry operations. In Quebradas Aguagorda, Dañina, Chivatera, Los Santos and Volantín to the north of Guayacán, no massive gypsum similar to that in the quarries was found (fig. 12). A trench in the hill "Pulpito" between Quebradas Chivatera and Los Santos exposed a bed of massive gypsum 50 centimeters thick.

One and a half kilometers southeast of El Toro, a trench in a small quebrada exposed a bed of massive gypsum 90 centimeters thick in the lower part of the gypsiferous section. The upper part is deeply covered by colluvium. Farther to the east, in Quebradas Pozo Negro and Tablazo, and in Caño de Castilla, no gypsum was found in the basal section of the Rosa Blanca.

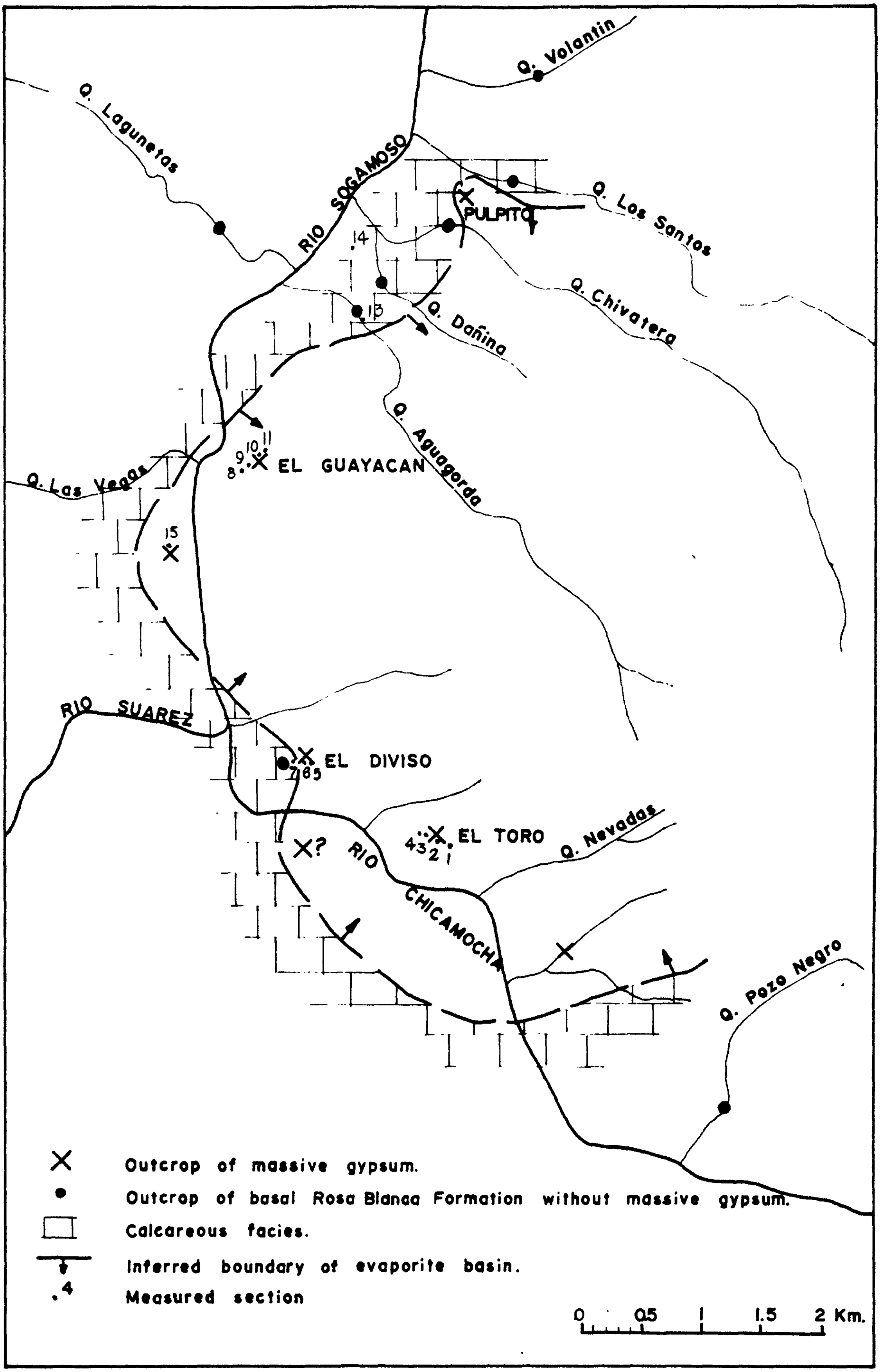

FIGURE 12 :-- Sketch map of the southwestern part of the Mesa de Los Santos where massive beds of gypsum occur in the basal section of the Rosa Blanca Formation.

In later field investigations, R. Vargas measured a total of 14 sections in the gypsum-bearing interval, including 11 at the three quarry sites and partial sections at Cerro Morrogrande (fig. 12, sec. 14), Quebrada Aguagorda (sec. 13), and on the western side of Río Sogamoso between Río Suárez and Quebrada Las Vegas (sec. 15). Figure 13 shows one of the sections at each quarry site. At each site one section extends downward into the upper beds of the Tambor Formation as in section 8 (fig. 13). Also one section at each site extends upward to a limestone bed with chert nodules that occurs above the gypsum as in section 6.

The gypsum beds cannot be traced continuously between the quarry sites because of thick colluvial cover. South of El Diviso and east of El Toro, the gypsum beds crop out on inaccessible scarps, but because the gypsum beds have weathered surfaces that are different in appearance from other beds, it was possible to trace them visually from a distance.

At Quebrada Lagunetas on the west side of Río Sogamoso, a detailed study was made of the entire Rosa Blanca section by I. de Julivert (1963), but only thin beds of gypsum 2 to 5 centimeters thick were found in the basal gypsiferous shales and dolomites of the formation (fig. 11).

The southeastern side of the canyon of Río Chicamocha was found too precipitous to trace the gypsum-bearing section there on foot, but on the basis of the weathered character of the beds as observed from the north side of the river, the gypsiferous section is believed to be present there.

Geology.--In the area of the gypsum deposit the mesa is carved from a section of Lower and middle Cretaceous rocks of marine origin. Sandstone of the Tambor Formation, about 150 meters thick, and thick limestone of the overlying Rosa Blanca Formation, about 300 meters thick, form the steep slopes of the mesa above river level. This changes abruptly to gentle slopes in the Paja Formation, about 300 meters thick, which caps the mesa in this area except for remnants of the Tablazo Formation at the highest points. All the formations have a gentle regional dip of 4°-12° toward the west. The main structural features are a few normal faults of small displacement. The most significant of these trends northeast and forms the north limit of the gypsum outcrops at El Guayacán and is associated with strong fracturing in the adjacent rocks. The north side of the fault is downthrown about 150 meters at El Guayacán. The gypsiferous section of the Rosa Blanca Formation has an average thickness of 12 meters and its base is approximately 20 meters above the Tambor-Rosa Blanca boundary (fig. 13, sec. 8). The massive, lenticular beds of gypsum range from 16 centimeters to 2.10 meters thick and are interbedded with calcareous gray shales (some of which contain gypsum), sandy gray shale, and fine-grained, dolomitic, bluish-gray limestone. Above the gypsum-bearing section is a thick series of hard bluish-gray limestone beds with chert nodules near the base (fig. 13, sec. 6). These beds crop out as a prominent ledge along the sides of the canyon.

Incrustations, fracture fillings, and thin beds are numerous in the section and are present to a lesser extent also in higher parts of the Rosa Blanca Formation, in the Paja Formation, and in the upper beds of the Tambor Formation.

Correlation of sections.--Figure 14 shows a correlation of the gypsum beds in the sections measured and described at the three quarry sites, El Toro, El Diviso, and El Guayacán, and on the west side of Río Sogamoso, based on a persistent limonitic pink claystone of 5-10 centimeters thickness at the top of the gypsiferous section as a key bed. The figure illustrates the lenticular nature of the gypsum beds which grade laterally to calcareous shales with or without gypsum. At El Toro, the gypsiferous section thins rapidly from section 1 to 4, a distance of 262 meters. Section 5 at El Diviso is correlated with section 4, but individual beds are thinner. From section 5 to 7 at El Diviso, a distance of 123 meters, the massive gypsum beds disappear from the section and only laminar beds of gypsum are present in the calcareous shale.

At El Guayacán, the first massive bed of gypsum is 20.4 meters above the Tambor-Rosablanca boundary (fig. 13, section 8), and the nine beds of gypsum in the gypsiferous section of 11.30 meters range from 16 centimeter to 1.97 meters in thickness.

Only two prominent beds of gypsum are exposed on the west side of Río Sogamoso (fig. 14, section 15). These are correlated with the lower beds of the section at El Guayacán. Above these beds the section is mostly covered, and it is possible that some of the higher gypsum beds are also present.

Figure 15 shows a suggested correlation between section 9 at El Guayacán and section 2 at El Toro, a distance of 3,800 meters. The

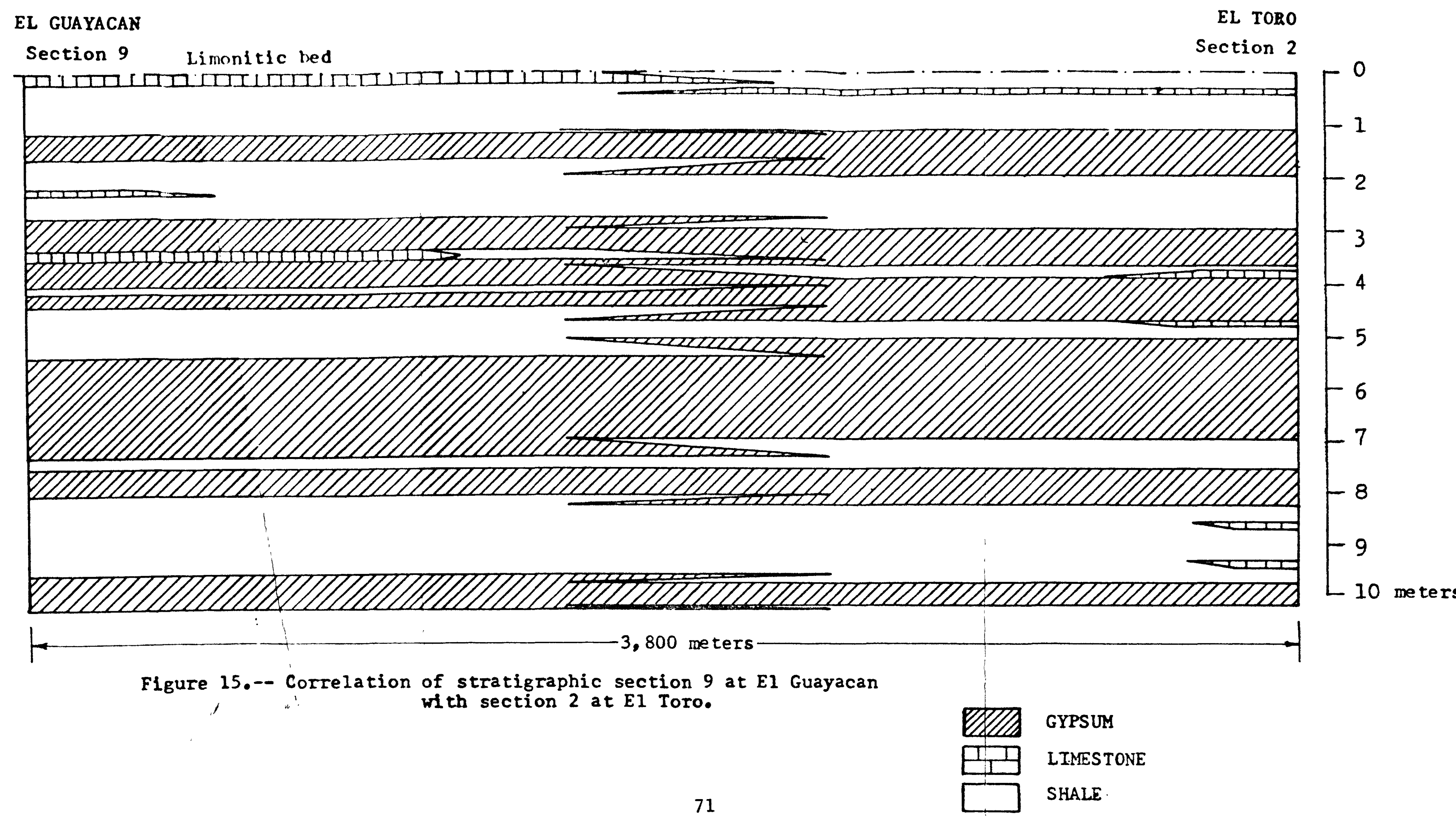

Figure 15.-- Correlation of stratigraphic section 9 at El Guayacan with section 2 at El Toro.

thickness of the gypsiferous sections and the distribution and thicknesses of individual beds is surprisingly similar.

In addition to the absence of massive beds of gypsum in section 7, other sedimentary features in the El Diviso locality suggest that the boundary of the basin is nearby. These phenomena include the presence of erosion channels and pot holes in the gypsum that have been filled with clayey material and pebbles of gypsum and shale, and thick beds of coarse clastics (fig. 13, section 6). On the basis of this information and the absence of gypsum in the basal part of the Rosa Blanca Formation elsewhere along the west side of the mesa, it is possible to outline the approximate western boundary of the evaporite basin in which the gypsum was deposited (fig. 12). The basin is thus indicated to have its deepest part under the Mesa de Los Santos to the east of the present quarry sites.

Characteristics of the gypsum and chemical analysis.--Three varieties of gypsum are present in the area of Mesa de Los Santos:

1. Selenite is associated principally with the shales of the Paja Formation that was studied by Jimeno and Yepes (1963).

2. Fibrous gypsum, or satin spar, occurs as tabular bodies parallel to the stratification, as fissure fillings, and as incrustations on exposed surfaces.

3. Massive beds of gray gypsum rock, coarse-grained, interstratified with shale, limestone, and dolomitic limestone. These beds have the main economic potential and are the object of this study.

Table 3 shows the results of analyses of 59 gypsum samples made by Laboratorio Químico Nacional in Bogotá. The samples from the three measured sections in figure 13 are included in this table.

For purposes of comparison of the properties of the gypsum of Mesa de Los Santos deposit with commercial requirements, the following information is useful: pure gypsum contains 20.9 percent combined water, 46.6 percent SO_3 and 32.5 percent CaO. Minimum purity for material to be called gypsum is 70 percent $CaSO_4.2H_2O$ (American Society for Testing Materials, Designation C 22-50). Most commercial gypsum is 85-95 percent pure as produced.

Calculation of reserves.--Reserves have been calculated in three categories, proved, indicated, and inferred, as determined by the amount of geological information available for making calculations.

Proved reserves: These reserves are calculated on the basis of the stratigraphic sections measured at the outcrops, the length of the outcrops, and the results of chemical analyses of collected samples. Figure 16 shows proved reserves in 11 blocks whose individual dimensions were determined as follows:

Height--thickness of the gypsiferous section measured at the outcrop.

Length--from the end of the gypsiferous outcrop to the midpoint between adjacent measured sections, or between these midpoints. Hence there are four blocks at El Toro, four at El Guayacán, two at El Diviso, and one on the west side of Río Sogamoso.

Width--equal to one-third of the total length of outcrop in the locality.

With the volume of the block and the percentage of gypsum rock in the measured section, the volume and tonnage of gypsum rock is calculated. With the average tenor, based on chemical analyses of samples, the tonnage of pure gypsum mineral is calculated for each block as shown in table 4. Total proved reserves thus calculated as 1,637,371 tons include 880,073 tons at El Toro, 367,239 tons at El Guayacán, 17,555 tons at El Diviso, and 364,504 tons on the west side of Río Sogamoso in the vicinity of section 15.

Indicated reserves: Considering the sedimentary origin and nature of the deposit and correlations between the measured sections, indicated reserves are calculated in two blocks shown on figure 16 as B.Ii and B.IIi.

Block B.Ii includes the area west of a line between measured sections 2 at El Toro and 9 at El Guayacán and extending to the outcrop or inferred boundary of the gypsiferous section with the slope of the mesa. Thickness of the gypsiferous section, percentage of gypsum in the section and tenor are average values based on measured sections 3, 4, 5, 6, 8, and 9.

Block B.IIi extends eastward from the line between sections 2 and 9 for a distance equal to one-third the distance between these two sections. The southeastern limit of the block is made perpendicular to the outcrop at El Toro, and the northern limit is the fault that borders El Guayacán on the north. Thickness of the gypsiferous section, percentage of gypsum in the section, and tenor are average values based on measured sections 1, 2, 3, 4, 8, 9, 10, and 11.

On the basis of the above assumptions, total indicated reserves are calculated to be 49,691,273 tons of gypsum including 38,032,253 tons in block B.Ii and 11,659,020 tons in block B.IIi (Table 5).

Table 4.--Calculations of proved reserves of gypsum in the Rosa Blanca Formation on the Mesa de Los Santos

Block No.	Thickness of gypsum sec. m.	Length of block m.	Width of block m.	Volume of block m^3	Gypsum rock in gypsum sec. m	Percent gyp. rock in gyp. sec.	Volume of gyp. rock in block m^3	Tons of gypsum rock in block	Percent gypsum min. in gypsum rock	Tons of gypsum mineral
El Toro										
B-I	13,88	270,00	170,00	637,092	6,39	46,03	293,253	645,157	77,23	498,254
B-II	11,31	107,50	170,00	206,686	6,19	54,73	113,119	248,862	86,04	214,121
B-III	9,19	61,00	170,00	95,285	4,66	50,70	48,309	106,280	77,89	82,781
B-IV	8,64	73,50	170,00	107,950	4,34	50,23	54,224	119,293	77,89	92,917
Total 888,073 T.										
El Diviso										
B-V	4,90	54,00	38,50	10,187	2,83	57,75	5,883	12,943	77,42	10,020
B-VI	3,61	61,50	38,50	8,547	1,75	48,47	4,143	9,114	82,68	7,535
Total 17,555 T.										
El Guayacán										
B-VII	11,30	133,50	117,66	177,490	5,12	45,31	80,420	176,924	76,05	134,551
B-VIII	9,06	87,50	117,66	93,269	5,01	55,29	51,568	113,450	86,28	97,884
B-IX	6,25	78,00	117,66	57,359	4,11	65,76	37,719	82,982	89,60	74,352
B-X	9,03	54,00	117,66	57,371	5,42	60,02	34,434	75,755	79,11	60,452
Total 367,239 T.										
West side of Río Sogamoso										
B-XI	1,36	900,00	300,00	367,200	0,86	63,23	232,180	510,796	71,36	364,504
Grand total								2,101,556		1,637,371

Table 5.--Calculations of indicated and inferred reserves of gypsum in the Rosa Blanca Formation on the Mesa de los Santos.

INDICATED RESERVES

Block No.	Ave. thickness of gypsum section	Area of block m^2	Volume of block m^3	Percent gypsum rock in gyp. sec.	Volume of gyp. rock in block m^3	Tons of gyp. rock in block	Percent gyp. min. in gyp. rock	Tons of gypsum mineral
B.IIi	9.83	4,053,230	39,843,250	53.50	21,316,138	46,895,503	81.10	38,032,253
B.Ii	7.78	1,666,360	12,964,280	51.29	6,649,379	14,628,633	79.70	11,659,020
TOTALS						61,524,136		49,691,273

INFERRED RESERVES

Ave. radius of basin m	Ave. thickness of gyp. sec. m	Area of basin m^2	Volume of basin m^3	Percent gyp. rock in gyp. sec.	Volume of gyp. rock in basin M^3	Tons of gyp. rock in basin	Percent gyp. min. in gyp. rock	Tons of gypsum mineral
3,000	8.70	28,274,400	245,987,280	53.42	131,406,405	289,094,091	80.89	233,848,210

TOTAL inferred reserves = 233,848,210 - (Indicated reserves + Proved reserves)

233,848,210 - 51,315,658 = 182,532,552 T

Inferred reserves: The inferred western limit of the basin in which the gypsum accumulated (fig. 12) suggests an approximately circular area with a radius of about 3 kilometers. Assuming an average thickness of 8.70 meters for the gypsiferous section, based on the various measured sections, and an average mineral content of 53.42 percent and tenor of 80.89 percent derived from the sections and chemical analyses, inferred reserves of 182,532,552 tons are calculated over and above the proved and indicated reserves (table 5). Total of proved, indicated, and inferred reserves is 233,848,210 tons.

Exploitation.--The present production of gypsum rock at the three quarry sites is approximately 30,000 tons per year. Present quarrying operations cannot be continued economically because of the amount of overburden that would have to be removed. These operations also subject the workers to great danger from landslides and require the removal of large volumes of material from the working face.

Conclusions.--In view of the strong indications of a gypsum deposit of good quality and large dimensions, an exploratory program is recommended toward increasing the amount of proved reserves by means of drilling or underground mining.

Drilling would encounter the problem of regional scarcity of water which might have to be brought by tank truck from as far away as Los Curos, a distance of 40 kilometers. The depth of drilling would be 225 to 250 meters to the gypsiferous section at the most favorable place (P on fig. 16). This point is only a few meters from the road to El Diviso and would give further information with regard to the correlation between sections 2 and 9 (fig. 15). At other places accessible to drilling equipment, the depth to the gypsiferous section would be from 250 to 300 meters. Toward the east side of the basin, the depth to the gypsum would be much less because of the regional dip of the mesa toward the west.

The rocks to be penetrated by drilling are massive limestones of the Rosa Blanca Formation and, in higher areas, also shales of the Paja Formation.

Exploration by means of underground mining would have a better economic outlook if it could be done with the collaboration of the owners and operators of the present quarries. The gypsum rock mined in the exploration drifts would compensate for the mining costs. However, in exploring with underground mining methods, a much longer period of time would be required to prove reserves.

Gypsum in the Paja Formation on the Mesa de Los Santos.--Previous to the discovery of gypsum in the Rosa Blanca Formation on the Mesa de Los Santos, gypsum was obtained by gathering the thin plates of selenite that are interbedded with the shales of the Paja Formation where these shales cap part of the Mesa de Los Santos and other mesa areas to the south. In a study of these areas by Jimeno and Yepes (1963), 18 gypsiferous localities with a total surface area of 283 hectares were defined in the 200 square kilometers where the Paja is at the surface.

Proved reserves of gypsum were calculated at 1,703,000 tons. These authors had accurately predicted that the gypsum in the Paja Formation would become of marginal value if a more easily exploitable source were ever found.

Limestone

On figure 2 are outlined areas in which limestone crops out and which are potential source areas. Cretaceous formations which contain limestone include the Rosa Blanca, Paja, Tablazo, and Simití Formations in the west, and the Tibú, Mercedes, and Capacho Formations in the east. Limestone is most abundant in the Rosa Blanca, Tablazo, Tibú, and Mercedes Formations, and the areas outlined on figure 2 include these formations. The other formations mentioned may also contain suitable limestone for commercial use in some places. The largest areas in which these formations crop out are the western foothills belt extending from San Vicente north-northeastward to Cuestarica and the southern parts of the plateau and mesa areas south of Bucaramanga from Zapatoca to Los Santo and San Gil. Other large areas are the belts extending from Cachirí southward to Tona, from El Portillo southward to Molagavita, and a large irregular area between Málaga and Pangote that extends to the north.

Limestone also is present in the much more limited outcrops of the Diamante Formation. The largest areas are a narrow belt immediately north of Bucaramanga and a longer but discontinuous belt from El Portillo northward to Mutíscua in quadrangle H-13.

Because of the abundance and widespread outcrops of limestone in the area, there are no problems of supply of this commodity, and therefore investigative efforts were directed toward needed commodities in short supply. A study of the limestone resources of North Santander by Martínez (1964) extends into the Mutíscua and Pamplona areas of the present report. In a section of the Cogollo Formation (Capacho Formation of this report) exposed along the Pamplona-Bucaramanga highway between Armenia and the junction with the road to Mutíscua, he sampled limestone beds scattered through 80 meters of dark-gray shales. Analyses of samples from nine of the thickest beds are shown in table 6.

Limestone beds of the Uribante Formation (probably the Mercedes Formation of this report) were sampled along the highway south of Pamplona near the junction with the road to Cácota. In a section of 38 meters containing mostly light gray sandstone, three limestone beds gave chemical analyses as shown in table 6.

The limestone beds of the Diamante, Rosa Blanca, and Tibú Formations are generally purer and more uniform and in thicker series than those of the Tablazo and Mercedes Formations which tend to be sandy and silty to varying degrees. Chert and dolomite are present in some beds of the Diamante, and dolomite is present in the basal part of the Rosa Blanca according to the study of I. de Julivert (1963, p. 29) at Quebrada Lagunetas near the gypsum deposit of Mesa de Los Santos.

In cement manufacture at Bucaramanga, limestone is quarried from the Diamante Formation in vertical beds on the west side of the Bucaramanga fault. The cement plant at San Gil uses limestone quarried from the Rosa Blanca Formation near Curití. Also in the Curití area, large blocks are quarried from the nearly flat-lying thick beds to be cut into slabs and polished for use as very attractive facing stone for interior walls of buildings.

Crushed limestone is used as an aggregate in much of the construction

Table 6.--Summary of chemical analyses of Cretaceous limestone in the Mutiscua and Cacotá areas, North Santander. Data from Martinez, 1964. (Analyses made by Laboratorio Quimico Nacional, Bogotá)

Bed No.	Thickness m	Sample No.	Losses 105-1000°C %	Insol. Resid. %	R_2O_3 oxides of Al, Fe, P %	P in P_2O_5 %	Ca in $CaCO_3$ %	Mg in $MgCO_3$ %
Capacho Formation, 110 III-B, A-14 NW, Municipality of Mutiscua, Santander:								
1	?	LM-152/C	39.02	10.62	0.85	$<$0.66	86.57	1.70
2	1.00	LM-152/F	38.82	9.56	1.70	1.13	88.04	0.92
3	1.50	LM-152/G	37.52	12.84	1.60	$<$0.06	84.16	0.13
4	3.00	LM-152/H,I	40.75	6.06	1.25	$<$0.06	91.09	1.21
5	1.00	LM-152/J	40.83	5.26	1.55	$<$0.06	91.98	0.54
6	1.20	LM-152/L	41.51	4.44	1.30	$<$0.06	92.23	0.42
7	1.45	LM-152/N	41.25	4.45	1.55	$<$0.06	92.23	0.42
8	0.80	LM-152/R	35.50	14.42	4.45	1.47	80.55	0
9	1.00	LM-152/S	33.79	14.45	7.10	1.41	76.48	3.08
Mercedes Formation, 110 IV-A, E-12 SW, Municipality of Cacotá, North Santander:								
1	3.00	LM-162/A,B,C	42.20	1.13	0.80	0.6	96.48	1.25
2	0.75	LM-162/F	30.95	27.30	2.30	0.6	69.14	1.02
3	1.10	LM-162/G	34.90	16.50	3.90	0.6	79.28	0

of asphalt-topped highways and comes mostly from the Cretaceous formations. The most widespread use of limestone is in the local manufacture of calcined limestone in many small and simple kilns. A little limestone is crushed and ground for agricultural use in mills near Suratá and Mutiscua.

Marble

Marble occurs in several places in the metasedimentary rocks of the Santander massif in quadrangle H-13 (fig. 2). In the Silgará Formation, marble occurs northwest of Berlín on the road to Vetas, east of Berlín along Río Mataperros near its junction with Quebrada Pescadero, and in a narrow belt west and northwest of Mutiscua. In the Floresta Formation, marble occurs southeast of Berlín on the road to Chitagá and in a narrow, discontinuous belt northward from Mutiscua to the northern boundary of H-13. Limestone of the Diamante Formation in the massif has been altered to some extent by metamorphism and is referred to as marble in the Mutiscua area.

Marble has limited use as chips in making terrazo and for grinding as agricultural lime. Fractures, silica, and iron content make it unsuitable for polishing as a decorative stone.

Three of the marble deposits were studied and sampled by E. Aya, and results of his work are summarized below.

Mutiscua area

West and northwest of Mutiscua, marble beds in the muscovitic garnetiferous schist and quartzite of the Silgará Formation are exposed in quebradas that drain eastward into Río La Plata. Although colluvium prevents tracing the outcrops between quebradas, the pattern of the outcrops indicates a narrow belt up to 300 meters wide that trends northward for at least 4 kilometers. In Quebrada El Chorrerón near the southern end of the belt, a section of 276 meters of the Silgará Formation contains 67 meters of marble in individual beds and series of beds up to more than 19 meters thick.

The marble is commonly white and light gray to darker gray with variations of greenish gray and pink. Many beds have a banded or foliated appearance. The texture is medium to fine crystalline in the lower part of the section, coarse to medium crystalline near the top. Pyrite and muscovite are present in some of the lower beds. Table 7 summarizes chemical analyses of marble samples from this and other sections at Quebradas Valegra and Lorenzo. For the thicker series, where more than three samples were analyzed, the range of values is given for each property analyzed, and the median of the values is given below in parentheses. Because of the wide ranges in values in some of the series, the median value is more significant than the average value.

In Quebrada Valegra, 2.5 kilometers north of Quebrada Chorrerón, a section of 110 meters of the Silgará Formation contains seven beds and series of beds of marble totaling 34 meters. The thickest series is 16 meters. The marble is mostly medium crystalline in texture and is commonly banded or foliated. Colors are light gray, pink, and white.

In Quebrada Lorenzo, 750 meters northwest of the outcrops in Quebrada Valegra, a single 16-meter-thick series of medium- to coarse-crystalline pink and gray marble beds crops out in 45 meters of exposed section. The marbles in the lower part of this series are massive, those in the upper part are commonly foliated.

The samples show wide variation in chemical composition. Series No. 1 at Quebrada Chorrerón and No. 5 at Quebrada Valegra are high in $CaCO_3$ content and low in insoluble residues, Fe_2O_3 and Al_2O_3. Dolomitic beds are indicated in the lower part of the section in Quebrada Lorenzo and in parts of series Nos. 4, 5, and 6 of Quebrada Chorrerón by the unusually high content of $MgCO_3$.

Marble (or more correctly recrystallized limestone) of the Diamante Formation occurs north of Mutiscua in a belt up to 1 kilometer wide and more than 6 kilometers long. It is in contact with the Mutiscua fault on the west and is overlain by thin phyllitic shales beneath the basal sandstone of the Cretaceous section to the east. On the western slope of Loma La Pileta the marble is exposed in a nearly continuous outcrop from the level of Río La Plata to an altitude of about 370 meters above the river. The rock is a very uniform dark gray and of fine- to medium-crystalline texture. Bedding planes and interbeds of other lithologies are lacking. On the assumption that the attitude of the beds is approximately the same as that of the overlying shales and Cretaceous rocks, a section was measured and sampled from river level up the slope to the shale section. In the absence of distinct beds or series of beds to designate as units, the thick section is divided into zones for purposes of summarizing the chemical analyses that are shown in table 8. These analyses generally reflect the very uniform physical appearance of the rock in outcrop. Carbonate content is uniformly high, insoluble residue, Fe_2O_3 and Al_2O_3, are uniformly low. Dolomitic zones 2, 5, and 14 stand out very sharply. The only use being made of this rock at present is for agricultural lime which is ground in a small mill north of Mutiscua.

Silos area

One kilometer southeast of Silos, marble of the Floresta Formation overlies the Silgara Formation in an area of about 1 square kilometer on the southern end of Cuchilla de Concaceras (fig. 2, 110 III-D). The marble is light gray to white and yellowish, rarely pink, fine and medium crystalline in texture, and banded or foliated in some beds. It occurs with muscovitic garnetiferous schist. Abundant fractures are recemented with calcite or filled with limonitic material.

Analyses of samples of marble collected from a section of 428 meters of marble and schist are summarized in table 9. Exposures were not sufficiently good to define the boundaries between marble and schist intervals, and therefore the section is divided into a number of zones. The analyses show wide variation in the content of $CaCO_3$, and content of insoluble residue is large and variable.

Río Mataperros area

Marble in this locality 5 kilometers east of Berlín is in the Silgará Formation. Ten beds of marble ranging from 0.75-5.25 meters thick are interbedded with quartzite and muscovite schist in a total section of 67 meters. The occurrence is near the contact of the Silgará with quartz monzonite, and a sill of this rock is present in the section which dips westward at an angle of 50°. The marble is gray, greenish gray, and pink. Chemical analyses of 15 samples from the marble beds are summarized in table 7.

Other localities

Six kilometers northwest of Berlín, marble crops out in the Silgará Formation over an area of about one-half square kilometer (110 III-A, I-11). It is in contact with granodiorite on the west and is intruded by aplite. The marble is light-blusih gray, coarse

Table 9. Chemical analyses of marble samples from Floresta Formation, southwest slope of Cuchilla de Concaceras, 110 III-D, C-11E, C-12 SW, Municipality of Silos (Analyses made by Laboratorio Químico Nacional, Bogotá)

Zone No.	Thickness m	Sample No. INMINERO	Ranges of values and (median values[1])					
			Losses 105-1000°C %	Insoluble residue %	Fe in Fe_2O_3 %	Al in Al_2O_3 %	Ca in $CaCO_3$ %	Mg in $MgCO_3$ %
1	40.0	14126-14131	11.00-35.29 (19.03)	17.30-67.51 (48.34)	0.93-3.65 (2.61)	0.73-6.57 (3.56)	22.59-71.43 (42.09)	0-7.44 (3.00)
2	41.0	14132-14138	25.04-38.21 (34.06)	12.20-39.34 (21.00)	0.18-1.94 (0.64)	0.02-1.70 (0.42)	56.12-86.36 (76.47)	0-0.81 (0)
3	75.0	14139-14145	30.07-41.35 (36.42)	4.50-30.73 (16.66)	0.10-0.51 (0.28)	0.05-0.80 (0.18)	68.07-93.61 (82.50)	0-5.48 (0)
4	42.0	14146-14153	29.94-40.15 (36.59)	8.83-31.49 (15.81)	0.07-0.73 (0.20)	0.13-1.55 (0.56)	66.37-88.07 (81.30)	0.88-3.39 (1.30)
5	41.0	14154	38.82	11.89	0.12	0.41	82.96	4.06
		14155	33.52	22.50	0.35	0.99	75.21	0.44
		14156	40.23	8.39	0.16	0.46	87.54	3.18
6	59.0	14157-14161	13.66-19.84 (14.64)	54.03-68.47 (65.21)	0.13-1.14 (0.61)	0-0.32 (0.01)	29.64-44.28 (33.03)	0-0.12 (0)
7	?	14162	34.65	16.88	3.75	0	76.96	0.63
8	41.0	14163	40.88	6.68	1.07	0	91.07	0
		14164	38.43	10.99	1.57	0	85.19	0.42
		14165	28.99	30.85	3.31	0	64.82	0.10
9	9.0	14166	8.96	77.71	1.14	0	20.54	0

% SO_3 0-0.97, ave. 0.08; % P_2O_5 0-0.73, ave. 0.06

[1] For zones with more than three samples

crystalline, and is thin bedded in the lower part of the section changing to thick, massive beds near the top. Many minor faults are present. A little of the marble has been quarried from outcrops near the road that crosses the area, but there is no sustained development. No samples were taken in this locality.

Thirteen kilometers southeast of Berlín, marble occurs in two northeast-trending lenticular zones in the Floresta Formation that are exposed along the road to Baraya (121 I-B, D-4, E-4). The marble is white and light gray to greenish gray, medium crystalline in texture, and siliceous. A little has been quarried from the exposures along the road, but there is no sustained development. No samples were taken in this locality.

Dolomite

In addition to the dolomitic beds in the Diamante Formation in the Mutiscua area (table 8, zones 2, 5, and 14), dolomite was found in the Diamante Formation in a locality north of El Portillo where barite is mined from outcrops (121 I-B, J-7 NW). The dolomite in which the barite lenses occur has a very fine crystalline texture and weathers light-brownish gray with abundant crisscrossing tiny fractures that have been recemented. Two samples submitted for chemical analyses are included in table 10 (samples 13846 and 13847).

In a later reconnaissance of the dolomite in this area, R. Vargas found a dolomite zone higher in the limestone section and about 250 meters northeast of the barite area. This zone can be traced for about 200

Table 10.--Chemical analyses of dolomite samples from the Diamante Formation at El Portillo, 121 I-B, J-7 NW, Municipality of Silos, North Santander.

(Laboratorio Químico Nacional, Bogotá)

Sample No. INMINERO	Losses 110-1000°C %	Insoluble residue %	Fe in Fe_2O_3 %	Al in Al_2O_3 %	Ca in $CaCO_3$ %	Mg in $MgCO_3$ %
13846	44.30	3.82	1.72	0.73	55.09	38.38
13847	45.80	1.84	0.97	0.21	57.75	39.00
14393	45.29	2.75	1.21	0.09	57.23	38.54
14394	45.63	1.88	0.81	0.14	60.68	36.28
14395	43.50	6.43	1.63	0.32	51.25	40.15
14396	45.42	2.87	1.01	0.14	55.71	40.07
14397	45.62	1.15	1.21	0.29	62.05	35.11
14398	47.00	0.36	0.81	0.04	53.93	44.59
14399	45.99	1.05	1.63	0.22	55.00	41.76

Tests for phosphorous and sulphur were negative meters (strike N. 50° W., dip 68° NE.). Samples 14396, 14397, and 14398 of table 10 came from the lower, middle, and upper parts of this zone respectively, where it reaches a thickness of 9.5 meters. The other samples (14393-14395 and 14399) were collected elsewhere along the zone.

Dolomite and dolomitic limestone occur in the lower 50 meters of the Rosa Blanca Formation in the southwestern Mesa de Los Santos area. A section of the formation measured in Quebrada Lagunetas on the west side of Río Sogamoso by I. de Julivert (1963, fig. 2) shows beds of dolomite, calcareous dolomite, and dolomitic limestone interbedded with limestone and shale of this part of the section. The thickest bed of dolomite is 70 centimeters and is near the top of the zone. No chemical analyses have been made of the dolomite beds of this area.

Phosphate rock

Although phosphate deposits have been sought in Colombia as far back as 1942, and studies since that time have shown that Upper Cretaceous rocks in the western part of the Cordillera Oriental seem to hold the most promise for finding economic deposits, no investigations of this potential resource were made in the area of this report until the present project. In their reconnaissance exploration for phosphate rock in Colombia in 1966, Cathcart and Zambrano (1967) visited nearly all the exposures of the La Luna Formation along roads and highways in Zone III and collected samples of the phosphatic beds for chemical analysis. When it became evident from their work that phosphatic beds of possible economic value are present over a wide area, a separate program was established to continue the investigations in this and other areas. Therefore, only a brief summary for this area is included here.

Thus far, no attempts have been made to develop the phosphate resources of the area beyond some small and inconclusive experiments with grinding the rock and applying it directly to the soil as a fertilizer. In this connection, the Universidad Industrial de Santander in Bucaramanga organized a symposium on the subject "Utilization of Phosphate Rock" in November 1967 to acquaint the local agricultural community with the presence of phosphate rock in the area and to encourage them to experiment with the ground rock as a fertilizer. Use of the rock in the manufacture of superphosphate-type fertilizers will be slow in developing, because of the many technical problems and uncertainties that must be faced and overcome in establishing a new industry.

Galembo Member of the La Luna Formation

Beds of phosphate rock in the Galembo Member are more widespread than those in other formations and locally are more than 2 meters thick. The phosphate rocks contain abundant small oval to cylindrical pellets and associated fish vertebrae and other bone fragments in a hard dark-gray calcareous matrix. At Quebrada La Sorda (109 III-D, F-11 NE and F-12 NW), the main phosphatic zone is near the base of the member and is 7 meters thick. The zone contains six phosphatic beds ranging in thickness from 6 cm to

1.5 meters. These beds are interlayered with slightly phosphatic to nonphosphatic calcareous shale, limestone, and chert. A channel sample across the thickest bed has an average of P_2O_5 content of 24.74 percent. The 8 subsamples had the following P_2O_5 content, from top to bottom of the bed: 19.11, 27.22, 27.53, 28.04, 26.69, 22.54, 22.85, and 23.97 percent.

At Quebrada El Portigo (north of the area of this report in 87 III-B, H-2 NW), the main phosphatic zone is about 4.5 meters thick. From top to bottom, analyses of channel samples of the three main phosphatic beds of 0.45, 1.70, and 0.50 meters revealed 19.08, 19.23, and 10.27 percent of P_2O_5, respectively.

Although thin phosphate beds can be found nearly everywhere in the widely distributed outcrops of the Galembo, the thickest beds having greatest economic potential thus far encountered occur along the outcrop belt from San Vicente to Vanegas in quadrangle H-12 and north of the report area in North Santander from Lourdes northward to Sardinata and to the northeast of Sardinata. An exploration program is now in progress in these areas, starting with detailed surface mapping and continuing with trenches at intervals between outcrops to expose the phosphatic zone for measuring and sampling. This program is expected to yield useful information with regard to reserves and feasibility of development. In May 1969, a diamond-drilling program was initiated at Quebrada La Sorda to obtain cores of the phosphatic beds below the weathered zone in order to determine the calcareous and phosphatic content of the fresh rock. Calcium carbonate is partly removed during weathering and, therefore, samples of the rock from below this zone are needed to determine if superphosphate can be produced from the rock without using excessive amounts of acid.

Capacho Formation

Phosphatic beds occur in the Capacho Formation in the eastern part of the report area. Southeast of San Andrés, thin phosphatic beds have been found about 65 meters above the base of the formation and thicker beds about 135 and 185 meters above the base (121 III-D, G-3, SW). At the 135-meter level, 60- and 120-centimeter beds, separated by 20 centimeters of limestone, contain abundant phosphatic pellets, bone and shell fragments, and quartz grains. Analysis of a single sample from each bed revealed P_2O_5 content of 9.8 percent in the lower bed and 7.5 percent in the upper. At the 185-meter level, a sample from a bed 2.5 meters thick analyzed 25.4 percent P_2O_5. None of these are channel samples and, therefore, they do not show the average phosphate content of the beds. The beds at 135 meters above the base of the formation have been traced for about 3 kilometers, but the higher bed is known in only one place.

Phosphatic beds have been noted in the cut along a new road west of Pamplona (110 I-D, B-15 SE), where fossiliferous, partly calcareous and phosphatic sandstone with abundant bone and shell fragments occur only a few meters above the top of the Aguardiente Formation. Other beds contain phosphatic pellets. The zone containing the phosphatic beds is about 13 meters thick. Although no analyses have been obtained, the phosphate content appears to be nonuniform and of relatively low grade.

A thorough investigation of phosphate in the Capacho Formation has not yet been made. The phosphatic beds are not associated with chert and siliceous shale such as are found in the Galembo, and their potential is considered to be less.

Base of the Umir Formation

Above the Galembo Member of the La Luna Formation, the basal sandy to pebbly beds of the Umir Formation in the west, and the Colón Formation in the east, contain varying amounts of phosphatic pellets and nodules as well as grains of glauconite. These beds lie above the unconformable contact with the Galembo, and the phosphatic material is thought to be derived from eroded beds of the Galembo. The Galembo-Umir contact is exposed in very few places and so this phosphatic zone is not well known. It is apparently rather variable in character and in phosphate content. The only place found thus far where it has sufficient thickness and phosphatic content to have possible economic value is in the Palmira area west of San Vicente (120 III-A, F-9).

Coal

As previous investigations of coal resources have identified the principal coal occurrences, this report summarizes published information of those coals that have economic potential.

These coals occur in the uppermost Cretaceous and Paleocene and Eocene rocks and range from subbituminous to semianthracite, depending on the tectonic histories of the localities in which they occur. Mining operations are on a small scale and produce coal only for local use, which is mainly as a fuel for brick and lime kilns. On figure 2 are outlined areas underlain by the coal seams that are presently being mined in some localities.

Umir, Lisama, and Esmeraldas Formations

In the west, the thickest and most continuous coal beds are in the upper part of the Umir Formation. Thinner beds occur in the Lisama and Esmeraldas Formations. West of San Vicente (120 III-A, SW), coal outcrops in the upper Umir beds in the southern end of the Nuevo Mundo syncline were studied by Paba (1946, 1948). He traced five beds ranging from 0.60 to 2.30 meters thick. Analyses of these coals indicate them to be of bituminous rank and of fair to good quality, but hardly any attempts have been made to develop them. The extent to which they continue northward along the outcrop belt of the Umir Formation is not known.

Coal beds in the Umir are mined about 5 kilometers south of Molagavita (136 I-D, E-6, E-7). The beds are in nearly vertical position in a narrow faulted syncline. Where the coal-bearing section is exposed in Río Negro, 16 coal seams ranging up to 4 meters in thickness and totaling 12 meters are scattered through a 150-meter section of shales and sandy shales, with the thickest coal beds and most of the coal in the upper 50 meters (Wokittel, 1953, p. 9 and fig. 2). Laboratory analyses indicate coal of bituminous rank and good quality (Paba, 1946, p. 14) and favorable for coking.

Mito Juan, Los Cuervos, and Carbonera Formations

In the eastern part of the report area, coal beds are mined only in the Los Cuervos Formation. Carbonaceous beds and thin coal beds are known in the section from the Catatumbo Member of the Mito Juan upward to the Carbonera Formation, but except for the Los Cuervos the coals are either not thick enough or not of high enough quality to be mined profitably.

The most active coal mining in the area of this report is east of Pamplonita where it has continued on a sustained basis for many years. The beds are in the lower part of the Los Cuervos Formation. Typical of mines in this area is the Santa Isabel mine where 16 coal beds range in thickness from 10 centimeters to 1.20 meters in a section of 75 meters (Del Rio, 1947). Only three beds, of 0.80, 1.00, and 1.20 meters, are mined (García and Manjarres, 1962, p. 49). The coals of the area are of bituminous and subbituminous rank.

Southward from Pamplona along the eastern side of the report area, coal is mined in several other places from the same carbonaceous zone of the Los Cuervos. Southeast of Mutiscua, coal is mined in the northern end of the La Carbonera syncline (110 IV-A, B-1). The largest area having coal beds in the Los Cuervos extends southward from Chitagá for nearly 60 kilometers. The tight folding in the western part of this belt has raised the rank of the coals in the area of Páramo del Almorzadero (121 II-C, SW, and 121 IV-A, NW) to semianthracite (Hubach, 1953). Ash and sulfur content are low. The main beds are 80 and 60 centimeters thick and are 50 meters apart. The beds are steeply inclined to vertical.

The thicker bed has been mined more extensively than the other because the walls do not require supporting timbers.

Asphaltite

Lenticular bodies of asphaltite occur in the La Luna Formation and a few are large enough to be mined by underground methods. The mined material is used as a fuel, mixed with other materials, in brick and lime kilns. During the investigations for the present report, only two known operations were recovering asphaltite. Extensive investigations of phosphatic beds in the La Luna have not encountered any other asphaltite deposits comparable to those being mined, and therefore it is concluded that potential for greater development is lacking.

At Quebrada La Sorda (109 III-D, F-11 E Central) asphaltite has been mined at the rate of 2 to 3 tons per day for the past several years. At least one other body was mined in that area before the present one which has a northeast trend and cuts across the north-northeast-trending beds of the La Luna at an oblique angle. The body was first mined on the northeast side of the quebrada by an adit of 50-60 meters along the trend and by stopes above and below to depths of 15-20 meters. Maximum width of the body in this part is 8 meters. Mining was later abandoned in this part of the body, probably because of water problems and caving, and operations were shifted to the southwest side of the quebrada. That part has also caved, and operations have been moved back to the northeast side in higher ground. The odor of gas is very strong in the mine tunnels.

The asphaltite at La Sorda has a black, coal-like appearance and is so very brittle that it crushes easily to small fragments. Some properties of two samples that were tested are shown in the following tabulation (Nos. 11446 and 11447):

Properties of asphaltites from the La Luna Formation in Zone III

[Analyses made by Laboratorio Químico Nacional, Bogotá]

Sample No. INMINERO	Specific gravity at 77°F.	Temperature of softening (°F.)	Penetration at 77°F. of 150 grams in 5 secs tenths of a mm	Insoluble residue in CS_2 (percent)	Fixed carbon (percent)
11446	1.127	436	0	0.9117	34.38
11447	1.177	442	1.0	0.8002	37.73
11448	1.084	256	0	4.5351	23.56
11449	1.131	465	1.0	0.7288	35.04

Properties of a sample of asphaltite from the Conchal area (No. 11449) are generally similar to those from Quebrada La Sorda, but other information about the deposit is lacking.

Asphaltite from a deposit about 65 kilometers northwest of Bucaramanga (No. 11448) is like hardened tar, and it breaks with a conchoidal fracture. The measured properties are considerably different from those of the other asphaltites tested. This deposit was exploited for a short time after being exposed by a landslide but is now covered by later slides.

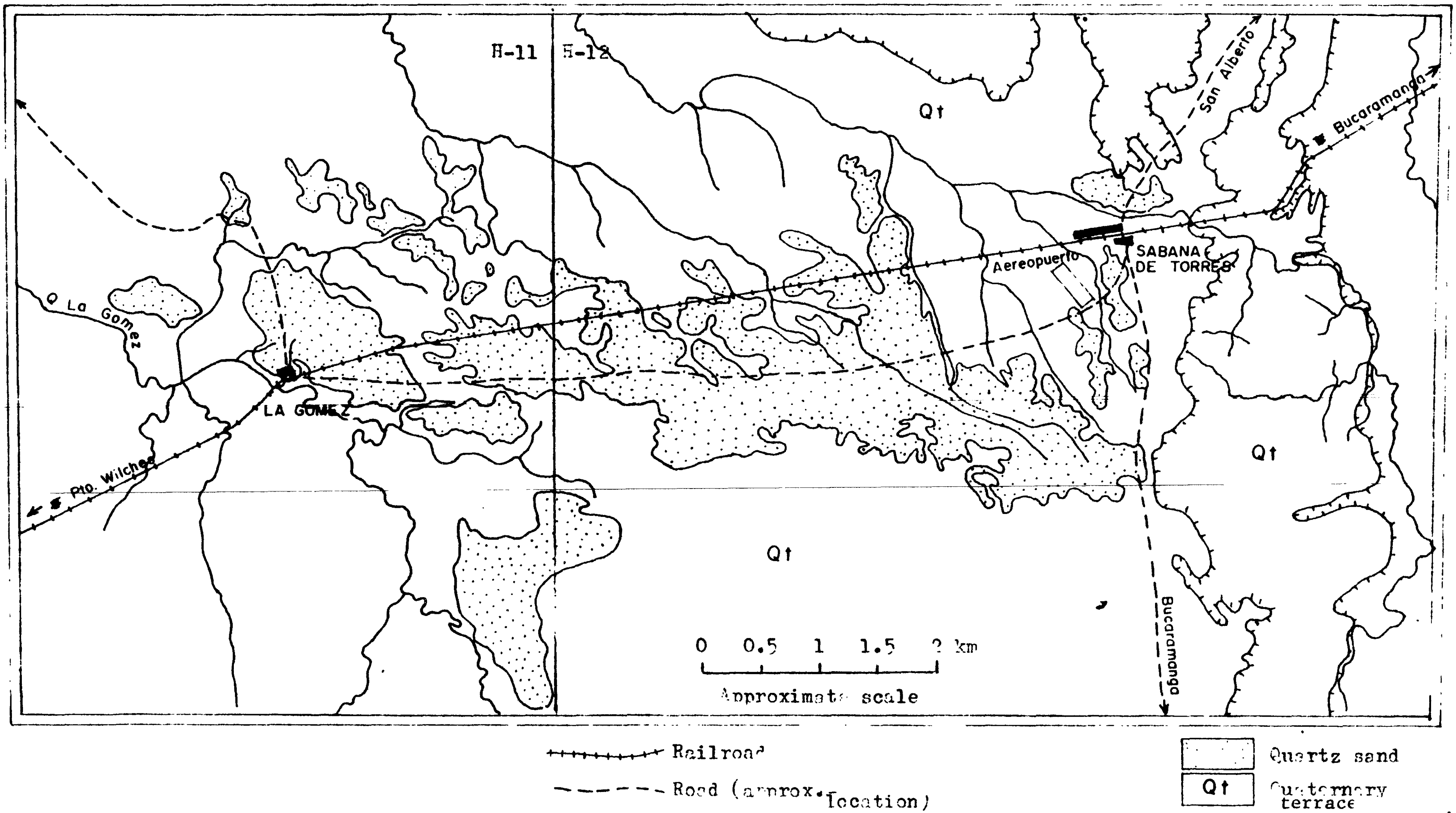

Figure 17.--Map of the Sabana de Torres-La Gomez area showing distribution of white quartz sand that caps low terraces of late Quaternary age, as defined on aerial photographs, municipality of Puerto Wilches, Santander.

Silica sand

White quartz sand used for making glass is obtained from Quaternary sediments in the northwestern corner of quadrangle H-12. In a study of aerial photographs of this area, J. Cruz outlined areas where the sand is exposed in a belt from 3 to 5 kilometers wide and extending westward 9 kilometers from Sabana de Torres to La Gómez in quadrangle H-11 (fig. 17). The railroad from Bucaramanga to Puerto Wilches extends through the middle of the belt and provides convenient transportation.

The sand, which is mixed with pebbles of porous, friable sandstone that are easily crushed, forms a layer from 1 to 2 meters thick that caps low terraces of late Quaternary age. Most of the material was derived from the erosion of the thick sandstones of the La Paz Formation that forms the first major ridge of the foothills to the east. Below the white sand and pebbles are more sand and pebbles of light-yellowish-brown color that are not suitable for shipment, apparently because of greater iron content. Chemical analyses of two white sand samples from this area gave the following results:

Chemical analyses of silica sand from the area of Sabana de Torres (109 I-C, NW) Municipality of Puerto Wilches, Santander

[Analyses made by Laboratorio Químico Nacional, Bogotá]

Sample No. INMINERO	SiO_2 (percent)	Al_2O_3 (percent)	Fe_2O_3 (percent)	Remarks
14349	97.24	0.93	0.75	Sample dried to 105°C.
14350	97.24	1.46	0.03	Sample dried to 105°C.

In small recovery operations, the sand is screened, dried, and bagged for shipment to Medellín and Barranquilla for glass manufacture. Total tonnage produced from these operations is not known.

Silica

Veins of almost pure quartz crop out in various host rocks in an area extending 4 to 5 kilometers west and southwest of Berlín in the Municipality of Tona, Santander (fig. 2, 110 III-C). The veins range from less than 1 meter to several tens of meters in width and to nearly 2 kilometers in length. They have not been studied or sampled, but impurities appear to be less than 1 percent. Such rock is used in industry as a refractory material and in ceramics. At present, the deposits in the Berlín area can be considered as only a potential resource.

Barite

Small amounts of barite have been produced from veins and lenses in various rocks, mostly from shallow pits dug into the outcrops. None of the deposits has been developed into a sustained underground mining operation. The mineral obtained is sold to companies that use most of it in preparing weight additives for drilling mud in drilling oil wells.

Most of the barite localities discussed here are on the Mesa de Los Santos and adjacent areas, and this area appears to hold the most promise for future discoveries. But unless attempts are made to develop the more promising deposits by underground methods, the production of barite will probably continue at its present low and erratic level.

Reconnaissance investigations were made by R. Vargas of all the deposits discussed below except the one at Las Juntas-south.

Mesa de Los Santos and adjacent areas

On figure 2 are shown eight localities where barite has been found in prospects or mined from surface outcrops of veins or lenses in various rocks.

Las Juntas-south.--135 II-A, A-7 NE, Municipality of Barichara, Santander. The deposit is 750 meters southwest of the junction of Ríos Suárez and Chicamocha. A report by Wokittel (1956) describes veins of barite with calcite and a little galena and stains of malachite in an area of more than a quarter square kilometer sloping northward to Río Suárez. Two vertical veins trend N. 60° E. and N. 80° W. They are in the Rosa Blanca Formation and pinch and swell to maximum widths of 2.5 meters. There is a particularly large concentration of minerals at the intersection of the two veins. At the time of his investigation, barite was being mined at the rate of 8-13 tons per day, and production during 1955 totaled about 2400 tons.

Las Juntas-north.--120 IV-C, 1-7 SE, Municipality of Zapatoca, Santander. This deposit is 1 kilometer north of the junction of Ríos Suárez and Chicamocha on the west side of Río Sogamoso. About 150 meters above the river, a vein of white barite 45 centimeters wide is exposed for a distance of 2 meters in fine-grained yellowish-white sandstone and gray, sandy shale of the Tambor Formation. Strike of the vein is N. 80° W., dip is vertical. Other veins of barite as much as 5 centimeters wide are 150 meters to the south. No mining has been done in this deposit.

Quebrada Montelargo.--120 IV-C, J-9, NW, Municipality of Los Santos, Santander. The deposit is located where the road to El Diviso gypsum quarry makes a sharp turn very near the quebrada. Abandoned pits alined east-west and a 12-meter adit remain from mining of veins of barite with calcite in the uppermost limestone beds of the Rosa Blanca Formation. A little chalcopyrite and stains of malachite are present, and numerous fractures of east-west trend.

Quebrada Chivatera-northwest.--120 IV-C, F-10 SW, Municipality of Los Santos, Santander. The deposit is about 750 meters north of the road to El Guayacán gypsum quarry. A lenticular vein of white barite extends for 25 meters with strike N. 50° E., dip 55° SE. through limestone of the Rosa Blanca Formation. The vein and wall rock are highly fractured and vein width changes abruptly, ranging from zero to a maximum of 1.90 meters. About 10 meters below outcrop level an adit has been driven in a direction of N. 80° W. toward the vein but was closed by timbers at the time of the investigation and could not be examined.

Along strike to the northeast, the vein is exposed at distances of 50-60 and 100-106 meters from the main outcrop; vein widths are 38 and 50 centimeters, respectively.

Quebrada Chivatera-southeast.--120 IV-C, G-11 NW, Municipality of Los Santos, Santander. This deposit is about 20 meters north of the road to El Guayacán gypsum quarry and 1250 meters southeast of the previously described deposit in this quebrada. Five trenches 10-20 meters long trending N. 50° W., apparently were dug along veins of barite with calcite and a little galena in the Rosa Blanca Formation, but the amount of barite recovered could not have been very large.

Quebrada de La Cañada.--120 IV-A, H-10 SE, Municipality of Zapatoca, Santander. The deposit is on the steep west slope of the canyon of Río Sogamoso. Martínez (1962, p. 12) reported two veins of barite in the Rosa Blanca Formation about 350 meters above the river. A. Rojas of the present project reported a 40-centimeter vein of barite in the Rosa Blanca that can be traced about 10 meters. Later, in landslide debris which extends from above the Rosa Blanca outcrop down the river, R. Vargas found large blocks of fine-grained, reddish-brown sandstone of the Girón or Tambor Formations, with veins of barite as much as 60 centimeters wide, and other blocks of light-colored sandstone in which barite forms a cement. These blocks were found on the lower slopes of the canyon and indicate that the barite veins probably extend through a thick section of rocks from the Girón to the Rosa Blanca. No recovery of the barite has been attempted in this deposit.

Los Montes.--120 IV-B, I-3 NW, Municipality of Los Santos, Santander. The deposit is 750 meters west of Los Montes and about 100 meters below the trail of El Guaimarú. A 12-centimeter vein of white barite, nearly vertical and with strike N. 50° W., occurs in nearly horizontal beds of reddish-brown siltstone of the Jordán Formation. The vein can be traced for 3 meters and a 5-centimeter parallel vein 1 meter away extends for 1 meter. No attempt has been made to recover the barite.

Quebrada Pomarroso.--120 IV-D, B-12 SE, Municipality of Los Santos, Santander. The deposit is on the north side of Quebrada Pomarroso at a distance of 2.5 kilometers N. 50° W. from Pescadero. An abandoned open-pit mine is now completely covered by landslides. According to local reports, a 60-centimeter vein of white barite in the Pescadero granite was mined to a depth of 4 meters.

Other barite deposits

Río de Oro.--120 II-A, I-12 SW, Municipality of Girón, Santander. About 2 kilometers south of Girón on the road along the east side of Río de Oro, the deposit extends eastward from the river for about 400 meters. An inclined adit, now abandoned and caved, was driven in conglomeratic sandstone of the Girón Formation to reach a barite vein with strike of N. 70° W. and dip of 40° SW. The nature and thickness of the vein could not be determined. About 50 meters toward the southwest, veinlets of barite are exposed in two pits of 2 and 8 meters length. Those in the larger pit strike N. 70° E. and dip 45° NW. About 250 meters farther to the southwest, and near the bank of the river, a 5-meter trench with trend of N. 50° E. is reported to have been dug to mine a 40-centimeter vein of barite, but none of the mineral could be found.

Loma La Ovejera.--109 IV-B, C-14 NW, Municipality of Charta, Santander. The deposit is about 1 kilometer north of the road from La Playa to Charta and on the steep eastern slope of the southern end of Loma La Ovejera. A vein of barite with trend of N. 60° E. in quartz monzonite was mined with a trench 30 meters long and 2 meters deep. Only small fragments of barite could be found in the long-abandoned trench.

El Portillo.--121 I-B, J-7 NW, Municipality of Silos, North Santander. The deposit is about 500 meters north of El Portillo, the highest point on the road from Berlín to Baraya. Barite is being recovered from veins and irregular lenses in limestone and dolomite of the Diamante Formation (strike north-south, dip 51° E.) The thickest lens increases from 3 meters at the surface to 6 meters at a depth of 5 meters. Another vein 30 meters lower in the section can be traced for 150 meters with much variation in the width to a maximum of 80 centimeters.

Since August 1967, when mining first started, the barite has been mined only from pits dug into the outcrops. Whether the veins are sufficiently thick and continuous to be mined underground has not been determined. Production has been at the rate of only about 10 tons per month which has reportedly been sold to companies in Bogotá and Bucaramanga.

Fluorite

Small amounts of fluorite have been produced intermittently at two localities near Pescadero in the past few years. Both operations involve small surface excavations, and nothing is known of possible continuations of the deposits in the subsurface. Fluorite at the Tembladal mine is discussed in the section on "Lead."

El Mirto

121 III-C, A-1 SE, Municipality of Umpalá, Santander. The deposit is about 400 meters east of the Bucaramanga-San Gil highway in the canyon of Río Manco and about 250 meters above the river. Fluorite occurs with quartz and minor amounts of galena in a vein up to 1.5 meters wide in the Pescadero granite and has been worked along the outcrop for about 15 meters (strike N. 25°-30° W., dip 70°? NE.). Fluorite has been mined at a rate of about 12 tons per month and sold to the steel, glass, and ceramics industries.

Lomas de Ventorillo

120 IV-D, D-14 NW, Municipality of Umpalá, Santander. The deposit is 1 kilometer west-northwest of Pescadero on the southeast slope of Lomas de Ventorillo above Río Chicamocha. A vein of colorless to light-green fluorite with quartz in the Pescadero granite ranges abruptly in width up to 50 centimeters and can be traced intermittently for about 30 meters along strike of N. 80° E., dip 65° NW. Fractures in the granite trend north-south with dip of 75° W., and N. 80° W. with dip of 52° NE. Veinlets of fluorite and quartz occur in the granite wall rock and were found also in blocks of pegmatite scattered about the area.

Over an area of about one-quarter of a square kilometer, shallow pits have been dug in the colluvium to recover loose pieces of the vein material.

Clay

Ordinary brick and tile for construction in the Bucaramanga area are made from widespread sandy clays in the Bucaramanga terrace and in beds of the Girón and Jordán Formations. Finer clays are found some of the beds of the Girón Formation near Lebrija, but in the absence of local manufacture of ceramics and sanitary ware, there is a lack of market for these materials. Users in other parts of the country are able to supply their needs from sources closer at hand. No attempt has been made to include clay deposits on figure 2.

Sand and gravel

In the Bucaramanga area where the need is greatest, deposits of well-sorted sand and gravel are lacking because the city is very near the mountain front. Farther to the west where the main rivers flow out of the foothills into the Magdalena Valley, there are large areas of alluvium where well-sorted sand and gravel are abundant, but because of the distance and lack of transportation, sand and gravel are "gleaned" by many small screening operations from the beds of streams around the base of the Bucaramanga terrace. Sand and gravel sources are not shown on figure 2.

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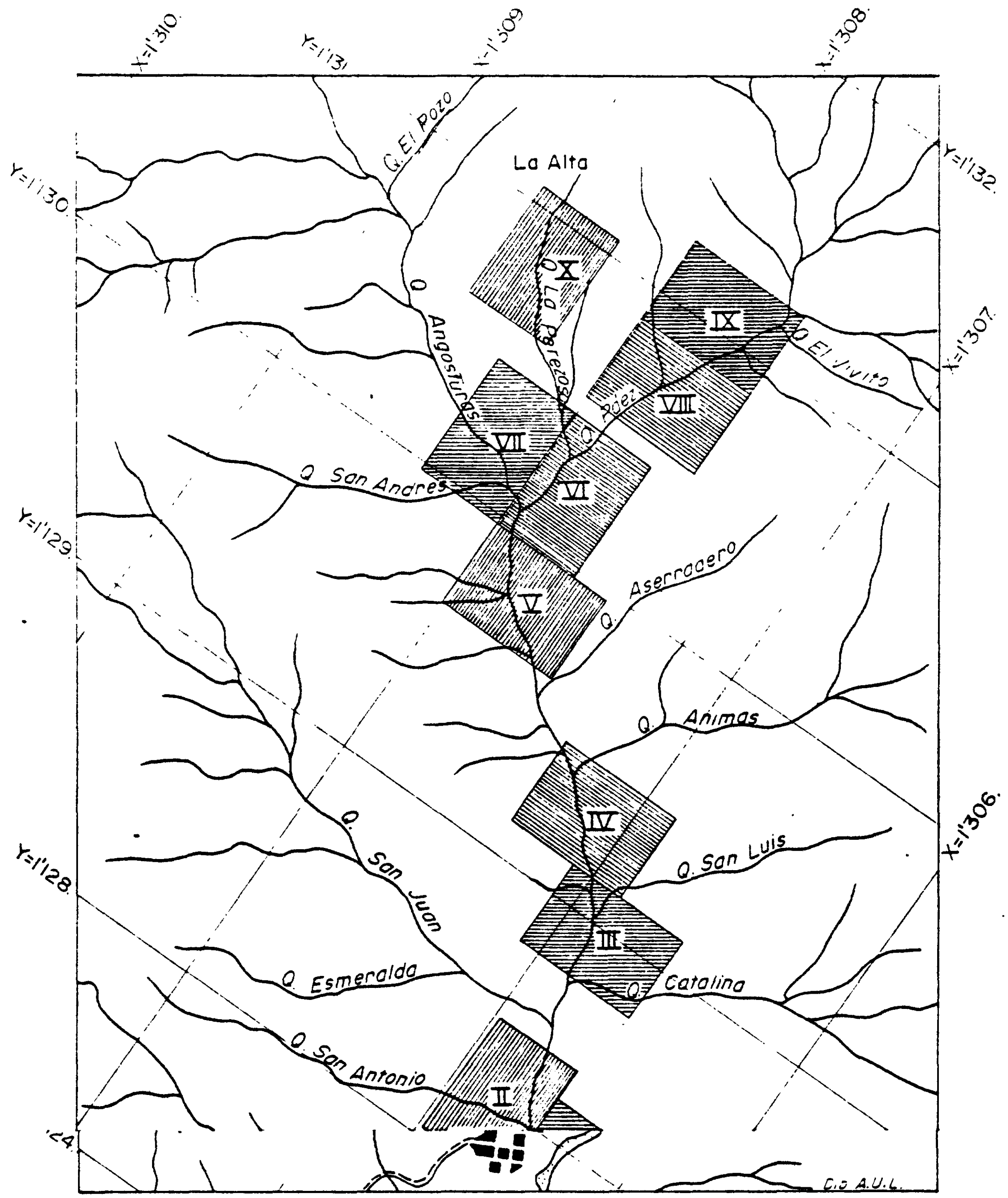
APPENDIX A

LOCATION OF PROSPECTS AND RESULTS OF ANALYSES

REPUBLICA DE COLOMBIA
MINISTERIO DE MINAS Y PETROLEOS
INVENTARIO MINERO NACIONAL
ZONA III BUCARAMANGA



MAPA INDICE
GRUPOS TUNELES MINAS DE CALIFORNIA
(ALTA Y BAJA)

I San Celestino
II San Antonio-Pie de Gallo
III El Cuatro - Catalina
IV San Cristobal - Animas
V La Mascota
VI Asturias-La Angostura
VII La Bodega-El Carmen
VIII El Silencio
IX La Picota-El Silencio
X El Diamante

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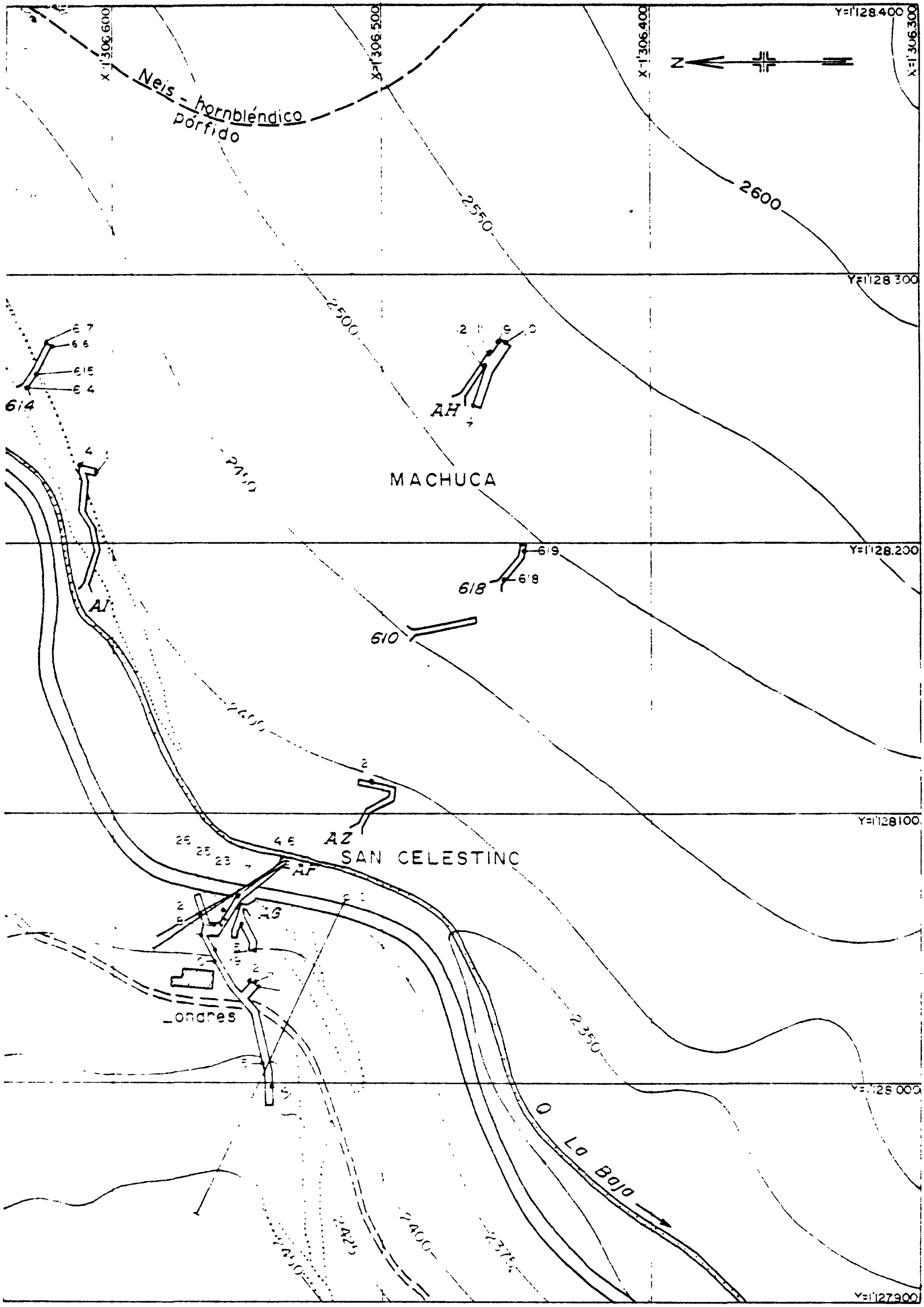
LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES "SAN CELESTINO"

CALIFORNIA
GRUPO I



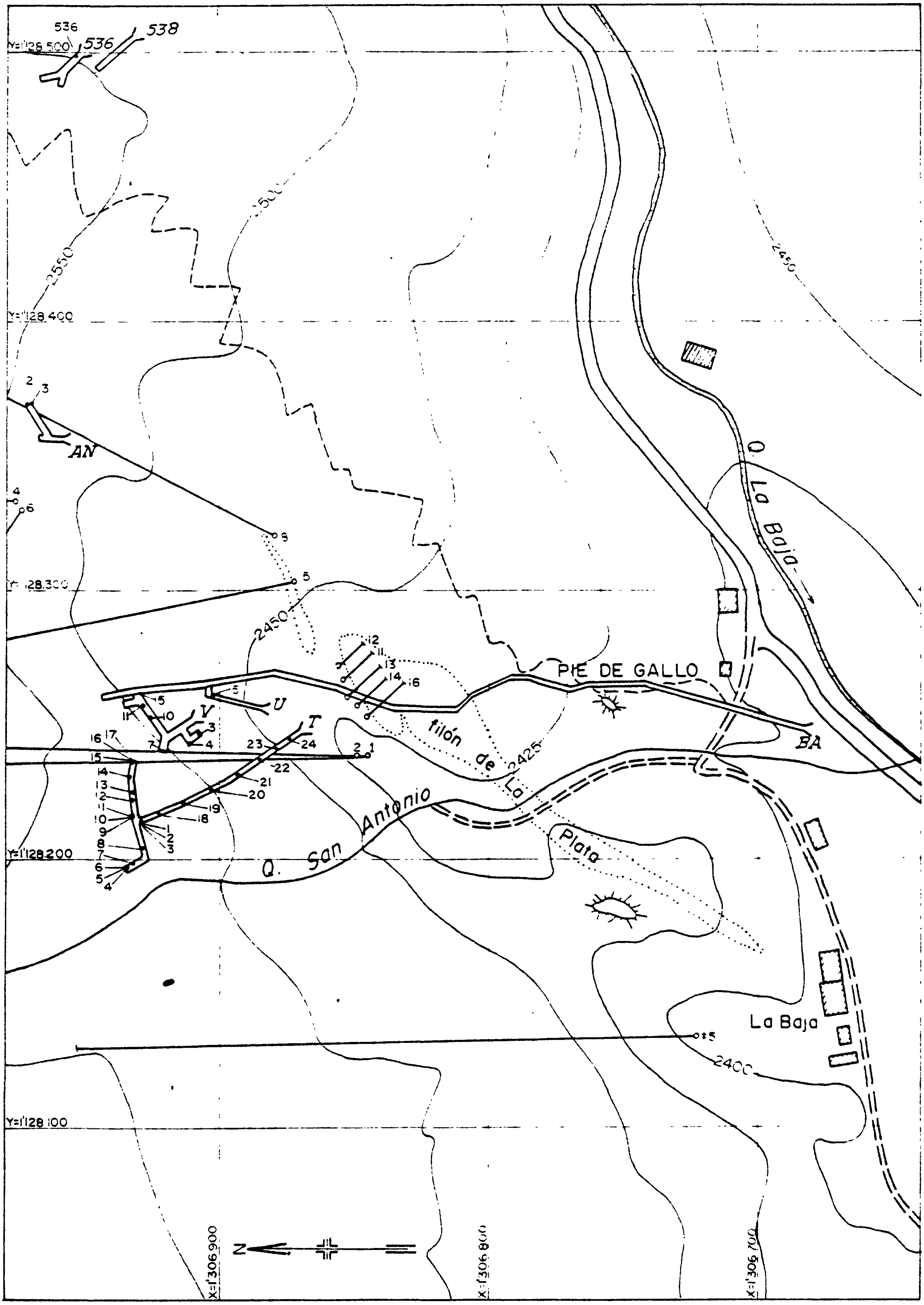
ANALISIS DE MUESTRAS
GRUPO TUNELES SAN CELESTINO

California
GRUPO I

	No. muestra	Au gr/Ton	Ag gr/Ton	% Cu	%Pb	%Zn	Espesor metros
Tunel AF- San Celestino							
	AF-1	trazas	3.00				
	AF-2	2.75	7.50				
	AF-4			0.04			
	AF-5	0.50	0.50	0.05			
	AF-7	6.50	12.25	0.06			1.10
	AF-10	21.00	249.50	0.24	2.36	3.70	
	AF-11	4.25	88.75				
	AF-12	12.25	149.00	0.22	2.40	1.23	breccia
	AF-17	0.50	5.75	0.06			
nivel sup.	AF-18	61.00	2977.33	0.02	1.53	37.82	0.35
nivel sup.	AF-19	34.75	283.00	0.20	2.15		
nivel sup.	AF-23	2.50	50.75	0.07			
nivel sup.	AF-25	1.50	99.50	0.19	1.49	4.19	
nivel sup.	AF-26	13.25	472.50	0.31	1.20	8.95	
Tunel AG - San Celestino							
	AG-1	2.50	115.50	10.25			breccia
	AG-5	19.25	581.50	1.09	2.44	8.15	
Tunel AH - Machuca							
	AH-7	42.50	311.00	0.24	3.47	0.10	
	AH-9	9.00	47.50	0.22	6.61	2.61	
	AH-10	trazas	2.00	0.03			
	AH-11	1.50	79.50	0.03			
	AH-12	35.00	74.15	0.05			
Tunel AI -							
	AI-1	0.37	5.10	0.04		0.12	
	AI-4	trazas	1.00	0.47			
Tunel AZ -							
	AZ-2	trazas	5.00	0.05			
Tunel 614- Machuca							
	614	10.50	25.25				0.40
	615	11.00	120.50				1.00
	616	3.50	63.00				0.30
	617	4.00	104.50				0.80
Tunel 618 -							
	618	45.00	28.00				0.40
	619	4.50	18.00				1.10

LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES SAN ANTONIO-PIE DE GALLO

CALIFORNIA
GRUPO II



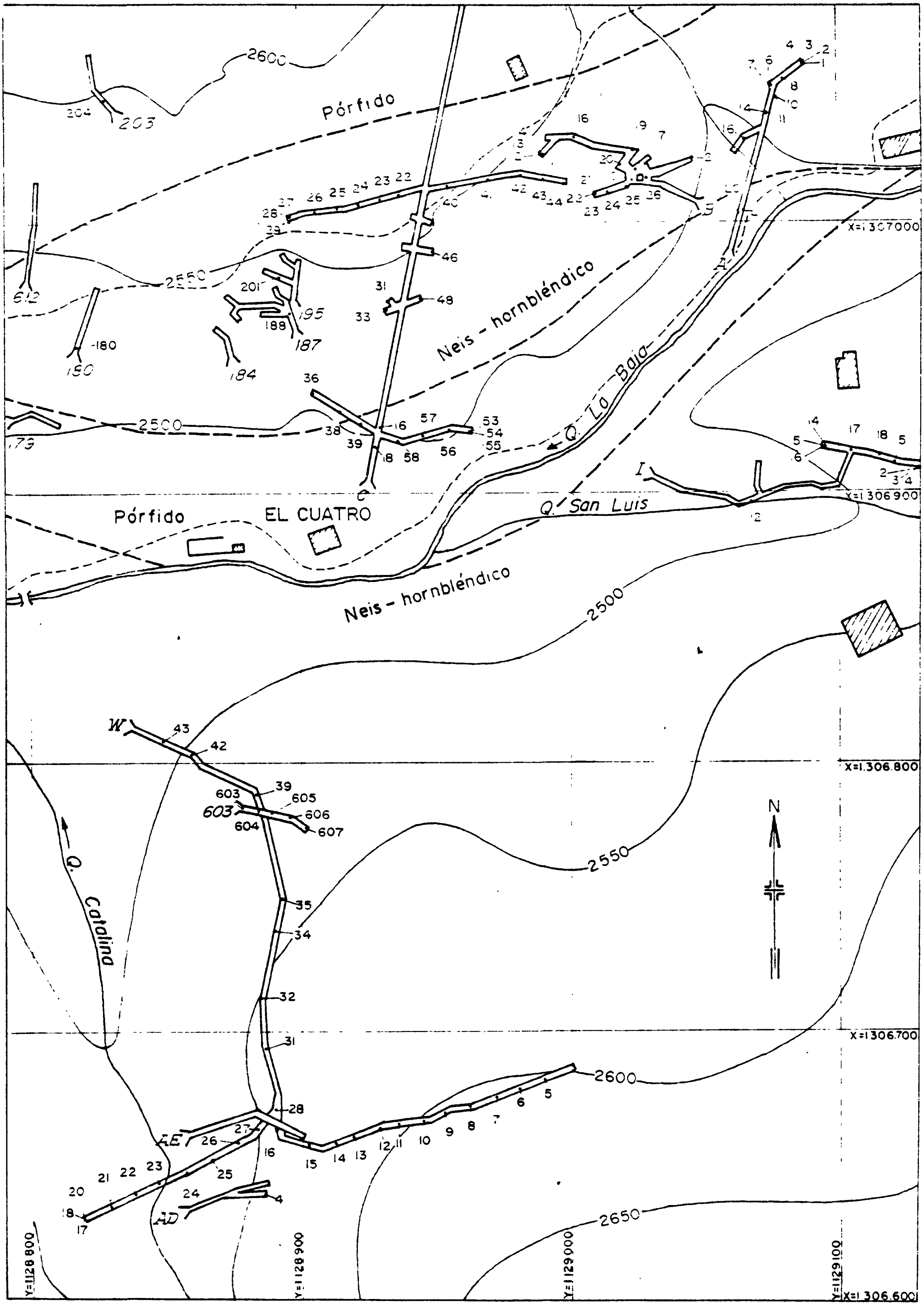
ANALISIS DE MUESTRAS
GRUPO TUNELES SAN ANTONIO-PIE DE GALLO

California
GRUPO II

No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel T- San Antonio						
T-1	0.25	2.50	0.08			
T-2	2.40	2.40	8.00	0.16	1.25	0.20
T-3	0.25	7.00	0.05			
T-4	0.25	4.75	0.02		0.06	
T-5	2.40	53.20	0.50	0.06	1.32	0.50
T-6	0.50	26.25	0.25			
T-7	0.50	27.00	0.05			
T-8	0.83	7.16	0.31			
T-9	0.37	2.25				
T-10	0.50	4.50	0.35			
T-11	0.25	9.75	0.50			
T=12	0.50	6.25	2.10			
T-13	0.50	2.25				
T-14	0.50	4.25	0.06			
T-15	0.25	3.00	0.04			
T-16	0.25	6.00	0.08			
T-17	0.25	5.00	0.06			
T-18			4.00			
T-19	0.50	3.50	0.15			
T-20	trazas	1.75	0.09			
T-21	0.25	3.25	0.74			
T-22	6.50	76.50	0.27	1.16	2.06	0.25
T-23	4.25	124.75	1.02		0.08	0.25
T-24	1.25	10.50	1.15			
Tunel U-San Antonio						
U-5	0.75	2.00	2.29			
Tunel V- Begonia -San Antonio						
V-3			0.72			
V-4	0.50	8.25	0.10			
V-7			8.80	0.03		
V-10	1.50	12.00				
V-11			11.00			
V-15			0.38	0.36		
Tunel AN - San Emidgio - San Antonio						
AN-2	2.50	12.50				1.00
AN-3	2.00	2.00	0.18	0.22		
Tunel BA - Pie de Gallo						
Tunel 536 - San Juan						
536	1.50	32.50				

LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES EL CUATRO - CATALINA

CALIFORNIA
GRUPO III



ANALISIS DE MUESTRAS
GRUPO TUNELES EL CUATRO-CATALINA

California
GRUPO III

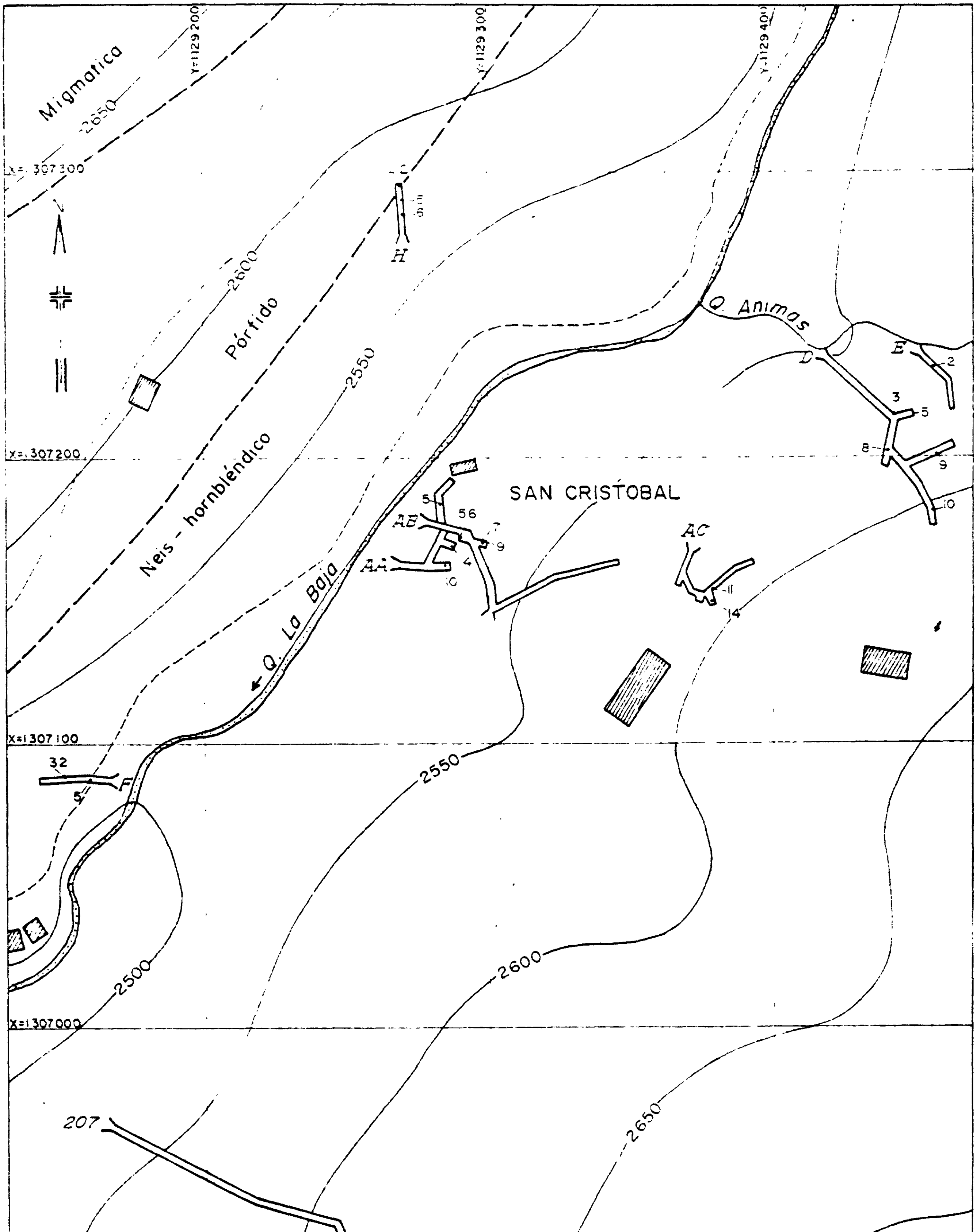
No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel A - El Porvenir - Potosi						
A-1	1.50	11.75	0.05			
A-2	4.80	220.40	1.28	0.09	0.53	0.30
A-3	6.80	342.40	0.76	0.16		0.30
A-4	2.00	22.50	0.05			
A-6	17.60	296.40	1.00	0.10		0.30
A-7	1.50	50.00	0.04			
A-8	4.25	304.50				
A-10	0.40	7.20	0.12	0.16	0.77	
A-11	6.00	161.50	0.60			
A-14	9.25	160.25	0.08			
A-16	4.00	56.50	0.05			
A-20	31.20	493.20	1.00	0.33	0.96	
A-21	37.20	987.60	2.54	0.08	0.77	
Tunel B- Potosi						
B-2	2.50	29.00	0.11			
B-7	1.50	48.50	0.05			
B-10	4.00	27.50	0.09	0.04		
B-11	0.50	23.00	0.75			
B-12			0.52	0.13	0.93	
B-13			0.24	0.09	1.63	
B-14	1.00	20.00	0.86			
B-16	3.20	128.00	0.76	0.08	0.35	
B-19	4.00	790.00	6.36	0.17		
B-20	14.00	822.00	3.32	0.34	0.40	
B-21	2.00	71.50	0.11	0.04		
B-22	71.60	479.20				
B-23	2.75	31.00	0.04			
B-24	3.60	76.40	0.12	0.17		
B-25	66.00	1354.80	0.52	0.01		
B-26	5.20	267.60	0.52	0.18	1.39	
Tunel C - El Cuatro						
C-16	0.50	7.00	0.10			
C-18	trazas	3.50	0.04			
C-22	1.50	21.00	1.65			
C-23	3.50	18.50	0.52			
C-24	3.00	73.00	4.90			
C-25	12.80	292.80	9.16	0.32	0.16	
C-26	6.00	169.20	0.76	0.31		
C-27	2.50	102.50	1.82		0.05	
C-28	4.80	245.20	1.52	0.60	0.24	

California
GRUPO III

No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
C-29	2.00	81.50	0.73			
C-31	3.00	26.00	0.23			
C-33	1.60	32.80	0.38	0.09	0.20	
C-36	26.00	137.60	0.20	0.70	0.10	
C-38	4.00	103.50	0.50			
C-39	56.10	385.40	2.25			
C-40	2.00	75.60	0.15	1.44	1.04	
C-41	6.80	185.20	0.15	2.43	0.16	
C-42	5.25	66.00				
C-43	0.50	101.50	0.70			
C-44	13.60	450.00	1.65	0.44	0.36	
C-46	0.80	40.40	0.15	0.32	0.64	
C-48	2.50	50.50	0.82			
C-53	16.40	50.40	0.15	0.27	0.42	
C-54	2.06	22.50				
C-55	1.00	12.00	0.05			
C-56	2.60	15.80	0.06			
C-58	1.00	13.50	0.09			
Tunel I - San Luis						
I-2	1.00	12.75	0.07			
I-3			0.15	0.25	0.13	
I-4			0.15	2.05	1.16	
I-5	7.00	139.50	0.06			
I-12	0.50	5.00	0.05			
I-14	1.50	21.25	0.05			
I-15	17.60	435.60	9.60	0.53	1.02	0.50
I-16	2.00	22.00	0.05			
I-17	3.30	144.50	2.13			
I-18	17.15	1015.00	9.25			
Tunel W - Catalina						
W-5	36.65	567.50	1.45		2.13	
W-6	11.00	169.00	0.05	0.02		1.30
W-7	0.50	33.25	0.04			
W-8	1.25	74.50	0.75			
W-9	3.25	349.25	0.06			
W-10	3.00	248.50	0.04			
W-11	3.25	74.00	0.07			
W-12	1.00	23.00	0.04			
W-13	0.75	127.00	0.04			
W-14	21.50	588.85	0.05		0.13	
W-15	0.50	18.00	0.07			

California
GRUPO III

No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	% Pb	%Zn	Espesor metros
W-16	1.00	23.50	0.05			
W-17	2.00	44.50	0.07			
W-18	7.00	122.50	0.05			
W-20	0.75	19.50	0.05	0.05		
W-21	0.50	27.50	0.06			
W-22	2.25	56.50	0.04			
W-23	2.50	134.50	0.05			
W-24	1.75	146.00	0.05			
W-25	2.50	76.50	0.07			
W-26	1.00	32.25	0.07			
W-27	2.00	69.25	0.07			
W-28	0.25	10.50	0.04			
W-31	trazas	6.25	0.06			
W-32	trazas	9.75	0.04			
W-34	trazas	19.50	0.07			
W-35	trazas	5.00	0.06			
W-39	0.25	1.00	0.05			
W-42	5.25	25.50	0.05			
W-43	8.50	47.75	0.07			0.50
Tunel AD - El Sube						
AD-4	16.50	477.50	3.14	1.16	24.51	
Tunel 180 -						
180	8.75	76.00	0.01	1.41	0.23	1.20
Tunel 187 -						
188	4.50	98.50				0.70
Tunel 195 -						
201	6.75	121.25	0.07	1.99	0.38	0.60
Tunel 203 -						
204B	8.50	60.50	0.04	1.73	0.29	
Tunel 603 - Santa Catalina						
603	52.00	2381.00				1.00
604	2.00	905.00				0.45
605	33.00	436.00				0.82
606	17.50	278.50				0.45
607	12.50	298.00				0.25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Pórfido
Neis - hornbléndico
Q. La Baja
Q. Animas
SAN CRISTOBAL
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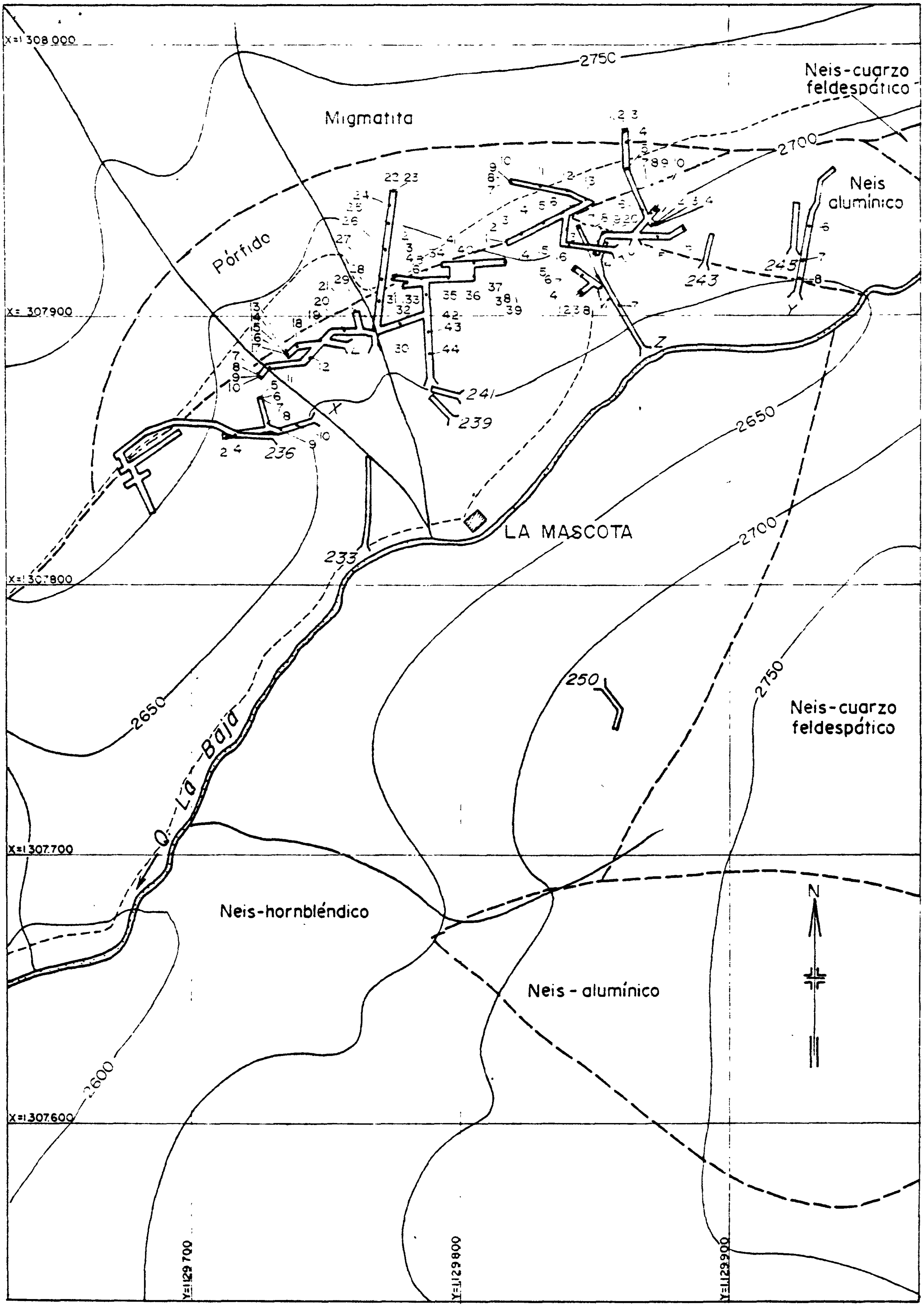
Y=1129400
2650
2600
2550
2500
2700
AA
AB
AC
H
D
E
207
211
211B
32

ANALISIS DE MUESTRAS
GRUPO TUNELES SAN CRISTOBAL-ANIMAS

California
GRUPO IV

No. muestra	Au gr/Ton	Ag gr/Ton	% Cu	%Pb	%Zn	Espesor metros
Tunel D -Animas inferior						
D-3	3.60	60.80	0.07	0.44	0.34	
D-5			0.15	0.61	2.08	
D-8	11.90	87.10	0.74			
D-9	48.00	758.40	0.15	0.84	0.19	0.20
D-10	17.80	517.40	0.61			
Tunel E- Animas superior						
E-2	4.00	62.00	0.10			
Tunel F - Potosi						
F-2	0.80	9.60	0.15	0.03	0.84	
F-3	1.50	10.50	0.07			0.30
F-5	9.00	294.00	1.28			
Tunel H - San Francisco						
H-1	28.00	52.00	0.05			
H-2	18.00	21.20	0.15	0.13	0.07	
H-5	5.00	68.00	0.06			
H-6	2.00	31.20	0.17	0.88	1.45	
Tunel AA-San Cristobal						
AA-5	2.00	48.50				
AA-10	3.50	45.50				0.40
AA-14	1.25	61.50				0.30
Tunel AB- San Cristobal						
AB-5	2.00	30.00				
AB-6	0.50	4.50	0.62			
AB-7	5.50	75.25	2.61	0.37	0.10	
AB-9	4.25	58.50				
Tunel AC - San Cristobal						
AC-11	1.16	22.15	0.15			
AC-14	16.30	420.50	0.05	0.10		
Tunel 207 -						
211	5.75	85.00	1.34	2.65	2.16	0.55
211B	9.50	20.50	0.02	0.83	0.18	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Pórfido
Neis-cuarzo feldespático
Neis alumínico
Neis-hornbléndico
Neis - alumínico
LA MASCOTA
Q. La Baja
233
236
239
241
243
245
250
X
Y
Z
N

ANALISIS DE MUESTRAS
GRUPO TUNELES LA MASCOTA

California
GRUPO V

	No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel J - La Mascota							
	J-1			0.06			
	J-2	2.00	10.00		0.04	1.10	
	J-3			0.06	0.07		
	J-4	55.20	19.20	0.52	1.35		
	J-5			0.04			
	J-6	3.30	87.10	0.07			1.00
	J-7	5.90	70.00	0.35			
	J-8			0.07			
	J-9	7.60	808.40	0.24	0.49	0.30	
	J-10			0.08			
	J-11	4.00	19.10	0.06			
	J-12	92.80	438.40	1.20	0.80	0.60	
	J-13	15.60	41.20	0.52	0.56		
	J-14	15.10	89.10	0.21			
	J-15	58.80	425.70	0.31			
	J-16	44.20	113.62	1.10			
	J-17	7.00	28.00	0.05			
	J-18	11.20	66.40	0.24	2.66		
	J-19			0.06			
	J-20	2.60	21.10	0.06			
Tunel K - Minaseca							
	K-1	7.50	95.00	0.04			
	K-2	8.40	412.80	0.52	0.30	1.00	1.00
	K-3	1.00	11.00	0.20			
	K-4			0.09			
	K-5	14.25	96.00	0.08			
	K-6	1.30	21.75	0.12			
	K-7	4.80	22.40		0.53	1.62	
	K-8	1.60	10.00		0.18		
	K-9	16.00	357.60		12.78	0.45	
	K-10	2.00	38.80		1.08	0.45	
	K-11	9.20	44.20	0.35			
	K-12	2.00	21.75	0.27			
	K-13	64.00	592.00	0.05			
	K-14	11.90	15.10	0.27			
	K-15	6.60	129.30	0.62			
	K-16	9.20	61.40	1.80			

California
GRUPO V

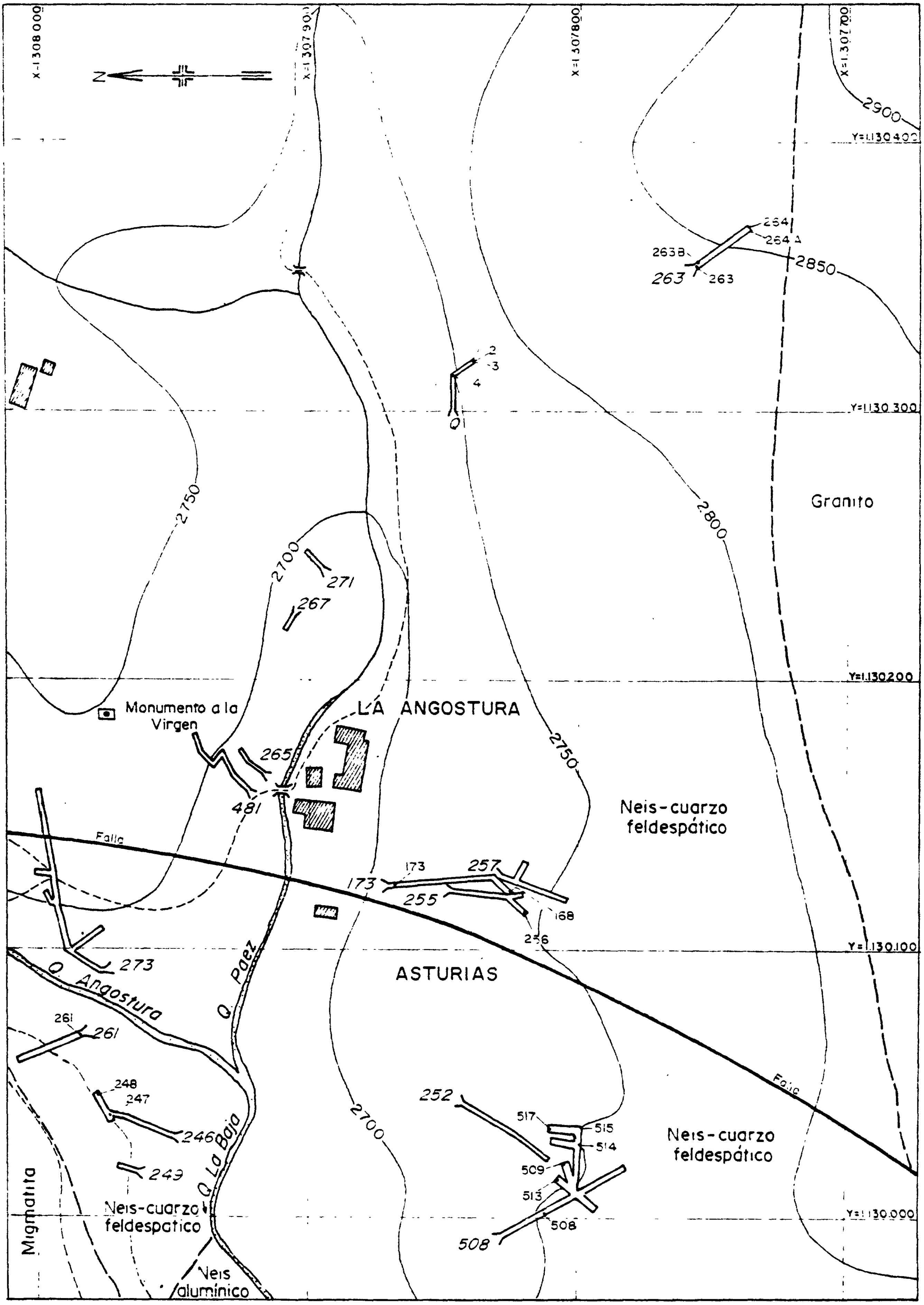
No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel L - Tres Aguas						
L-1			0.06			
L-2	26.40	421.60	0.95	1.34	0.53	2.70
L-3	10.00	64.80	0.64	0.03	0.51	
L-4	19.20	260.40	0.95	0.10	0.43	
L-5	22.00	162.80	0.64	0.17	0.85	
L-6			0.05			
L-7	1.60	10.40	0.64	0.55	1.14	
L=8	1.60	12.40	0.64		0.16	
L-9	4.40	31.60	0.32	0.27	0.37	1.20
L-10	1.60	16.40	0.64	0.33	0.29	
L-11	33.00	173.50	0.55			
L-12			0.05			
L-13			0.07			
L-14	10.00	82.00	0.15	0.12	0.68	0.30
L-15	1.60	3.60		0.29	0.22	
L-16	0.80	4.80		0.11	1.32	
L-17			0.06			
L-18	6.00	167.00	0.06			
L-19	6.60	56.10	0.08			
L-20	4.00	144.00	0.50			
L-21	trazas	6.50	0.04			
L-22			0.03			
L-23			0.04			
L-24	trazas	8.00	0.05			
L-25	1.50	17.00	0.08			1.70
L-26			0.05			
L-27			0.07			
L-28	10.50	12.50	0.05			
L-29	10.50	68.60	0.30	0.06		
L-30	trazas	6.00	0.04			
L-31	4.00	121.40				0.50
L-32	0.50	12.50	0.04			
L-33	0.50	13.50	0.06			
L-34	13.80	297.00	2.26			
L-35	8.00	242.22	1.44			
L-36	2.75	21.00	0.35			
L-37			0.03			
L-38	10.50	382.80	0.08	0.03	0.06	0.50
L-39	1.00	25.00	0.06			
L-40	12.50	24.50	0.14			

California
GRUPO V

No muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
L-41			0.09			
L-42			8.20			
L-43			0.09			
L-44			0.06			
Tunel M - La Bota						
M-1	5.00	6.00	0.05			
M-2	15.20	2.40		2.03	2.17	0.45
M-3			0.10			
M-4			0.06			
M-5	2.75	325.00	0.09			0.40
M-6	1.20	0.40		0.40	1.43	
M-7	1.50	459.00	0.07			
M-8			0.03			
Tunel X - La Mascota						
X-2	10.50	33.75	0.49			0.25
X-4	7.50	49.50	0.25	2.49	0.10	
X-5	9.00	237.80	0.06			
X-8	7.25	141.25	1.92	0.70	0.10	
X-9	3.25	36.50				
X-10	10.50	27.00	0.11	0.64	0.23	
Tunel Y - San Expedito						
Y-6	1.50	3.75	0.05			
Y-7	0.25	2.75	0.05			
Y-8	14.25	68.50	0.04			1.50
Tunel Z - El Libertador						
Z-3	3.75	42.00				
Z-4			0.05			
Z-7			0.04			

LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES ASTURIAS - LA ANGOSTURA

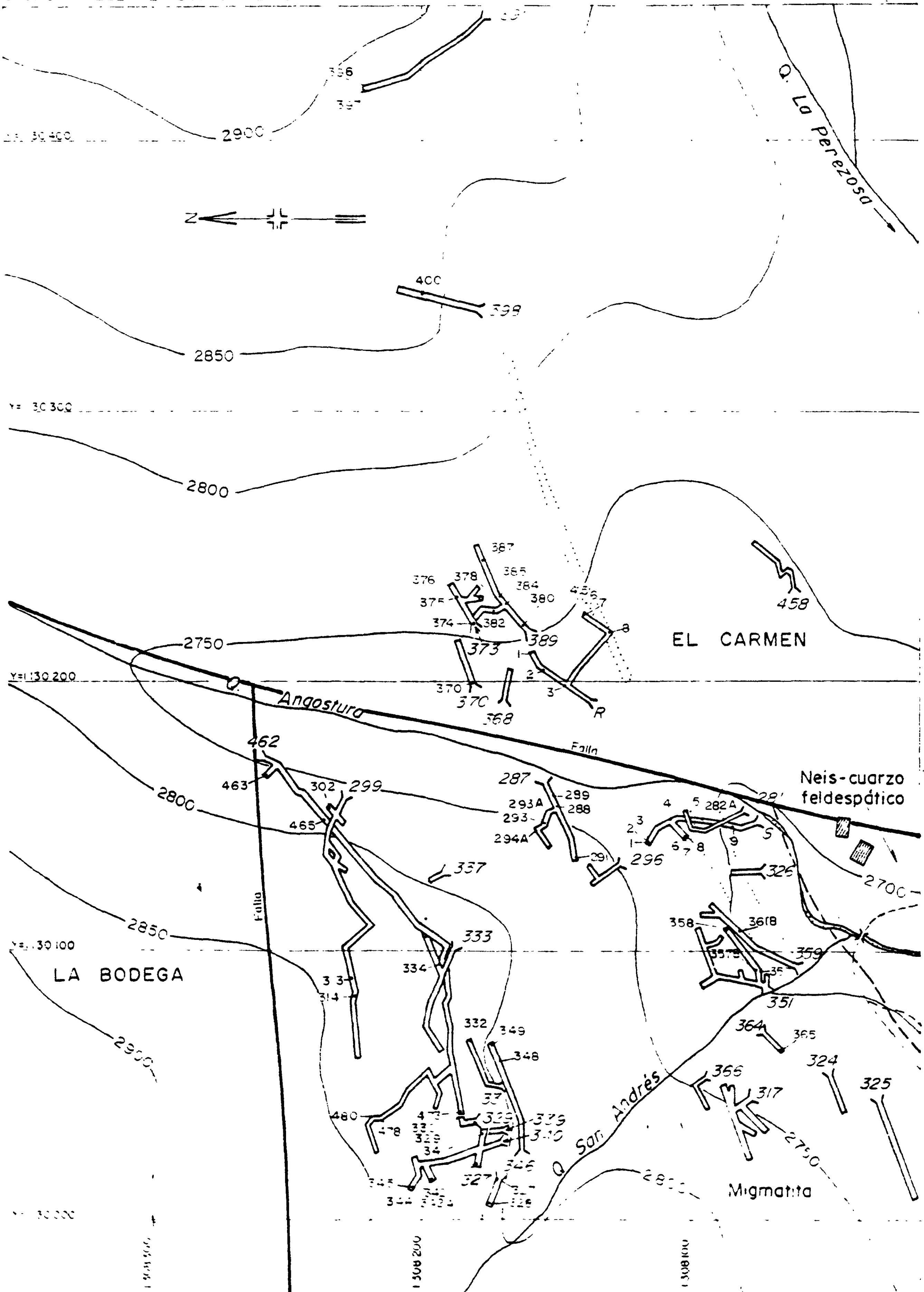
CALIFORNIA
GRUPO VI



ANALISIS DE MUESTRAS
GRUPO TUNELES ASTURIAS-LA ANGOSTURA

California
GRUPO VI

	No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel Q - Las Mercedes							
	Q-1			0.03			
	Q-2	1.00	17.75	0.05			
	Q-3	0.50	0.75	0.03			
	Q-4	10.50	30.25	0.07			
Tunel 173 - Asturias							
	168	41.50	76.50	1.57	1.49	0.57	0.50
	173	2.00	16.00				1.00
Tunel 246							
	247	2.25	29.50				0.80
	248	1.00	2.00				0.75
Tunel 255 -							
	256	11.50	24.50	0.07	1.32	0.33	0.90
Tunel 261 -							
	261	3.00	7.50				
Tunel 263 -							
	263	54.00	35.50	0.05	1.07	0.25	
	263B	0.50	10.50				
	264A	1.25	27.00				
	264	15.50	266.00	0.07	0.82	0.26	0.80
Tunel 508 -							
	508	38.50	9.50				
	509	7.00	30.50				2.00
	513	3.50	37.50				1.35
	514	4.50	18.50				0.95
	515	8.75	12.75				0.60
	517	4.00	12.25				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2900
2850
2800
2750
2700
Y= 130 200
EL CARMEN
LA BODEGA
Q. Angostura
Falla
Neis-cuarzo feldespático
Migmatita
Q. San Andrés
458
462
287
299
333
351
389
373
398

ANALISIS DE MUESTRAS
GRUPO TUNELES LA BODEGA-EL CARMEN

California .
GRUPO VII

No. muestra	Au gr/Ton	Ag ,gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel R - El Carmen						
R-1	2.00	4.25	0.05			0.61
R-3	2.50	9.25	0.04			
R-4	21.50	10.00	0.04			0.90
R-5	3.60	4.00				
R-6	2.80	4.00	0.19	1.19	1.78	
R-7	2.00	10.75	0.10			
R-8	1.50	6.50	0.05			
Tunel S - La Bodega						
S-1	0.50	8.25	0.07			
S-2	0.37	8.12	0.08			
S-3			0.05			
S-4			0.15			
S-5	1.75	22.50	0.05			
S-6			0.03			
S-7	1.75	14.00	0.04			
S-8	19.00	4.50	0.08			0.70
S-9	5.50	26.00	0.06			
Tunel 281 - La Bodega						
282A	58.00	9.00	0.05	0.58	0.10	
Tunel 287 - La Bodega						
288	3.50	19.50				0.20
289	0.50	7.00				0.80
291	3.50	17.50				0.50
293	1.50	6.00				0.65
293A	0.50	1.60				
294A	1.00	12.00	1.09	0.66	0.25	
Tunel 299 - El Matacho						
302	1.00	6.25				0.40
313	1.85	6.50				0.25
314	8.50	4.50	0.005	0.74	0.18	0.45
Tunel 327 - San Andrés						
327	13.50	55.50	0.23	1.20	0.28	0.30
328	9.00	47.50	0.28	1.70	0.29	0.45

California
GRUPO VII

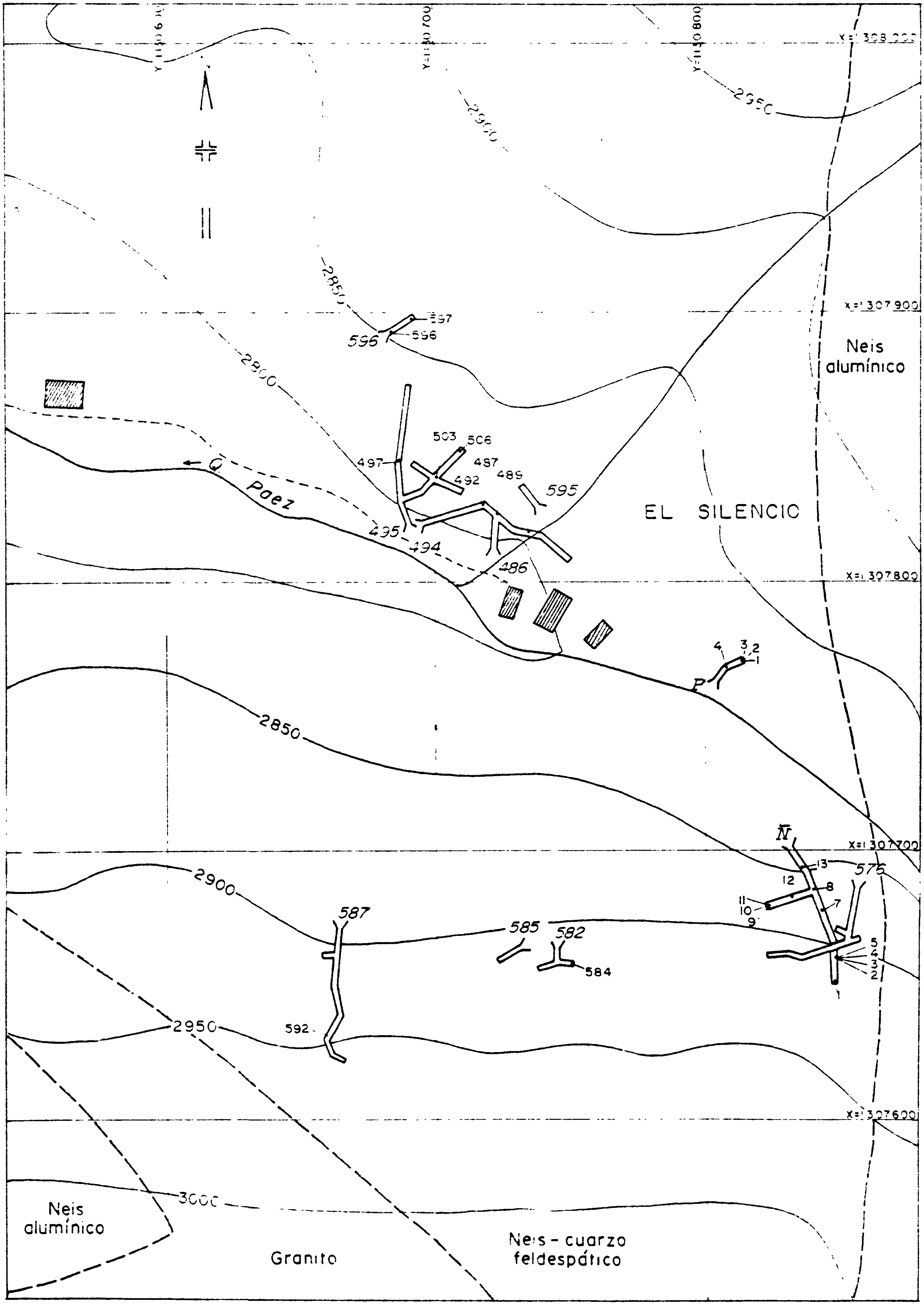
	No. muestra	Au gr/Ton	Ag gr/Ton	% Cu	%Pb	%Zn	Espesor metros
Tunel 329 -	San Andrés						
	329	58.00	108.00	0.43	2.32	0.63	0.20
	330	3.75	26.50				0.35
Tunel 331 -	La Paja						
	332	8.00	26.00	0.12	0.74	0.35	0.20
Tunel 333 -	La Paja						
	334	6.00	23.50	0.30	1.07	0.36	0.70
Tunel 339 -	San Andrés						
	339	4.80	27.50	0.70	1.16	0.40	0.50
Tunel 340 -							
	341	17.75	61.50	0.90	2.65	0.35	0.28
	342A	7.00	25.50	0.37	1.08	0.46	
	342	7.00	39.50	0.16	1.32	0.22	0.26
	344	9.50	73.00	0.06	1.16	0.23	
	345	54.50	273.50	0.45	2.28	0.33	0.35
Tunel 346 -	San Andrés						
	348	1.25	18.00				0.40
	349	4.75	37.50	0.15	1.48	0.31	0.25
Tunel 351 -	La Bodega						
	357	1.50	3.50				0.95
	357B	8.25	34.50	0.61	0.70	0.55	
	358	1.25	6.75				1.40
Tunel 359 -	La Bodega						
	361B	5.25	13.75	0.06	2.32	0.10	
Tunel 364 -	Las Ventanas						
	365	8.75	31.25	0.15	1.24	0.31	0.90
Tunel 370 -	El Carmen						
	370	4.50	19.00				

California
GRUPO VII

	No. Muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor Metros
Tunel 373 - El Carmen							
	374	9.50	36.00				
	375	3.50	25.50				0.60
	376	18.00	29.00				0.70
	378	2.50	10.00				
Tunel 389 -							
	380	3.50	23.25				1.70
	382	15.75	30.50				0.95
	384	9.50	13.00				
	385	21.00	37.00				
	387	3.00	27.75				
Tunel 391 - Punta Piedra Gorda							
	396	17.00	77.50				1.30
	397	3.00	50.25				
Tunel 398 - El Carmen							
	400	168.50	32.50	0.04	0.77	0.21	2.30
Tunel 462 - Bodega Vieja							
	463	8.50	42.50				1.30
	465	3.21	91.50				0.50
	473	2.50	13.50				
	478	169.00	403.50				0.65
	480	20.12	35.12	0.46	3.31	0.25	0.38

LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES EL SILENCIO

CALIFORNIA
GRUPO VIII



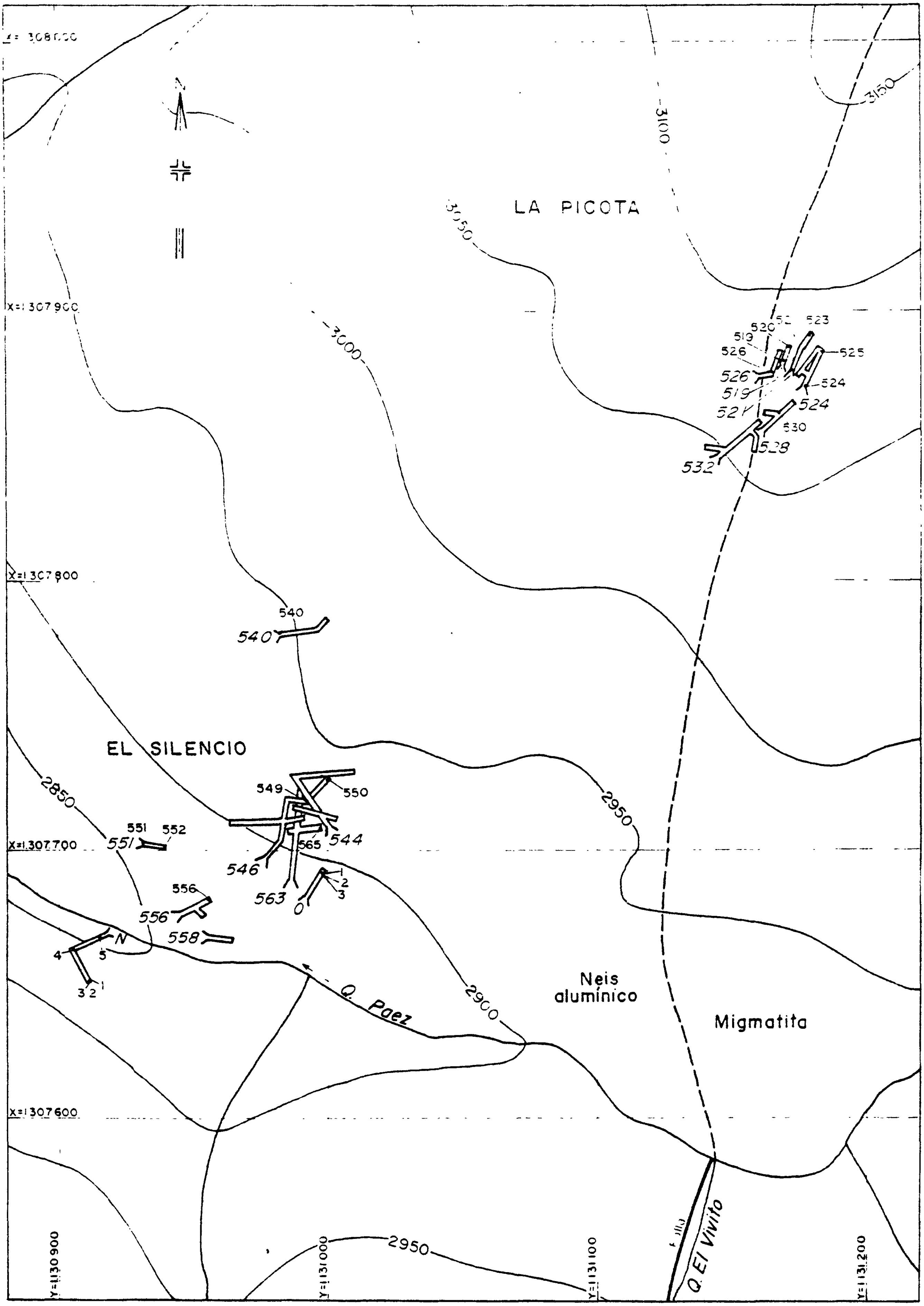
ANALISIS DE MUESTRAS
GRUPO TUNELES EL SILENCIO

California
GRUPO VIII

	No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel Ñ - El Silencio							
	Ñ-1			0.05			
	Ñ-2	1.50	10.00	0.06			
	Ñ-3	14.00	85.20	0.15	0.17	1.16	1.00
	Ñ-4	3.20	9.20		0.67	0.27	
	Ñ-5	1.00	12.50	0.02			
	Ñ-7	0.50	14.00	0.07			
	Ñ-8			0.06			
	Ñ-9			0.05			
	Ñ-10	3.20	1.60		0.18	0.36	
	Ñ-11			0.19			
	Ñ-12			0.04			
	Ñ-13			0.07			
Tunel P - El Silencio							
	P-1	17.00	27.00	0.15			
	P-2	1.50	3.00	0.06			
	P-3	4.00	13.00	0.05			
	P-4			0.04			
Tunel 486 - El Silencio							
	487	19.75	131.00	0.60	0.97	0.20	0.40
	489	11.50	45.00	0.19	0.75	0.24	0.77
	492	29.75	12.75	0.18	0.83	0.23	0.35
Tunel 495 - El Silencio							
	497	0.50	12.00				0.08
	503	1.00	18.00				0.70
	506	3.50	32.00				0.15
Tunel 582 -							
	584	5.85	29.25				0.20
Tunel 587 O EL Silencio							
	592	2.50	6.00				
Tunel 596 -El Silencio							
	596	21.00	38.00				0.30
	597	5.00	26.50				0,45

LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES LA PICOTA - EL SILENCIO

CALIFORNIA
GRUPO IX

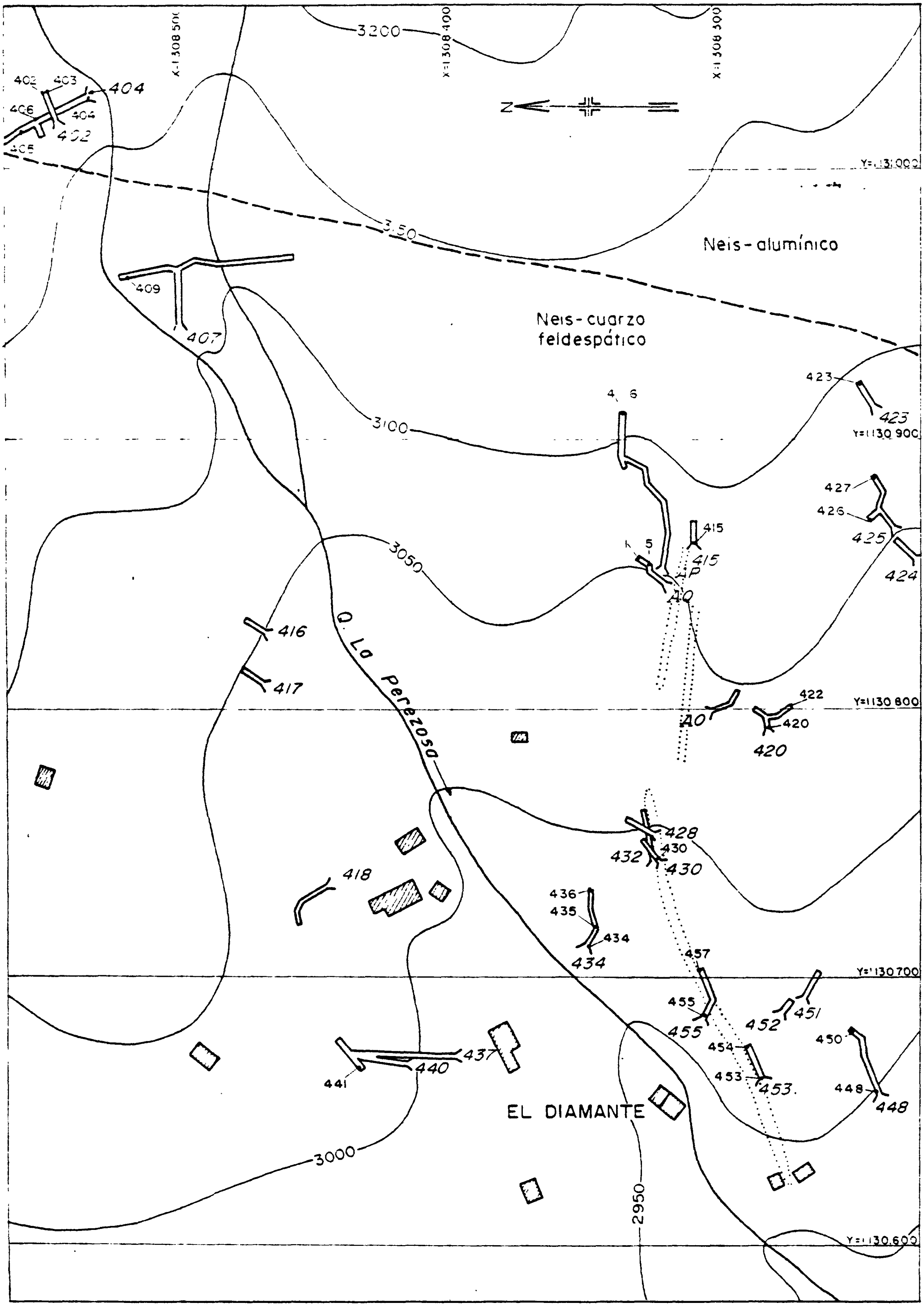


ANALISIS DE MUESTRAS
GRUPO TUNELES LA PICOTA-EL SILENCIO

California
GRUPO IX

	No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel N - El Silencio							
	N-1	0.50	3.50	0.05			
	N-2			0.07			
	N-3	trazas	5.00				
	N-4	trazas	10.50	0.10			
	N-5	0.75	10.50	0.07			
Tunel 0 - El Silencio							
	0-1	3.75	12.75	0.02			
	0-2	26.80	235.20	0.15	0.09	0.16	0.70
	0-3	7.00	24.50	0.05			
Tunel 519 - La Picota							
	519	5.25	28.75				0.50
	520	5.50	53.00				0.40
Tunel 521 - La Picota							
	521	24.00	20.00				0.60
	523	1.00	22.50				
Tunel 524 - La Picota							
	524	5.25	9.50				0.25
	525	2.75	15.00				0.60
Tunel 526 - La Picota							
	526	65.00	12.50				1.00
Tunel 528 -La Picota							
	530	203.00	34.00				0.60
Tunel 540 -							
	540	1.75	10.00				0.15
Tunel 546 - El Silencio							
	549	17.50	24.00				0.45
	550	12.75	76.75	0.14	0.62	0.22	0.85
Tunel 551 - El Silencio							
	551	31.75	271.75				
	552	46.00	59.00				
Tunel 556 -							
	556	6.50	42.50				0.90
Tunel 563 -							
	565	2.50	8.00				0.95

LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES EL DIAMANTE



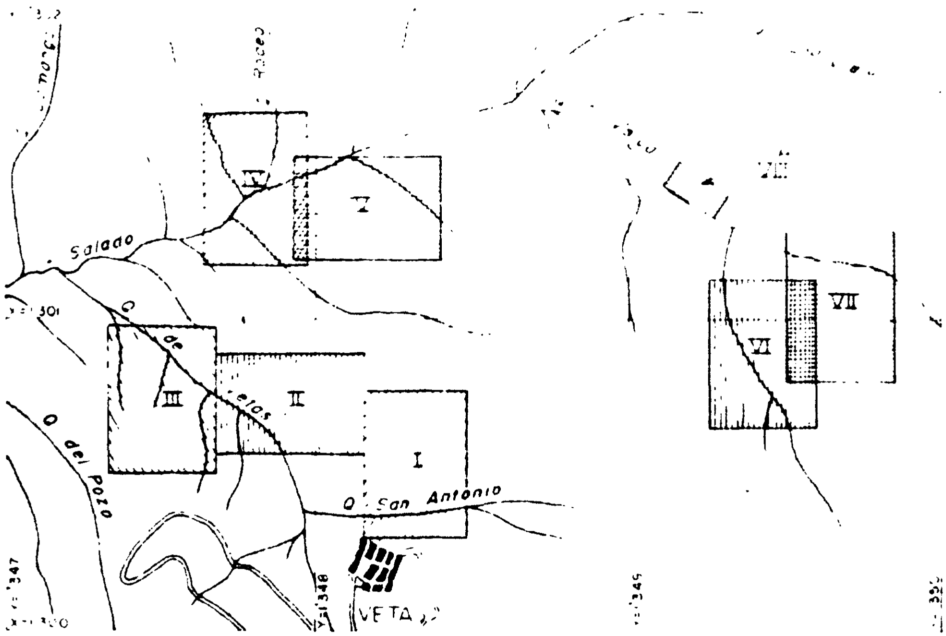
ANALISIS DE MUESTRAS
GRUPO TUNELES EL DIAMANTE

California
GRUPO X

No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel AP - El Diamante						
AP-4	6.25	67.50	0.19	1.32	28.34	0.90
AP-6	0.37	7.75	0.06			
Tunel AQ - El Diamante						
AQ-1	1.75	18.00	0.04			
AQ-5	5.80	17.15	0.04			
Tunel 402 - La Picota						
402	4.50	33.75				0.40
403	1.00	39.00				0.10
Tunel 404 - La Picota						
404	0.75	7.00				
405	3.00	24.00				2.50
406	16.00	132.00	1.35	0.58	0.22	0.35
Tunel 407 - El Diamante						
409	9.00	17.50				0.19
Tunel 415 - El Diamante						
415	2.50	27.50				
Tunel 420 -						
420	26.50	13.75				0.15
422	5.00	8.00				0.45
Tunel 423 -						
423	trazas	27.00				0.40
Tunel 425 -						
426	2.00	83.00				0.40
427	35.75	32.50				0.25
Tunel 430 - El Diamante No. 2						
430	0.50	9.00				0.70
Tunel 434 - El Diamante No. 2						
434	1.00	21.00				
435	1.00	34.00				0.18
436	3.50	10.00				

California
GRUPO X

	No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Ob	%Zn	Espesor metros
Tunel 440 -	El Diamante No. 2						
	441	5.00	22.00				1.10
Tunel 448 -							
	448	6.50	22.00				0.60
	450	8.00	150.00				0.20
Tunel 453 -	El Diamante No. 2						
	453	3.65	47.50				0.60
	454	14.25	32.75				0.50
Tunel 455 -							
	455	17.00	16.10				0.20
	457	1.00	13.50				0.90



MAPA INDICE

GRUPO TUNELES MINAS DE VETAS
MPIO. DE CALIFORNIA–DPTO DE SANTANDER

I San Bartolo

II Buenavista–La Colombo

III Trompeteros–La Elsi

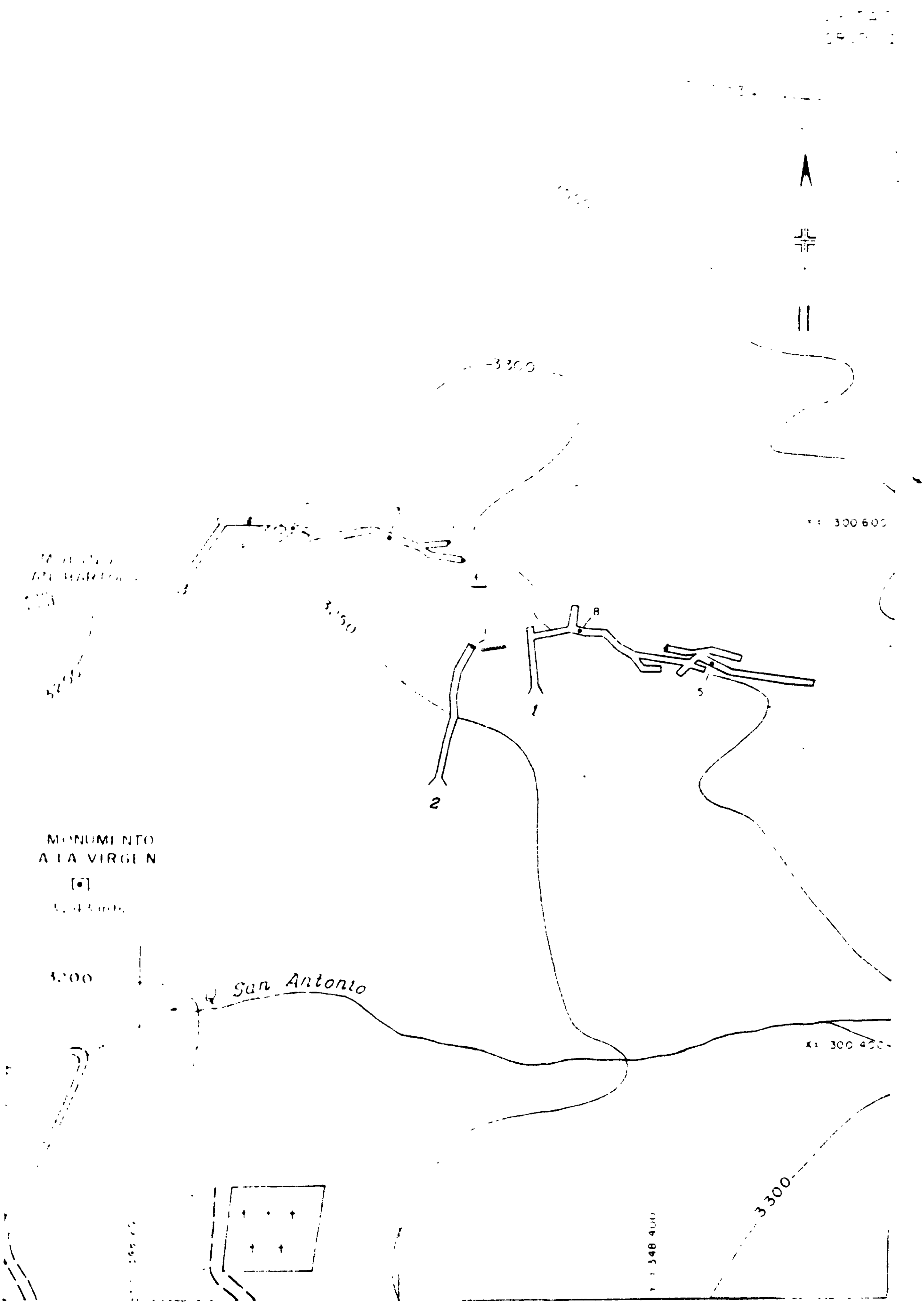
IV La Tosca

V La Tosca Oriental

VI [illegible]

VII [illegible]

VIII [illegible]



INVENTARIO MINERO NACIONAL

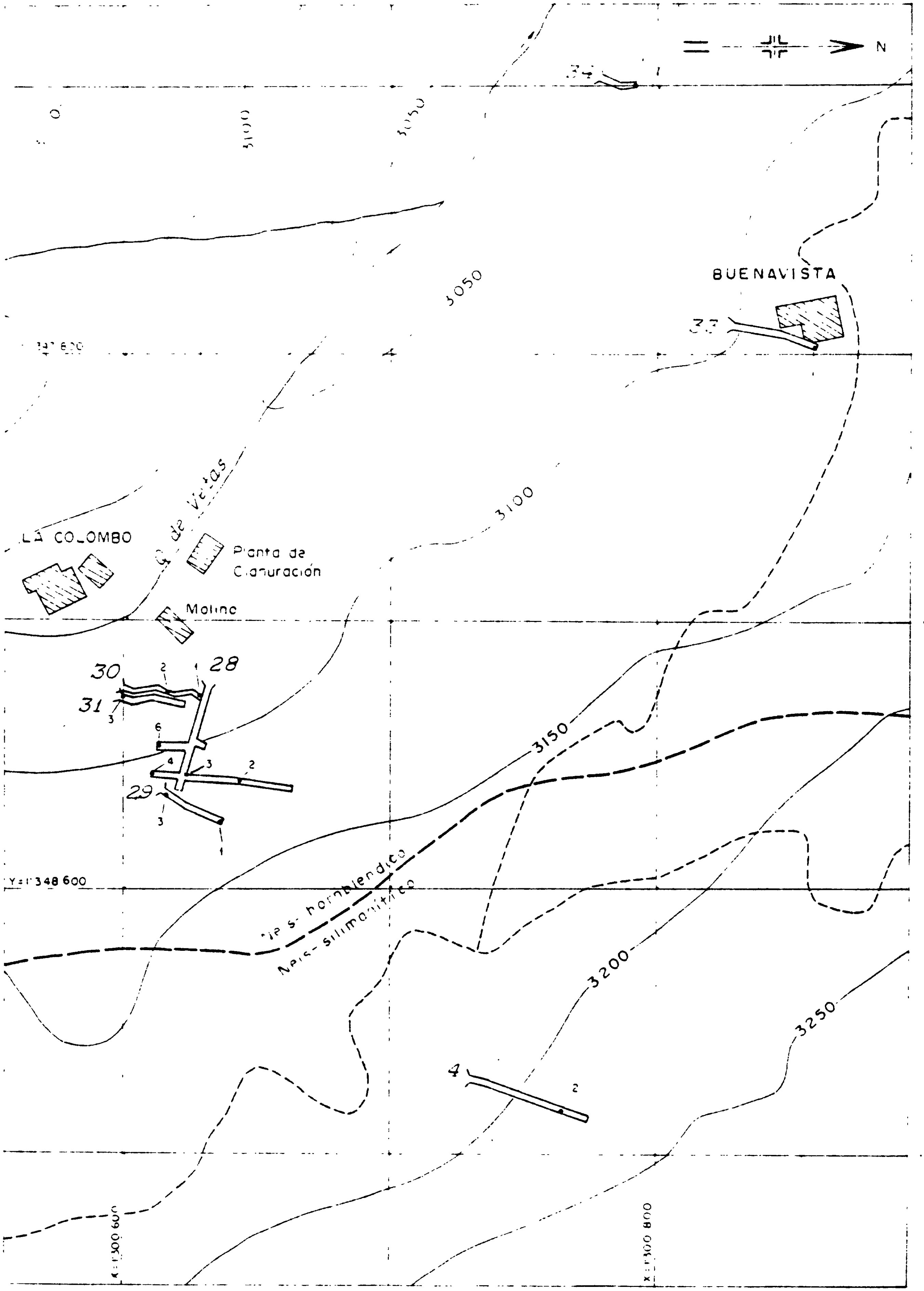
ANALISIS DE MUESTRAS
GRUPO TUNELES SAN BARTOLO

Vetas
GRUPO I

No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel 1 - San Bartolo - Elevación 3260 metros						
1-2	0,50	9.35				1.20
1-5	1.50	16.50				
1-8	1.00	19.50				1.80
Tunel 2 - San Bartolo - Elevación 3234 metros						
2-1	6.25	12.00				1.15
Tunel 3 - San Bartolo - Elevación 3228 metros						
3-1	12.50	31.50				
3-2	1.15	33.50				1.70
3-3	1.00	36.75				1.50
3-5	1.00	9.50				1.30
3-6	1.00	20.25				0.90

LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES BUENAVISTA - LA COLOMBO

VETAS
GRUPO II



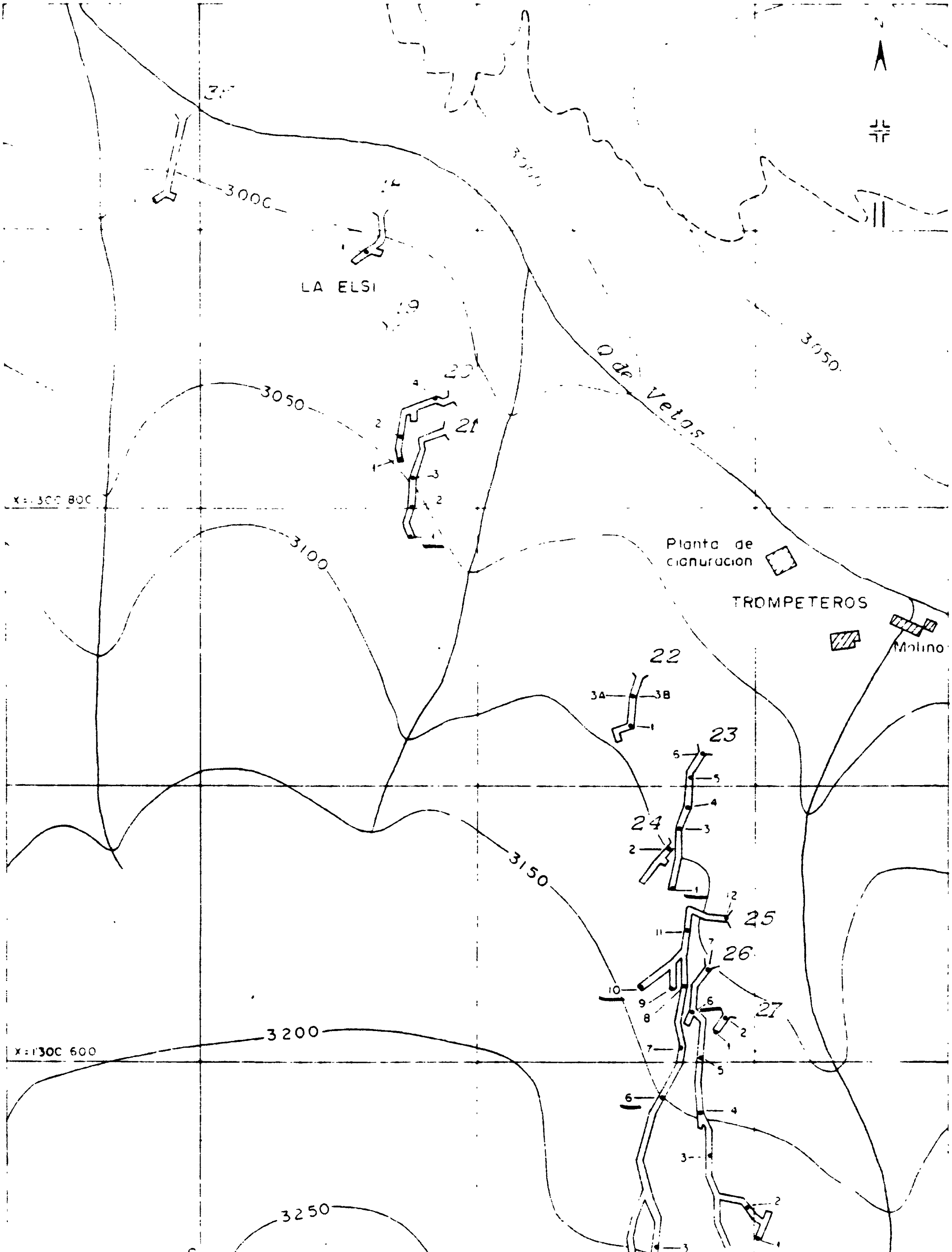
ANALISIS DE MUESTRAS
GRUPO TUNELES BUENAVISTA - LA COLOMBO

Vetas
GRUPO II

	No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel 4 - Aguado - Elevación 3189 metros							
	4-2	trazas	9.50				1.60
Tunel 28 - La Colombo - Elevación 3082 metros							
	28-2	0.50	6.00				1.20
	28-3	1.50	7.50				0.30
	28-4	trazas	6.25				0.90
	28-6	trazas	8.25				
Tunel 29 - La Colombo - Elevación 3105 metros							
	29-1	0.50	7.00				1.20
	29-3	0.50	6.15				
Tunel 30 - La Colombo - Elevación 3073 metros							
	30-1	trazas	5.15				
	30-2	0.50	3.25				1.50
Tunel 31 - La Colombo - Elevación 3076							
	31-3	trazas	2.50				
Tunel 33 - Buenavista - Elevación 3101 metros							
	33-1	1.50	45.75				
Tunel 34 - Trompeteros - Elevación 3033 metros							
	34-1	trazas	4.00				1.10

LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES TROMPETEROS - LA ELSI

VETAS
GRUPO III

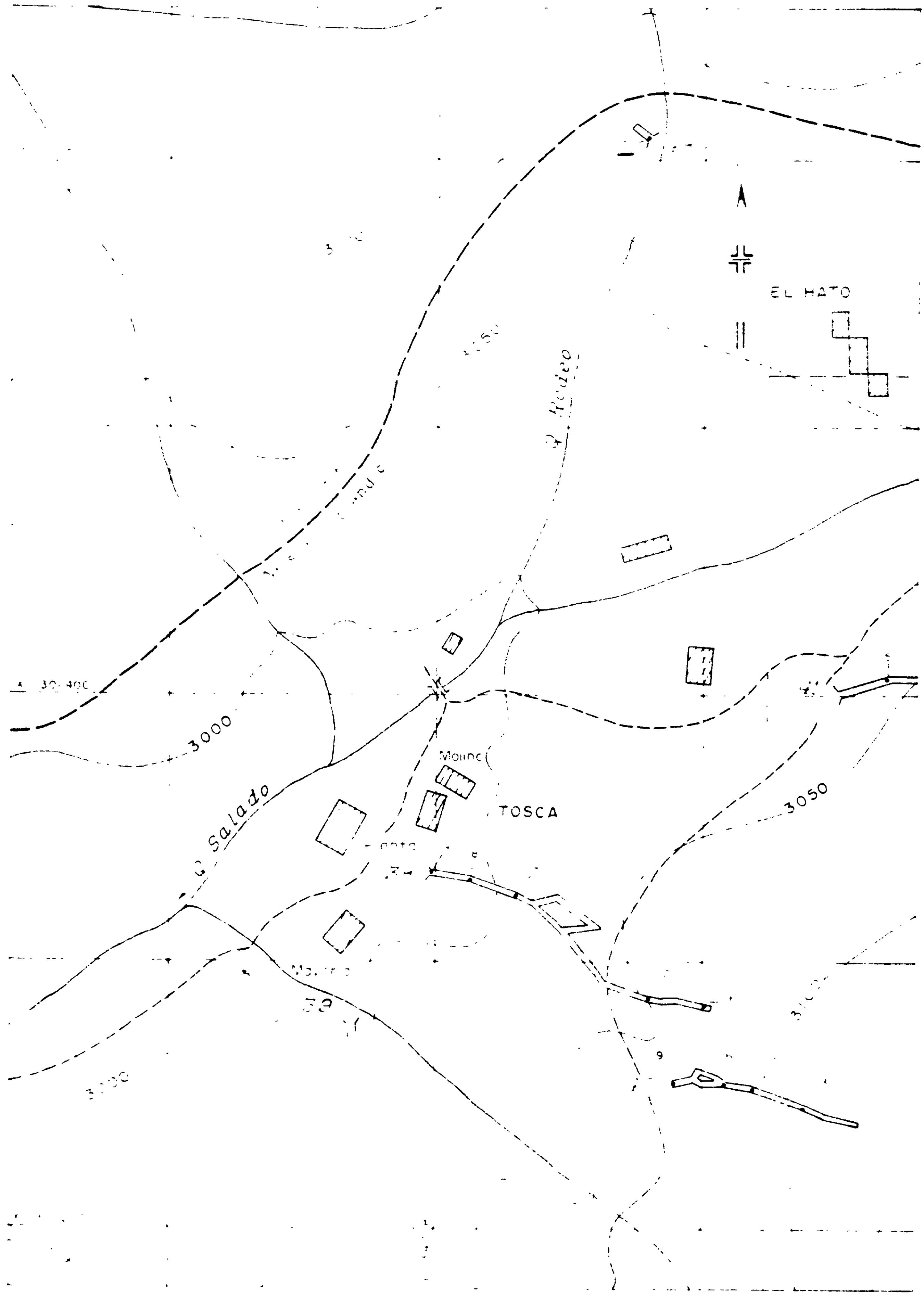


ANALISIS DE MUESTRAS
GRUPO TUNELES TROMPETEROS - LA ELSI

Vetas
GRUPO III

No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel 18 - La Elsi - Elevación 2991 metros						
18-1	trazas	4.50				
Tunel 20 - La Elsi - Elevación 3007 metros						
20-1	1.00	3.00				
20-2	0.50	24.25				
20-4	trazas	2.50				
Tunel 21 - La Elsi - Elevación 3018 metros						
21-1	5.50	197.00				
21-2	trazas	6.00				
21-3	1.00	6.65				
Tunel 22 - Trompeteros - Elevación 3068 metros						
22-2	1.25	15.00				
22-3A	0.50	23.25				
22-3B	1.00	6.25				
Tunel 23 - Trompeteros - Elevación 3085 metros						
23-1	7.00	41.75				
23-3	3.50	12.75				
23-4	2.65	33.30				
23-5	1.15	35.30				
23-6	1.50	43.75				

No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel 24 - Tromperos - Elevación 3098 metros						
24-2	trazas	3.75				
Tunel 25 - Tromperos -Elevación 3092 metros						
25-2	1.50	15.75				0.50
25-3	0.80	6.50				0.90
25-6	21.00	trazas				1.00
25-7	trazas	66.00				1.05
25-8	0.50	31.00				1.10
25-9	4.50	79.25				1.00
25-10	7.50	8.75				0.70
25-11	3.25	28.00				2.00
25-12	trazas	13.75				
Tunel 26 - Tromperos -Elevación 3100 metros						
26-1	1.00	8.75				0.65
26-2	1.50	9.25				0.60
26-3	1.75	11.50				0.70
26-4	trazas	5.75				0.90
26-5	1.00	38.50				0.80
26-6	6.50	50.75				1.00
26-7	1.65	69.80				0.90
Tunel 27 - Tromperos - Elevación 3115 metros						
27-1	0.37	19.00				0.85
27-2	1.00	12.25				0.60
Tunel 35 - La Elsi - Elevación 2955 metros						


VETAS
GRUPO IV
EL HATO
Q. Rodeo
3000
Q. Salado
Molino
TOSCA
3050

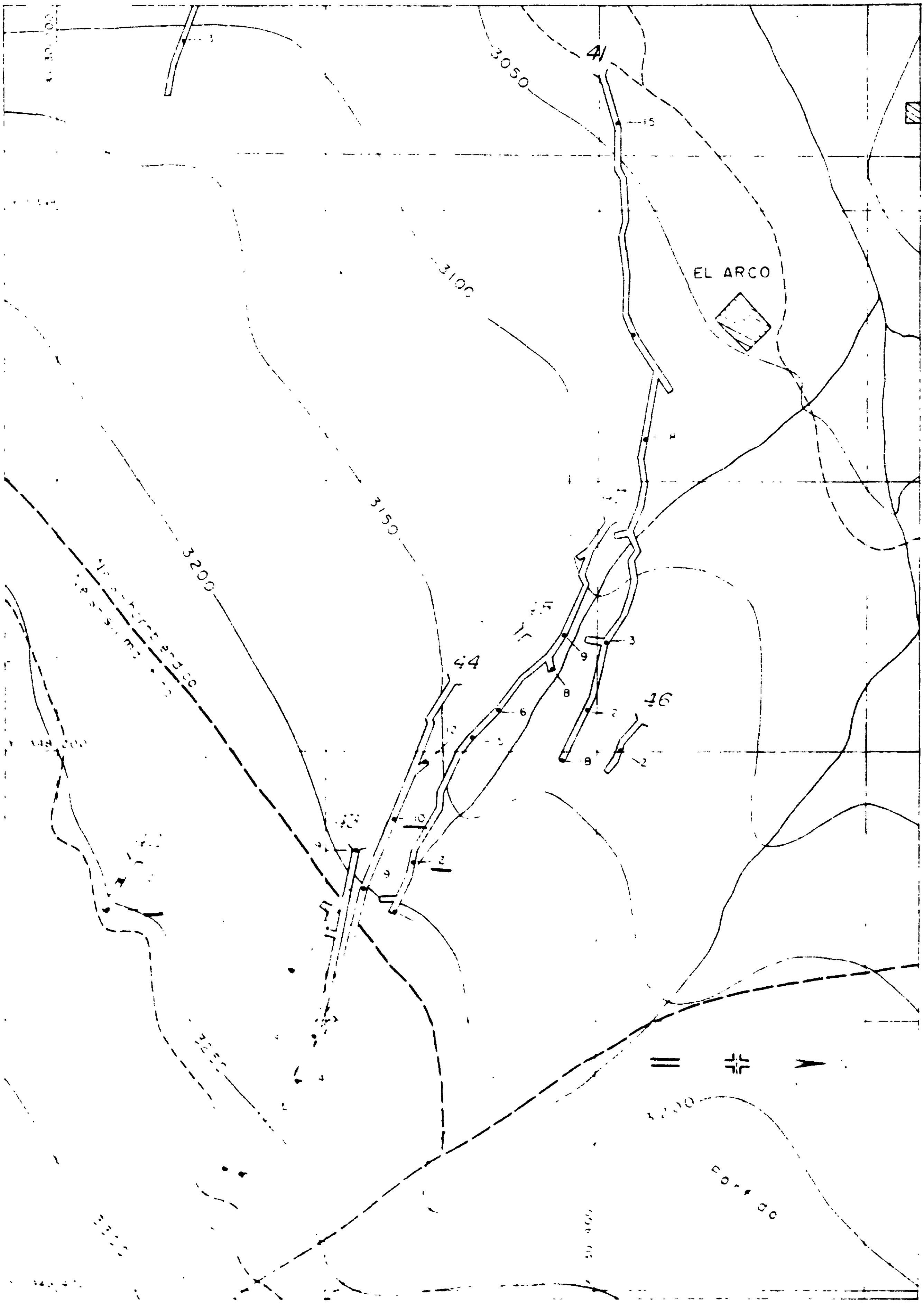
TUNELES DE MUESTRAS
GRUPO TUNELES LA TOSCA

Vetas
GRUPO IV

No. muestra	Au gr/Ton	Ag gr/Ton	% Cu	%Pb	%Zn	Espesor metros
Tunel 38 - La Tosca - Elevación 2996 metros						
38-1	2.50	119.75				0.80
38-2	1.00	10.50				
38-7	1.50	30.25				0.60
38-8	1.00	10.00				
38-9	trazas	63.50				
Tunel 40 - Puente Caido - Elevación 3062 metros						
40-3	1.25	14.75				1.00
40-5	1.00	3.75				0.80
40-6	0.50	11.75				
40-9	0.50	10.00				
Tunel 48 - - Elevación 3062 metros						
48-2	6.30	15.75				0.90

LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES LA FOSCA ORIENTAL

VETAS
GRUPO V



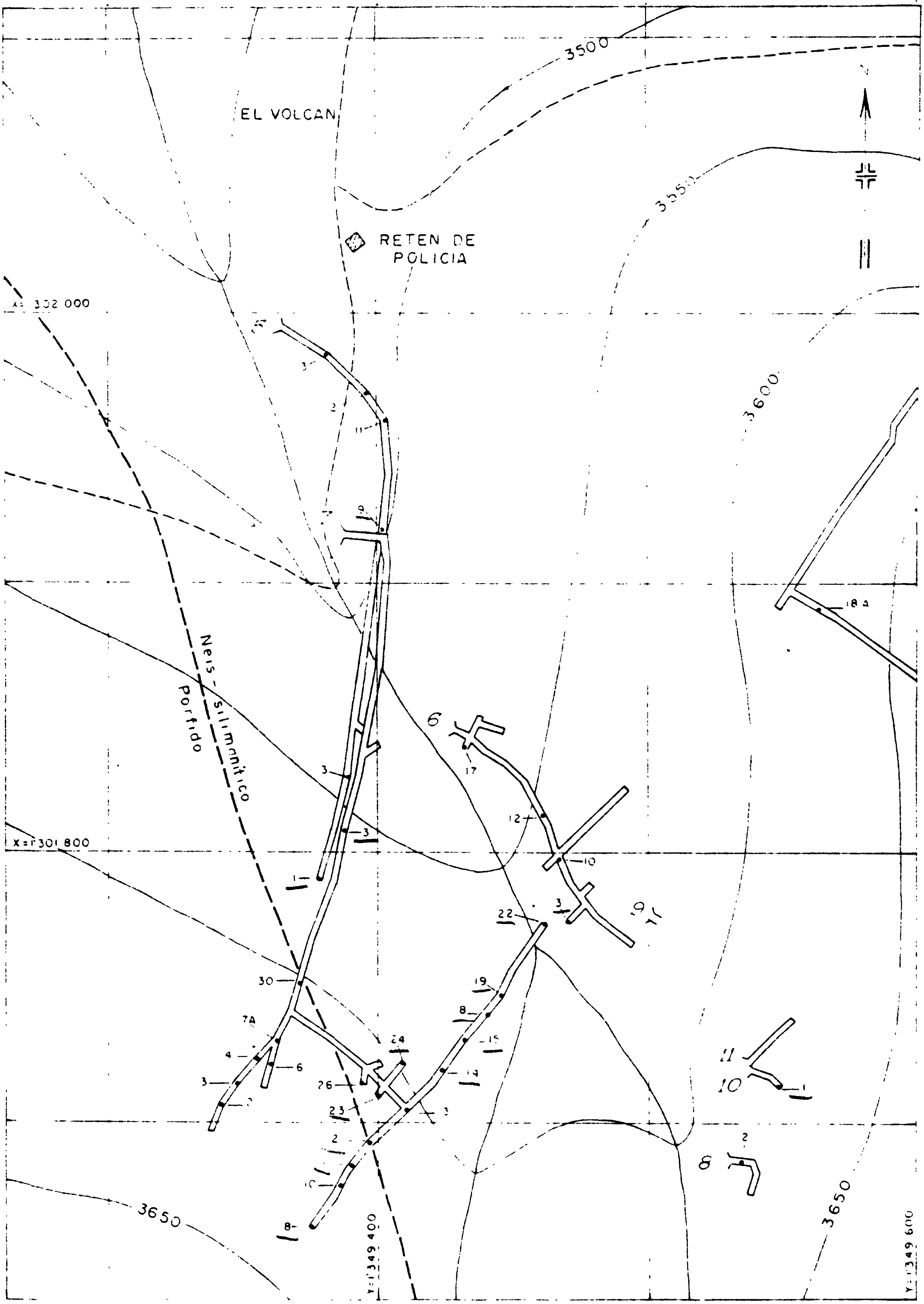
ANALISIS DE MUESTRAS
GRUPO TUNELES LA TOSCA ORIENTAL

Vetas
GRUPO V

No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel 41 - Salvación - Elevación 3030 metros						
41-1B	1.80	98.00				
41-2	1.50	30.00				1.50
41-3	2.25	13.00				
41-8	1.00	2.75				0.90
41-11	1.00	19.00				1.35
41-15	0.50	6.00				1.30
Tunel 42 - Las Perdices						
42-1	9.25	40.25				
42-3	4.75	5.75				
Tunel 43 - Locura - Elevación 3191 metros						
43-1	0.37	3.62				0.50
43-4	0.50	9.50				1.50
43-9	0.50	15.00				1.10
43-12	2.30	3.50				0.80
Tunel 44 - Cimbreadera - Elevación 3132 metros						
44-1	0.50	5.25				0.20
44-4	1.50	47.25				0.90
44-9	1.00	16.00				1.80
44-10	50.00	trazas				1.40
44-12	1.30	37.65				1.05
Tunel 46 - La Peñuela - Elevación 3112 metros						
46-2	9.00	59.50				
Tunel 47 - Italia - Elevación 3089 metros						
47-1	4.00	53.65				0.90
47-2	9.50	404.00				0.80
47-5	4.50	195.00				0.65
47-6	4.30	12.15				1.00
47-8	0.50	3.00				0.65
47-9	1.50	10.75				1.10

LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES EL VOLCAN

VETAS
GRUPO VI



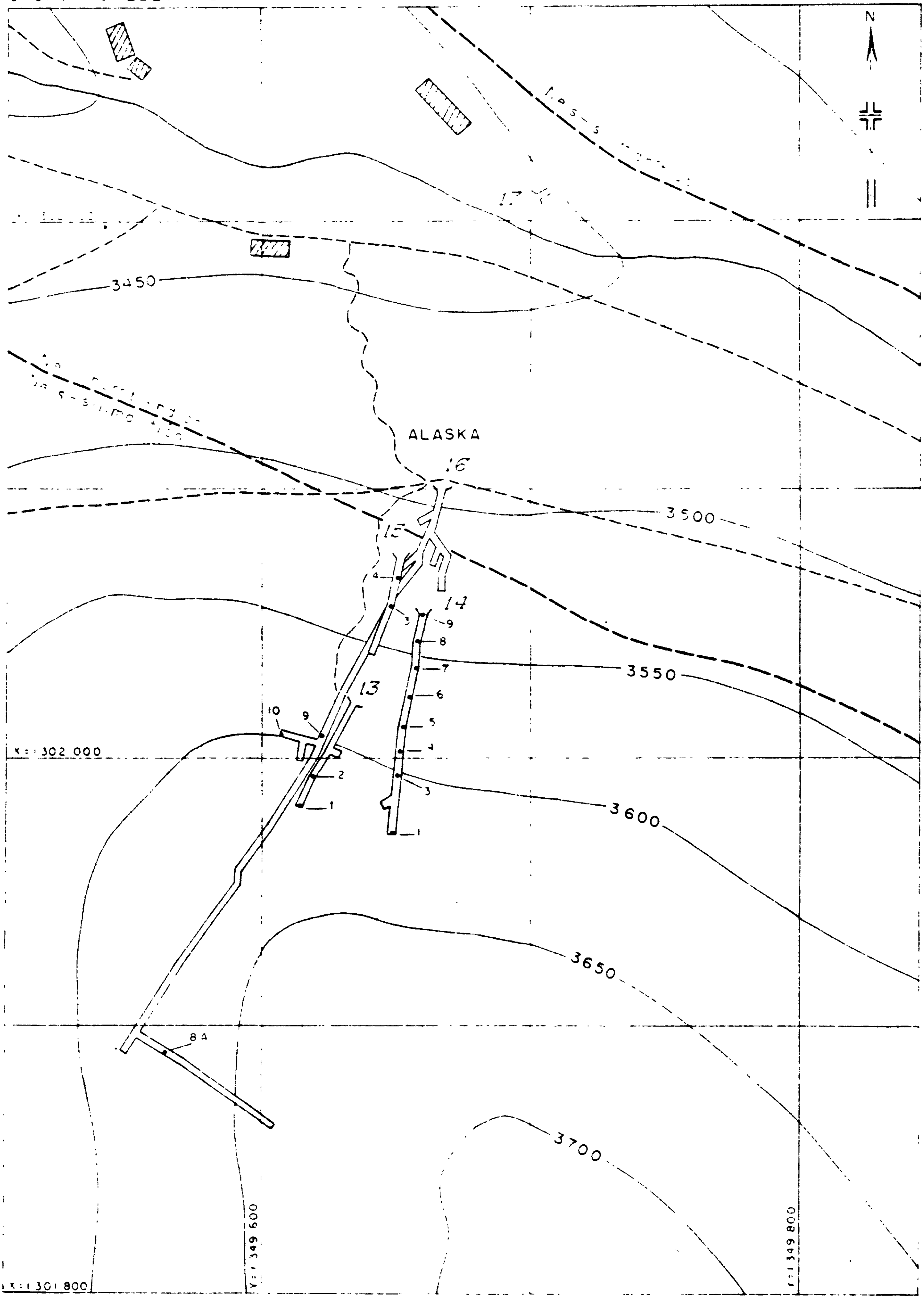
ANALISIS DE MUESTRAS
GRUPO TUNELES EL VOLCAN

Vetas
GRUPO VI

	No. muestra	Au gr/Ton	Ag gr/Ton	% Cu	%Pb	%Zn	Espesor metros
Tunel 5 -	El Volcan - Elevación 3455 metros						
	5-1	15.50	85.50	0.018	0.51	0.44	1.00
	5-3	3.00	7.00	0.007	0.95	0.08	1.15
	5-9	37.25	11.50	0.013	0.95	0.17	1.20
	5-11	trazas	9.00	0.015	0.91	0.14	
	5-12	trazas	3.50	0.018	0.70	0.20	
	5-13	trazas	3.50		0.74	0.17	
Tunel 6 -	El Volcán -Elevación 3522 metros						
	6-3	20.25	29.50	0.04	0.54	0.16	
	6-10	trazas	1.00	0.02	0.29	0.22	
	6-12	0.50	7.75	0.02	0.70	0.21	0.40
	6-17	3.25	16.75		0.62	0.31	0.30
Tunel 7 -	El Porras -Elevación 3493 metros						
	7-2	2.50	41.30	0.02	0.79	0.13	0.80
	7-3	19.65	44.00		0.74	0.13	
	7-4	2.00	4.25	0.01	0.78	0.13	
	7-6	4.75	18.25	0.02	0.74	0.26	
	7-7A	1.25	11.25	0.01	0.66	0.18	1.20
	7-8	57.80	1.50	0.03	0.66	0.08	0.90
	7-10	0.37	2.37	0.02	0.66	0.10	
	7-11	14.50	58.75	0.03	0.52	0.12	1.10
	7-12	76.75	14.25		0.25	0.17	
	7-13	5.25	8.00	0.02	0.58	0.17	0.80
	7-14	14.50	26.75	0.01	0.37	0.12	1.50
	7-15	76.00	116.30	0.02	0.41	0.14	1.20
	7-18	43.00	83.30	0.03	0.66	0.18	
	7-19	47.00	84.30	0.005	0.70	0.16	
	7-22	10.25	33.50	0.02	2.27	0.06	
	7-23	76.65	75.30	0.005	0.37	0.11	0.90
	7-24	7.25	8.50		0.83	0.12	1.30
	7-26	4.33	0.33	0.07	0.70	0.16	0.80
	7-30	1.00	4.00	0.04	0.41	0.14	
	7-33	1.50	8.65	0.01	0.62	0.16	1.25
Tunel 8 -	El Volcán - Elevación 3607 metros						
	8-2	trazas	trazas	0.02	0.82	0.17	
Tunel 10-	El Volcán - Elevación 3610 metros						
	10-1	87.50	55.00	0.023	0.58	0.23	1.00

LOCALIZACION DE MUESTRAS ANALIZADAS
GRUPO TUNELES ALASKA

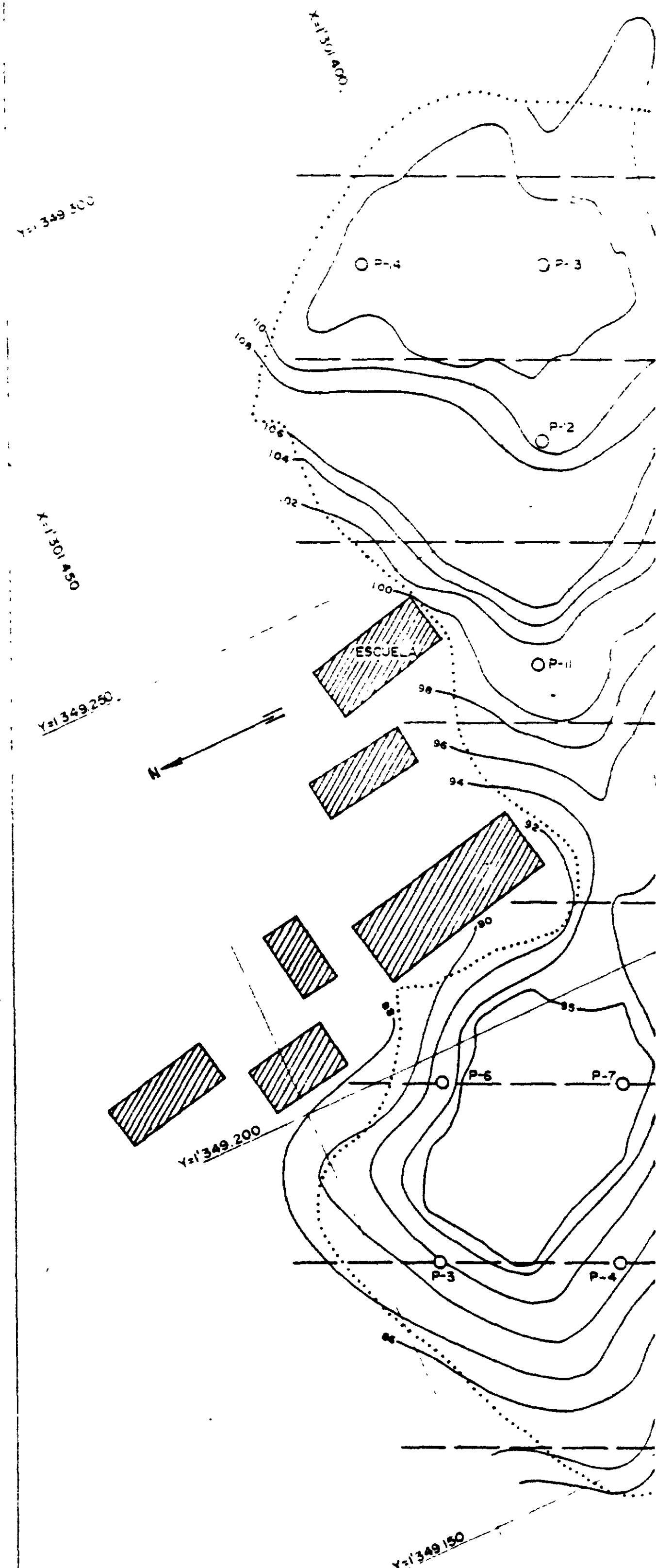
VETAS
GRUPO VII



ANALISIS DE MUESTRAS
GRUPO TUNELES ALASKA

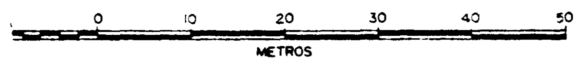
Vetas
GRUPO VII

No. muestra	Au gr/Ton	Ag gr/Ton	%Cu	%Pb	%Zn	Espesor metros
Tunel 13 - Alaska - Elevación 3567 metros						
13-1	0.75	12.75	0.01	0.41	0.08	
13-2	trazas	8.25		0.58	0.11	
Tunel 14 - Alaska - Elevación 3537 metros						
14-1	0.37	20.50	0.028	0.49	0.17	0.65
14-3	2.00	2.50	0.018	0.79	0.18	
14-4	0.87	5.62	0.068	1.53	0.18	
14-5	1.75	24.50	0.005	0.88	0.18	0.65
14-6	1.50	7.75	0.013	0.93	0.13	
14-7	0.50	25.50	0.025	0.79	0.16	0.65
14-8	trazas	9.00	0.017	0.91	0.22	
Tunel 15 - Alaska - Elevación 3518 metros						
15-3	trazas	7.00	0.015	0.70	0.21	0.75
15-4	0.13	5.25	0.012	0.62	0.16	
Tunel 16 - Alaska - Elevación 3498 metros						
16-9	trazas	4.00	0.02	1.03	0.21	
16-10	0.50	3.00	0.013	1.95	0.23	
16-18A	0.75	6.75	0.008	1.16	0.22	0.40



ANALISIS DE MUESTRAS OBTENIDAS POR LAS PERFORACIONES

Perforación Nº	Metros Perf	Au gr/Ton	Ag gr/Ton
P-3	4.10	1.75	8.50
P-4	5.30	1.75	13.50
P-6	4.80	10.00	22.66
P-7	4.50	11.75	25.00
P-9	3 0	2.16	83
P-11	6.60	7.25	14.25
P-2	7.30	9.83	18.50
P-13	6.80	12.33	22.66
P-14	3.35	4.25	19.50



INVENTARIO MINERO NACIONAL
ZONA III - BUCARAMANGA

COLAS DE LA MINA EL VOLCAN VETAS-MUNICIPIO DE CALIFORNIA DEPARTAMENTO DE SANTANDER

Levanto· Clemente Ropain U.   Dibujo A Ujueta L.

Abril de 1.968

LOCALIZACION DE LAS PERFORA
Las cotas son arbitrarias y la elevac
aproximadamente a 3300 metros sob

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Table 3.--Chemical analyses of gypsum samples from the Rosa Blanca Formation on Mesa de Los Santos.

14.204	0.04	15.38	11.08	2.01	0.10	0.50	36.18	0.06	34.46	74.09
14.205	0.02	11.38	17.71	7.07	0.34	1.16	31.15	5.77	25.06	53.88
14.206	0.02	16.95	7.46	2.85	0.14	0.36	31.59	2.68	37.73	81.12
14.207	0.03	18.31	3.89	2.86	0.10	0.90	32.52	0.05	41.15	88.47
14.208	0.01	15.31	11.67	2.27	0.05	1.00	32.51	2.05	34.55	74.28
14.209	0.02	19.38	2.13	3.56	0.06	1.09	30.62	0.31	42.77	91.96
14.210	0.05	18.94	3.96	1.30	0.05	0.65	32.16	0.21	42.36	91.07
14.211	0.06	18.40	3.96	3.43	0.10	1.00	31.52	0.74	40.68	87.46
14.212	0.02	17.70	4.67	6.23	0.10	1.15	29.44	0.55	40.06	86.12
14.213	0.02	18.83	2.87	3.93	0.06	1.04	30.72	0.00	41.99	90.28
14.214	0.03	18.66	4.41	2.68	0.04	1.06	30.47	0.30	42.05	90.41
14.215	0.01	18.30	4.52	2.80	0.06	0.74	31.59	0.69	41.02	88.19
14.216	0.03	14.20	14.22	4.66	0.08	1.42	30.75	2.80	31.68	68.11
14.217	0.02	17.75	6.85	1.84	0.22	0.63	29.66	2.38	40.19	86.41
14.218	0.05	14.84	8.98	7.82	0.21	3.61	26.97	4.09	33.19	71.36
14.219	0.01	20.43	0.90	0.20	0.00	0.30	32.21	0.11	45.76	98.38