Mineral Resources of Colombia

(other than Petroleum)

By QUENTIN D. SINGEWALD

GEOLOGIC INVESTIGATIONS IN THE AMERICAN REPUBLICS, 1949

GEOLOGICAL SURVEY BULLETIN 964-B

Prepared in cooperation with the Foreign Economic Administration

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1950

UNITED STATES DEPARTMENT OF THE INTERIOR

Oscar L. Chapman, *Secretary*

GEOLOGICAL SURVEY

W. E. Wrather, *Director*

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Washington 25, D. C. - Price $1.00. (paper cover)

CORRECTION

In the table of contents of Bulletin 964-B, page iv, credit for the section on gold was inadvertently given to Charles Mentzel. As stated on page 120, this section was reproduced, with slight modification, from a summary report written by J. K. Cathcart for FEA.

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MINERAL RESOURCES OF COLOMBIA (OTHER THAN PETROLEUM)

By QUENTIN D. SINGEWALD

ABSTRACT

The following report summarizes data acquired during 1942–45, in Colombia, by geologists and engineers of the Foreign Economic Administration, with whom the United States Geological Survey cooperated. Twenty-nine mineral commodities are considered, but the data for five of them are scant because they were of no interest to FEA personnel. Petroleum is not considered. Preliminary to a review of individual mineral commodities, résumés are given of the general geography and geology of Colombia and of the country's mining laws.

The principal mineral commodities, besides petroleum, produced in Colombia are (1) emeralds, gold, platinum, and silver, mainly for export, and (2) barite, cement, clay, coal, gypsum, salt, sand and gravel, silica, and stone, mainly for the domestic market. A large number of other mineral commodities are known in "raw" prospects, some of which may eventually become productive. Their distribution and apparent potentialities, as of 1945, are given. Factors unfavorable to mining are the ruggedness of the terrain, the scarcity of outcrops, and the very high transportation costs.

Present mining interest, apart from that in petroleum, is restricted to the west-northwestern half of the country, which includes the three main ranges of the Andes, two outlying ranges, intermontane valleys, and extensive coastal-lowland areas.

The eastern range of the Andes, named the Cordillera Oriental, is composed mainly of intensely folded and faulted strata of Cretaceous and early Tertiary age, but Jurassic-Triassic and even Paleozoic strata are fairly widespread. Several massifs of crystalline complex, partly or wholly pre-Cambrian in age, and a long belt of slightly metamorphosed early Paleozoic rocks also crop out in the Cordillera Oriental. The Cordillera Central is essentially a massif of metamorphic and plutonic igneous rocks that cannot be closely dated yet are regarded as pre-Cretaceous; however, sedimentary strata of Mesozoic age, with much locally interbedded igneous material, reach into and even across the southern part of the range. The western range of the Andes, named the Cordillera Occidental, is a little-known assemblage of (1) layered sedimentary rocks, in some places and in some sequences interbedded with an abundance of igneous rock, and (2) cross-cutting igneous batholiths, stocks, and hypabyssal bodies which have been tentatively assigned a Mesozoic age.

The outlying Santa Marta range is essentially a massif, containing a central batholith surrounded by metamorphic rocks of pre-Jurassic age, and the Serranía de Baudó is thought to be constructed of rocks analogous to those of the Cordillera Occidental. The principal coastal lowlands are areas of marine Tertiary strata, whereas the intermontane valleys are areas of nonmarine Tertiary strata.

Both marine and nonmarine strata as young as Miocene in age were strongly folded and faulted during the Andean revolution. Undeformed andesite flows, tuffs, and volcanic breccias in the mountains and sedimentary materials in the valleys and lowlands postdate the Andean revolution.

Antimony prospects are known in Caldas, Tolima, and Cauca. During 1939–45 three prospects yielded intermittently an aggregate output of 30 to 50 metric tons of stibnite, and other prospects doubtless could be exploited on a small scale, given adequate demand and price.

Chrysotile asbestos occurs in Antioquia, Nariño, and perhaps other departamentos. Although the deposits remain almost unprospected, they offer little hope of leading into large ore bodies.

Barite deposits have been exploited in Huila, Norte de Santander, Santander, and Tolima, and promising deposits have been discovered in Magdalena. In general, they are veins which individually contain no more than a few thousand metric tons of barite. The demand for barite, chiefly for oil-well drilling, is expected to increase, and the domestic output from mines favorably located with respect to transportation and markets likewise should increase. The consumption of barite during 1944 was about 3,000 metric tons, of which perhaps half came from domestic mines.

Bauxite has not been discovered in deposits that could be utilized as raw material for aluminum.

Cement was produced in 1945 by six plants, owned by five companies and located in four departamentos. The daily output averaged about 950 metric tons, valued at approximately $66,000, American currency. The demand probably would have been 1,500 metric tons per day if that quantity of cement had been available. Accordingly, five plants intended to expand capacity as soon as equipment became available, and two new plants were envisaged.

Chromite has been found at scattered localities in Antioquia. None of these, however, is promising.

Clay products, particularly roofing tile and brick, are made at countless localities scattered throughout the country, but no production statistics are available. In addition, small quantities of household ware, electrical insulators, and other products of intermediate to high-grade clay are made in Antioquia and other departamentos.

Coal is mined (1) in the Bogotá-Tunja region of Cundinamarca and Boyacá, (2) in the Amagá-Angelópolis-Titibirí region of Antioquia, and (3) in the Cali-Timba region of Valle del Cauca and Cauca, but a minor output comes from the western flank of the Cordillera Oriental in Cundinamarca, the Cúcuta-Pamplona region of Norte de Santander, the Ríosucio-Quinchía region of Caldas, and scattered localities in Santander. The total output during 1944 amounted to some 595,000 metric tons, valued at about $2,700,000. Reserves have not been reliably estimated but may be tentatively placed at 10 billion metric tons or more. The coal ranges from sub-bituminous to bituminous and locally will yield a low-grade coke.

Copper deposits are widespread, but probably not a single known outcrop offers reasonable hope, if explored, of leading into a large, commercially valuable body of ore. On the other hand, more intensive and systematic scouting, areal mapping, and prospecting in selected areas of abundant though lean mineralization conceivably could yield favorable clues. Moreover, several localities merit soil stripping to determine the surface dimensions and tenor of small mixed-sulfide lodes. Copper said to have been produced during colonial and later times apparently came from small shoots which may have been worked primarily for their gold content.

Emeralds have long been an important and famed mineral product of Colombia. More than 150 occurrences have been reported, but apparently only three—Muzo, Cosquez, and Chivor (Somondoco)—have attained an important output during precolonial, colonial, or postcolonial times. The Muzo mines have been consistently outstanding; worked intermittently, they have produced more than $1,000,000 worth of gem stones during some years. They were shut down in 1938, but mining was to have been resumed about 1948.

Gold aggregating nearly a billion dollars in value has been mined in Colombia since 1537. The output during 1944 amounted to 553,530 ounces, valued at approximately $19,370,000. Two-thirds came from placers, the remainder from lode mines. Antioquia contributed 59.3 percent of the total, and Nariño, the Chocó, Cauca, Caldas, and Tolima all but 2 percent of the remainder. The report discusses individually the leading mines in each departamento.

Gypsum is mined in Cundinamarca, Boyacá, Santander, Tolima, and Huila. In general, the deposits are stockworks of narrow seams and veinlets in shale; the aggregate gypsum content of the mined ground averages about 5 percent. At a few places, lenses containing a few thousand metric tons of gypsum are exploited. In 1944, the total output was about 13,000 metric tons of gypsum, valued at about $260,000. Most of the gypsum is used as a retarder in cement.

Iron ore has not been discovered in sizable deposits of superior grade. The most promising deposits are those of Paz del Río, Boyacá, where the reserves of siliceous oolitic ore, averaging some 46 percent iron, are not less than 20 million tons. Very small deposits of iron ore occur in Cundinamarca, and iron-rich laterites in Antioquia.

Lead prospects have been reported in six departamentos, but only two prospects in Santander and one in Caldas merit consideration as possible sources of ore for the domestic market and none seems promising as a possible source of ore for export. Perhaps 1 metric ton of galena concentrate per day could be recovered from a large gold mine in Antioquia, given adequate financial inducement. The consumption of lead in Colombia during 1944 may be roughly estimated as more than 1,000 metric tons.

Manganese prospects are decidedly unpromising. Two in Caldas could perhaps produce, at high cost, very small tonnages of hand-sorted ore averaging about 40 percent manganese.

Mercury deposits at Quindío (Bermellón), west-central Tolima, are the only ones known to have commercial possibilities. Their output in the past may have aggregated 5,000 to 10,000 metric tons of ore, whose grade remains unknown. Certain geological possibilities, explained in this report, offer reasonable hope for a modest production in the future.

Mica of excellent quality, both muscovite (white) and phlogopite (amber), may be procured in size 6 and in larger sizes at many places. However, neither variety could be profitably exploited under the conditions and prices prevailing in 1943–44.

Molybdenum prospects are scattered through six departamentos, being most numerous in Tolima. Their abundance suggests a metallogenic province in which commercial ore bodies could be expected, but none of the known showings of molybdenite offers promise of readily leading to either a single large deposit or a cluster of small deposits.

Optical calcite has been procured from one deposit, in Cundinamarca, which yielded 120 pounds of commercial material before being mined out. Other prospects are decidedly unpromising.

Platinum is mined from placer deposits, where it is associated with gold. Although at least very small amounts of platinum accompany gold in all placers

along streams draining the western slope of the Cordillera Occidental, a platinum-gold ratio in excess of 1:20 is found only along the drainage of the Río San Juan north of latitude 4°50′ N. Accordingly, more than 99 percent of Colombia's platinum output is derived from the Chocó, where dredges of the Cía. Minera del Chocó-Pacífico account for 50 to 70 percent and primitive native mines nearly all the remainder. The output during 1944 totaled 34,304 ounces, valued at $950,000.

Quartz crystals were procured during 1942–44 from Boyacá, Antioquia, and several other departamentos. A total of 2,430 pounds was shipped, of which 1,503 pounds, valued at $7,870, was accepted. The crystals were derived from small lodes which, in general, must be exploited by underground mining in hard rock. Therefore the aggregate cost of production greatly exceeded the value of the crystals recovered. The report lists six regions from which an aggregate output not exceeding 1,000 pounds of acceptable crystals per year doubtless could be attained at a cost 5 to 10 times their value according to 1944 prices.

Salt is derived in Colombia from rock salt mines, saline springs, and marine salinas. The output during 1943 totaled some 108,000 metric tons of salt, including an estimated 77,000 metric tons contained in 25,750,000 decaliters of brine. The aggregate value of the mine products sold was $3,280,000. The rock salt mines are in Cundinamarca and Meta; the principal saline springs are in Boyacá and Cundinamarca; and the principal marine salinas are in Guajira. The rock salt occurs in the form of "stocks," as a "hybrid" of halite and black shale.

Silica for the manufacture of glass at factories in Antioquia, Caldas, and Cundinamarca is procured mainly from sandstones of Upper Cretaceous and Eocene age, but the Caldas factory also utilizes milky quartz.

Silver is mined only as a byproduct of gold. A total of 167,614 ounces, valued at about $87,000, was recovered in 1945.

Stone, sand, and gravel are procured locally, as needed, throughout Colombia. The material most commonly used as concrete aggregate and road metal is gravel at Cali, Cúcuta, Ibagué, Manizales, Medellín, Neiva, Pereira, and Popoyán; crushed sandstone at Bogotá and Tunja; crushed limestone at Barranquilla and Cartagena; and crushed igneous or metamorphic rocks at Pasto and Santa Marta.

Sulfur occurs in very small deposits, formed by fumaroles and springs in proximity to volcanoes of recent age, in Nariño, Cauca, and Tolima. The deposits have been exploited only to a very small degree; apparently they contain no substantial reserves.

Zinc prospects are scattered mainly in Caldas, Cundinamarca, and Tolima. Near Junín, Cundinamarca, is a prospect offering reasonable promise of an ultimate recovery not exceeding a few tens of thousands of metric tons of hand-sorted ore averaging about 60 percent zinc. Boulders similar to the ore at Junín have been found near La Vega, Cundinamarca. There is also a possibility of recovering sphalerite where it occurs as a minor constituent of gold lodes, particularly at Segovia, Antioquia, and at Marmato, Caldas. At Segovia, 1 to 2 metric tons of concentrate per day doubtless could be procured, given adequate financial inducement.

INTRODUCTION

SCOPE OF REPORT

The data summarized herein were acquired during 1942–45 by the Metals and Minerals Division of the Foreign Economic Administra-

tion's mission to Colombia. The mission concerned itself primarily with strategic minerals, but for various reasons it also made reconnaissance surveys of certain nonstrategic commodities such as coal, cement, and salt. The mission did not concern itself, however, with clay, sand and gravel, silica, stone, or petroleum; therefore, the first five of these are discussed only briefly, and petroleum is not considered at all. For a summary of the petroleum geology and resources of Colombia, together with a list of references to earlier publications, the reader may consult an article by J. L. Anderson.[1]

The resource picture given in ensuing sections on individual commodities applies to the early part of 1945. It will of course be modified by exploration and development at active mines, by exploration at "raw" prospects, by the discovery of new prospects, and by systematic scouting and geologic mapping in selected areas.

STATUS OF MINING AND PROSPECTING IN COLOMBIA

The principal mineral commodities, apart from petroleum, that have been mined in Colombia during the decade ending 1944 are here listed, together with the approximate quantity and value of the output during either 1944 or the last preceding year for which statistics were available to the author:

Principal minerals (other than petroleum) produced in Colombia, 1934–44

	Approximate output	
	Quantity	*Value in U. S. dollars*
Barite (1944 consumption)	2,700 metric tons	10,000
Cement (1944)	250,000 metric tons	6,500,000
Clay	(?)	(?)
Coal (1944)	595,000 metric tons	2,700,000
Emeralds	(1)	(1)
Gold (1944)	553,530 ounces	19,370,000
Gypsum (1944)	13,000 metric tons	260,000
Mica	Bulk samples only	
Optical calcite (1944 total)	120 pounds	850
Platinum (1944)	34,304 ounces	950,000
Quartz crystal (1942–44 total)	2,430 pounds	7,900
Salt (1943):		
Brine (estimated salt content)	77,000 metric tons	2,040,000
Rock salt	5,257 metric tons	110,000
Refined salt	25,586 metric tons	1,130,000
Sand and gravel	(?)	(?)
Silica	(?)	(?)
Silver (1944)	197,321 ounces	88,300
Stone	(?)	(?)

[1] Mines inactive since 1938; sales from accumulated stock pile.

Emeralds, gold, optical calcite, platinum, quartz crystal, and silver represent high-value commodities which, with petroleum, are produced mainly for export. Barite, cement, clay, coal, gypsum, salt,

[1] Anderson, J. L., Petroleum geology of Colombia, South America: Am. Assoc. Petroleum Geologists Bull., vol. 29, pp. 1065–1142, 1945.

sand and gravel, silica, and stone are produced for the domestic market. The output of the latter group is small in Colombia as compared with production in more populous and more industrialized countries. Nevertheless, a good start has been made, and the number and quantity of minerals mined for the domestic market should gradually increase as the country becomes more industrialized. Excessively high transportation costs within Colombia automatically protect mines located near domestic markets but hamper the development of mining for export.

A large number of mineral commodities that are not listed in the foregoing table occur in "raw" prospects, and a few commodities, such as antimony, asbestos, iron ore, mercury, and sulfur, have actually been produced in insignificant to small quantities. As would normally be expected, many of these prospects appear to be worthless, but they are briefly described in order to save others the time-consuming task of tracking them down, examining them, and appraising them.

The FEA procedure for acquiring information on undeveloped prospects varied according to the urgency of the demand for the particular commodity involved. In general, a list of known and alleged prospects was compiled—first by canvassing the literature, unpublished data made available by the Servicio Geológico Nacional, the records of mining companies, and information volunteered by promoters; then by seeking out persons who might be reluctant to divulge the location of prospects; and finally by active scouting within selected areas. Many prospects could be rejected on the basis of specific information supplied either by non-FEA personnel or by FEA mineral scouts who made preliminary inspections. The remaining prospects were examined in the order of their importance and accessibility. At quartz crystal, mica, and optical calcite prospects, soil stripping was resorted to where needed for a decisive preliminary appraisal of potentialities; the owners of favorable prospects were then accorded guidance in prospecting, development, and mining.

At many Colombian prospects, a mineral showing is exposed over an area not exceeding a few square meters or an alleged former showing is covered by a soil slide, whereas outcrops in the immediate vicinity are scarce or absent. At such prospects an examination yields nothing more than a decision as to whether soil stripping seems warranted. At some prospects, however, the soil has been stripped, small open-cuts excavated, and short adits driven. The least tangible prospects, in general not considered here, are alleged mineral showings whose locations are only vaguely known to the persons reporting them.

MAPS

Plate 5 is a map of part of Colombia, greatly generalized from the 1942 edition of the Map of the Americas, which in turn was compiled

from the 1:1,000,000 International Map of the World published by the American Geographical Society. Plates 6 through 10 and plate 12 show the locations of the principal mines and prospects of selected commodities.

Figure 2 and plate 11 set forth new contributions to the geology of the Quindío mercury deposits; figures 4 and 5 and plate 13 record pertinent geologic and mining data at the three principal quartz crystal deposits; and figure 3, a sketch of part of the Chocó, shows the main drainage pattern within the area of gold and platinum placers.

Several geologic maps made by the author in collaboration with members of the Servicio Geológico Nacional have already been published in Colombia. Reference to them is made at appropriate places in the text.

To supplement further the maps published herewith, use may be made advantageously of two generalized geologic maps. One is entitled "Mapa Geológico General de la República de Colombia" and was published in 1944, on a scale of 1:2,000,000, by the Servicio Geológico Nacional, Ministerio de Minas y Petróleos; it will be referred to as the 1944 geologic map of Colombia. The other is entitled "Geologic Map of South America," a preliminary edition of which was published in 1945, on a scale of 1:5,000,000, by the Geological Society of America; it will be referred to as the GSA geological map of South America. The final edition of this second map will include some revisions of the 1944 geologic map of Colombia that were shown on an unpublished 1946 version prepared by the Servicio Geológico Nacional.

The locations of towns, mines, and prospects mentioned throughout the text, except those shown on plate 5, are given by means of coordinates which refer to degrees and minutes of latitude north of the Equator and of longitude west of Greenwich. Thus they may be located by the reader either on plate 5 of this report or on larger-scale maps. The coordinates here given apply specifically to locations on the 1:1,000,000 sheets of the International Map of the World published by the American Geographical Society, from which the base for plate 5 was compiled. Colombian readers who may use the 1:2,000,000 Mapa de la República de Colombia, together with the 1:500,000 maps of individual departamentos published by the Oficina de Longitudes (Bogotá), must subtract 74°05′ from longitudes given in this report in order to obtain degrees and minutes of longitude east or west of Bogotá.

NOTE.—The primary political divisions in Colombia are departamentos, intendencias, and comisarías. Departamentos are analogous to the States of the United States; intendencias and comisarías may be compared to the Territories, the name indicating whether the chief executive is an intendente or a comisario. A list of primary political divisions follows:

Departamentos
Antioquia
Atlántico
Bolívar
Boyacá
Caldas
Cauca
Cundinamarca
Huila
Magdalena
Nariño
Norte de Santander
Santander
Tolima
Valle del Cauca

Intendencias
Chocó
Meta

Comisarías
Amazonas
Arauca
Caquetá
Guajira
Putumayo
Vaupes
Vichada

The secondary political divisions are municipios. They are analogous to counties in the United States but invariably bear the same name as the principal town, which also is the "county seat."

PERSONNEL AND ACKNOWLEDGMENTS

The FEA metals and minerals work in Colombia began in August 1942 and terminated in April 1945. At the outset, William Burns directed the work and the author served as chief geological adviser. After December 1943, when Burns returned to the United States, the author directed the work. The other geologists and engineers who participated were:

Name	*Address (1946)*	*Period of participation*
James R. Balsley	U. S. Geological Survey.	Mar. 1943–July 1943.
Gilberto Botero Restrepo	Servicio Geológico Nacional.	Sept. 1943–Apr. 1945.
James K. Cathcart	Medellín, Colombia	May 1943–Apr. 1945.
Christopher E. Dixon	Bogotá, Colombia	Oct. 1944–Feb. 1945.
Louis Gence	Catavi, Bolivia	Apr. 1944–July 1944.
Walter E. Hammond	U. S. Tariff Commission.	Mar. 1943–Feb. 1944.
George R. Leland	Medellín, Colombia	Feb. 1943–Sept. 1944.
W. D. Longan	Cali, Colombia	Sept. 1942–Jan. 1943.
William T. Pecora	U. S. Geological Survey.	Mar. 1943–May 1943.

The field data and FEA reports of all these men have been incorporated into this report. Therefore, except to name the person or persons who contributed most of the information on specified mines, prospects, or groups of prospects, no further citations to them are made.

Some of the information procured by FEA mineral scouts also is utilized in this report. The contributors are Eliécer Lugo M., Jorge Reyes, and Eduardo Rengifo, all of Cajamarca. They are miners who were employed to assist the FEA technical personnel and to do independent scouting, as assigned.

The vast amount of information, assistance, and other aid rendered by officials of the Colombian Government, by private citizens of Colombia, and by American mining and petroleum personnel residing in Columbia is most gratefully and cordially acknowledged.

Indeed, the number of persons who substantially aided the mission is so great that only the outstanding ones may be mentioned here.

To the Ministerio de Minas y Petróleos the mission is indebted for innumerable and continuing services—particularly to the Servicio Geológico Nacional, directed by Dr. Benjamín Alvarado, and to the Laboratorio Químico Nacional de Análisis e Investigación, directed by Dr. Jorge Ancízar Sordo. The mission likewise is grateful for the leave of absence granted Dr. Gilberto Botero Restrepo from the Servicio Geológico Nacional in order that he might participate directly in the FEA work.

To the dean and the geology department of the Facultad Nacional de Minas, in Medellín, the mission is indebted for much information on Antioquia.

Innumerable private citizens of Colombia rendered great assistance. Particular mention should be made of Sres. Alfredo Londoño Mesa, Ignacio Martínez Cárdenos, and Santiago Trujillo Gómez, all of Bogotá, and Sr. Daniel Peláez Restrepo and Dr. Juan de la Cruz Posada, of Medellín.

Among the American mining and petroleum companies, the Cía. Minera del Chocó-Pacífico gave a great deal of aid, and personnel of the Timmins-Ochalí Co., Texas Petroleum Co., Richmond Petroleum Co., American Metals Co., and several smaller organizations furnished invaluable assistance. Mention also is made of the cooperation and information given by the Frontino Gold Mines, Ltd., a British company.

The author wishes to express his appreciation of the splendid official cooperation and support given by the FEA metals and minerals branch, whose technical work was under the direction of Dr. Alan M. Bateman in Washington, and by members of the American Embassy in Bogotá and of the American consulates, particularly in Medellín and Cali.

GEOGRAPHY AND GEOLOGY

TOPOGRAPHIC FEATURES

Colombia may be divided physiographically into two major provinces. The first includes the mountain ranges, intermontane valleys, and coastal lowlands of the west-northwestern half of the country; the other includes the plains of the east-southeastern half. Approximately 98 percent of the population and essentially all transportation facilities, manufacturing, and mining are in the west-northwestern, or Andean, province. (See pl. 5.)

Three ranges, from east to west the Cordillera Oriental, Cordillera Central, and Cordillera Occidental, comprise the backbone of the

Andes. The first two are separated by the Río Magdalena, the last two by the Ríos Cauca, Patía, and Guaitara, respectively, from north to south. Each range has one or more snow-clad peaks, which attain altitudes ranging from 4,800 to 5,800 meters (15,700 to 19,000 feet). South of latitude 1°45′ N., the Cordillera Oriental coalesces with the Cordillera Central. North of latitude 7°15′ N., the Cordillera Oriental forks into a western range that continues northward as far as the Guajira Peninsula, northwest of Lake Maracaibo, and an eastern range that curves into Venezuela to the south of Lake Maracaibo. The northern end of the western range is locally called the Sierra de Perijá.

Standing as outliers of the main ranges are the Sierra Nevada de Santa Marta, on the northern coast east of the Río Magdalena, and the Serranía de Baudó, on the western coast north of latitude 5°15′ N. The former, which attains an altitude of 5,900 meters, is separated from the Cordillera Oriental by the Ríos César and Ranchería; the latter, which has an altitude of only 1,800 meters, is separated from the Cordillera Occidental by the Ríos Atrato and San Juan.

The Colombian mountains are extremely rugged. Commonly, there are narrow divides between gorges several hundred to several thousand meters deep, and the intervening slopes have angles of 25° to 60°. Despite their steepness the slopes retain a cover of soil and vegetation. This vegetation consists of dense brush and timber, except in local tracts cleared for crops or pasture and in paramos which lie above the timber line.

To the north of the Andean mountain chain, across Magdalena, Atlántico, and Bolívar, is an extensive lowland characterized by swampy jungle areas, grassy plains, and ranges of hills that rarely attain altitudes of more than a few hundred meters. This lowland extends up the principal river valleys as embayments—for example, up the Magdalena Valley to La Dorado (lat. 5°27′ N., long. 74°40′ W.), and up the Cauca Valley to Caceres (lat. 7°35′ N., long. 75°21′ W.). Another extensive tropical lowland extends southward from the Gulf of Urabá, along the Ríos Atrato and San Juan, and then along the Pacific coast to Ecuador. By contrast, the Guajira Peninsula is an arid plain from which isolated hills rise to altitudes rarely exceeding a few hundred meters.

To the east-southeast of the Cordillera Oriental is a vast low plain that is drained by tributaries of the Amazon and Orinoco Rivers. The plain is grass-covered to the northeast and timber-covered to the southwest.

ECONOMIC GEOGRAPHY

Colombia is dominantly an agricultural country, but precious metals, emeralds, and petroleum are important export commodities, and an

excellent start has been made in producing minerals and manufactured goods for the domestic market.

Transportation costs are excessively high. This retards mining and manufacturing for export but automatically protects mines and factories that produce for local markets. Although airplane service is available between a number of points, including several of the mines, the main arteries of travel are the railroads, the highways, and the lower courses of several large rivers. Railroads and highways are costly to build and, during the rainy season, difficult to maintain. Reaching out from the railroads and highways are trails, which provide the only local access to most rural areas. These trails in general are tortuous and steep, so that a mule or horse normally travels a distance equivalent to an air-line distance of only 1 or 2 kilometers per hour.

With a total of about 9 million inhabitants, the country has average population densities of nearly 24 persons per square mile in the west-northwestern province and less than 1 person per square mile in the east-southeastern province. However, the population tends to concentrate in the more desirable agricultural areas and in the immediate vicinity of towns and cities, and so most of even the west-northwestern province is very sparsely inhabited.

GENERAL GEOLOGY: ANDEAN PROVINCE

Neither a satisfactory account of the general geology of Colombia nor an adequate setting for local geologic details at specific prospects can be given, because many of even the salient features remain undeciphered. Nevertheless, a synthesis of published information provides a useful background for mining men who may be interested in the geologic features.

The east-southeastern province of Colombia is not considered here because it holds no present interest for mining, apart from petroleum. For the west-northwestern, or Andean, province, first a preliminary summary of the geology and then a brief review of the lithology, areal distribution, and structural relations of the principal rocks are given. For descriptive convenience, the rocks are divided into five main groups, each of which includes one or more of the units shown on the 1944 geologic map of Colombia and on the GSA geological map of South America. Best studied are the sedimentary rocks, which pertain directly to the search for petroleum, in the Magdalena Valley and in the Cordillera Oriental.

The west-northwestern half of Colombia is built of heterogeneous geologic elements having different histories. The Cordillera Oriental is composed mainly of intensely folded and faulted sedimentary strata that range in age from Cambrian to Miocene, but it contains several massifs of metamorphic and igneous basement complex that are partly

or wholly pre-Cambrian in age, a belt of slightly metamorphosed early Paleozoic rocks, and some intrusions of post-Jurassic igneous rocks.

The Cordillera Central, which may be regarded as the geological core of the Andes range, is essentially a massif of metamorphic and plutonic igneous rocks that stood as a land mass during most of the Tertiary and Cretaceous and perhaps even earlier times; however, sedimentary strata of Mesozoic and Tertiary age locally extend into and across the southern part of the range. The metamorphic rocks may include several sequences of different ages, but they can be dated assuredly only as pre-Cretaceous. The plutonic igneous rocks, according to Trumpy,[2] range in age "from Caledonian to post-Liassic, and more detailed surveys will be needed to distinguish the different intrusions." Dikes, sills, and other hypabyssal bodies of igneous rocks were intruded during Mesozoic, late Tertiary, and perhaps other times, and there were at least two periods of volcanism, Mesozoic and late Cenozoic.

Geological data concerning the Cordillera Occidental are particularly scant; probably widespread are (1) sedimentary rocks, in many places interbedded with an abundance of sills, flows, and pyroclastic material, and (2) cross-cutting igneous bodies of both acidic and basic rocks, all of which are assigned to the Mesozoic era on the 1944 geologic map of Colombia. Similar rocks may comprise most of the core of the Serranía de Baudó. Both ranges stood as land masses during Tertiary time and perhaps late Mesozoic time.

The Sierra Nevada de Santa Marta is essentially a massif of pre-Jurassic metamorphic rocks that surrounds a central batholith of uncertain age. The lowlands of the Andean physiographic province are areas of prevailingly marine Tertiary strata, but the middle and upper Magdalena and Cauca Valleys, as well as the upper Patía Valley, are areas of predominantly nonmarine Tertiary strata; both the marine and nonmarine strata of Miocene and older ages are strongly deformed.

PRE-CRETACEOUS METAMORPHIC AND PLUTONIC IGNEOUS ROCKS

Metamorphic rocks and intimately associated igneous rocks form massifs of basement complex in all the ranges, except possibly the Serranía de Baudó. The metamorphic rocks are not necessarily all of identical age, for they include a variety of facies which even in the same massif may show different grades of metamorphism. Some in the Cordillera Oriental are definitely pre-Cambrian, but the metamorphic rocks in most places cannot be assigned an age more precise than pre-Cretaceous. In like manner, some of the plutonic igneous

[2] Trumpy, Daniel, Pre-Cretaceous of Colombia: Geol. Soc. America Bull., vol. 54, p. 1286, 1943.

rocks of the Cordillera Oriental are pre-Cambrian, but the ages of most of the igneous rocks within massifs of basement complex remain uncertain.

Slightly metamorphosed strata—that is, slate, phyllite, very fine grained schist, and greenstone—occur outside of massifs. A crucial question in Colombian geology is whether any of these rocks are contemporaneous in age with the more highly metamorphosed rocks of the massifs.

CORDILLERA ORIENTAL

Cropping out in the Cordillera Oriental are three massifs of basement complex and, in addition, a belt of slightly metamorphosed early Paleozoic sedimentary rock.

The slightly metamorphosed rocks have been named the "Quetame series," which Trumpy [3] states is "not * * * a stratigraphic unit but a facies." They include phyllite, very fine grained chloritic and sericitic schists, quartzitic sandstone, conglomerate, and graphitic shale. These rocks, according to Trumpy, in places grade laterally into unmetamorphosed sediments of uppermost Cambrian or lowermost Ordovician age and upward into rocks of Upper Devonian or early Carboniferous age. The "Quetame" crops out along the eastern flank of the range, approximately from latitude 3°20′ N. to latitude 5°05′ N., and at a few places farther to the north.

The Macarena massif in the central and southern parts of the Cordillera Macarena (lat. 2°15′ N., long. 73°50′ W., to lat. 3°20′ N., long. 73°55′ W.), an outlying virgation of the Cordillera Oriental proper, is composed of igneous and metamorphic rocks of assured pre-Cambrian age. According to Trumpy,[4] the metamorphic rocks include mica schist, alkali feldspar (mostly microcline and perthite) gneiss, hornblende gneiss, amphibolite, and injection gneiss—with all gradations from sericite schist to granosyenitic gneiss. The igneous rock is mainly quartz-poor "granosyenite."

The Garzón massif comprises the core of the Cordillera Oriental from latitude 1° N. to latitude 3° N. The northern and central parts are composed mainly of a moderately fine grained to medium-grained quartz-mica gneiss into which an abundance of pegmatite has been erratically injected and intruded, but acid plutonic igneous rocks and other facies occur locally. The rocks almost certainly are pre-Cambrian, for according to Trumpy [5] "the Ordovician * * * covers apparently the north plunge of the Garzón massif." The southern part of the massif is assigned a pre-Cretaceous age on the 1946 version

[3] Trumpy, Daniel, op. cit., p. 1290.
[4] Trumpy, Daniel, op. cit., pp. 1282–1284.
[5] Trumpy, Daniel, op. cit., p. 1290.

of the geologic map of Colombia and so presumably is composed of rocks different from those of the northern and central parts.

The Santander massif, extending from latitude 6°30′ N. to latitude 9°40′ N., has in plan roughly the shape of a lens but is greatly indented by reentrants and by elongated islands of sedimentary rocks. Acid plutonic rocks in bodies ranging from mere blobs to batholiths predominate in three areas that comprise about half the massif, as shown by the 1944 geologic map of Colombia, whereas metamorphic rocks predominate elsewhere. At least near Ocaña (lat. 8°15′ N., long. 73°22′ W.), the prevailing igneous rock is quartz-poor. Pegmatites are abundant in metamorphic-rock areas. The metamorphic rocks include fine-grained and medium-grained quartz-mica schist, quartz-mica gneiss, injection gneiss, and other local facies; whether the gneisses are older than the schists has not yet been reliably determined. Near Bucaramanga, according to Trumpy,[6] Carboniferous strata overlap "granite" of the massif. Moreover, not more than 20 kilometers distant from the west-northwest border of the massif are Devonian strata that unconformably overlap unmetamorphosed "gray slates, arkosic sandstones, and fine arkosic conglomerates" which Trumpy [7] regards as probably Cambrian and Ordovician. Thus the metamorphic rocks of the Santander massif may be pre-Cambrian.

CORDILLERA CENTRAL

The Cordillera Central is essentially a complex massif of crystalline rocks bounded along the Ríos Magdalena and Cauca by Mesozoic and Cenozoic sedimentary rocks. However, the sedimentary rocks extend into the southern part of the range to crop out over considerable areas in Cauca, Nariño, and Putumayo; and late Cenozoic volcanic rocks, particularly along the highest parts of the range, cover six areas shown by the 1944 geologic map of Colombia.

The metamorphic rocks north of latitude 2°20′N. are mostly fine-grained mica and chlorite schists. The mica schist grades into quartz-rich and even quartzitic facies, and the chlorite schist into a non-schistose rock resembling graywacke. Although the mica and chlorite schists commonly occur together, one or the other may predominate in different regions. For example, chlorite schist is widespread in central Tolima, but scarce in Antioquia. Amphibole schist and gneiss have been reported at different localities; they are most abundant in a discontinuous belt along the western and northern borders of the Antioquia batholith, where they are associated with basic intrusive rocks, including serpentine. In east-central Antioquia, a magnesium-

[6] Trumpy, Daniel, op. cit., pp. 1287–1288.
[7] Trumpy, Daniel, op. cit., pp. 1291.

bearing marble is intercalated in mica schist. Scattered dikes of pegmatite and felsite cut the metamorphic rocks in most places, yet injection gneiss is scarce. Ordovician (?) graptolites have been reported [8] in shale or phyllite near Cristalina (lat. 6°25′ N., long. 74°35′ W.), Antioquia, but whether the surrounding mica schist is contemporaneous in age with, or older than, the shale has not been reliably determined.

The metamorphic rocks south of latitude 2°20′ N. are known only through scant descriptions of scattered areas. They crop out in discontinuous belts inasmuch as part of the range is covered by sedimentary strata. Facies similar to the metamorphic rocks farther north are said [9] to be common; in addition a graphitic rock, either a phyllite or a fine-grained schist, probably is widespread.[10] Grosse [11] states that all the metamorphic rocks antedate a nonfossiliferous sequence of strata, perhaps of Girón (Jurassic) age, that in turn antedate fossiliferous strata of early or middle Cretaceous age; however, Royo [12] postulates that metamorphic rocks of both Paleozoic and Mesozoic ages are present and that the latter include strata as young as early Cretaceous.

The principal bodies of igneous rock tentatively regarded as pre-Cretaceous are shown by the 1944 geologic map of Colombia. The Antioquia batholith, described by Botero Arango,[13] is composed of tonalite and related minor facies, has a quartz content averaging about 10 to 20 percent, and is regarded as post-Ordovician but pre-Cenozoic. The central Tolima batholith, along the eastern flank of the range, includes facies ranging from granite to diorite, but the prevailing rock megascopically appears to be a quartz-poor monzonite (or syenite [14]). The eastern part of the northern Huila batholith has been designated by White Uribe [15] as granodiorite. Elsewhere the plutonic rocks are less well known.

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[8] Botero Arango, Gerardo, Geología sobre el Ordoviciano de Antioquia: Rev. minería (oragno de la Asociación Colombiana de Mineros), vol. 17, nos. 97–98, p. 8255, 1940.

[9] Grosse, Emil, Acerca de la geología del sur de Colombia, I: Compilación de los estudios geológicos oficiales en Colombia, tomo 3, p. 55, 1935.

[10] Grosse, Emil, op. cit., p. 57; Royo y Gomez, José, Datos para la geología económica de Nariño y alto Putumayo: Compilación de los estudios geológicos oficiales en Colombia, tomo 5, p. 154, 1942.

[11] Grosse, Emil, op. cit., p. 59.

[12] Royo y Gomez, José, Datos para la geología económica del Departamento del Huila: Bol. minas y petróleos, nos. 121–144, p. 151, 1939–40.

[13] Botero Arango, Gerardo, Contribución al conocimiento de la petrografía del batholito Antioqueño: Rev. minería (organo de la Asociación Colombiana de Mineros), vol. 20, nos. 115–117, pp. 9318–9330, 1942.

[14] White Uribe, H. E., Departamento del Tolima, Estudio minero practicado en los Municipios de Ibaqué, Anzoátegui, y Quesada: Bol. minas y petróleo, tomo 13, nos. 73–78, map opposite p. 280, 1935.

[15] White Uribe, H. E., Informe sobre los estudios mineros practicado por el ingeniero H. E. White Uribe en el Departamento del Huila: Bol. minas y petróleo, tomo 12, nos. 67–72, p. 220, 1934.

Basic igneous rocks, including diorite, gabbro, pyroxenite, and serpentine, occur locally on the western flank of the range in Antioquia, Cauca, and Nariño.

OTHER RANGES

The only known massifs of pre-Cretaceous metamorphic and igneous basement rocks in the Cordillera Occidental, as shown by the 1944 geologic map of Colombia, are north of latitude 7° N., where the crystalline complex of northern Antioquia extends across the Río Cauca from the Cordillera Central and also forms a small outlier farther west. Other small massifs may eventually be found, however, for the bedrock of extensive areas remains unknown.

The metamorphic rocks of the Sierra Nevada de Santa Marta, according to Oppenheim,[16] include gneiss, mica schist, chlorite schist, amphibolite, quartzite, and phyllite. Their age is assuredly pre-Jurassic and probably pre-Cambrian. The metamorphic rocks in places are injected and transected by aplite and pegmatite. Concerning the igneous rocks, Trumpy[17] states:

> Very probably the central batholith is Paleozoic, similar to the Central Cordillera batholiths, with a predominance of biotite granites, hornblende granites, and granodiorites. Similar rocks were also observed at the west margin of the Santa Marta uplift intruded into a complex metamorphic series.

On the 1944 geologic map of Colombia, however, the central batholith is assigned a post-Jurassic age.

A metamorphic and igneous basement complex, according to White Uribe,[18] may constitute a very minor part of the core of the Serranía de Baudó.

PALEOZOIC SEDIMENTARY ROCKS

Paleozoic strata containing marine faunas have been identified at many scattered localities in the Cordillera Oriental and at one locality on the eastern flank of the Cordillera Central. Their occurrence and distribution are reviewed by Trumpy,[19] who concludes:

> An early Paleozoic (mainly Ordovician) geosyncline was probably present in the area of the East Cordillera, but its sediments were to a large extent greatly metamorphosed or eroded in later periods. Caledonian folding is indicated in the Perijá range.
>
> Thick Devonian, Carboniferous, and Permian marine deposits were folded in late Permian or more likely lower Triassic orogenic phases, and to a large extent they were eroded.

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[16] Oppenheim, Victor, Geología del Departamento del Magdalena: Compilación de los estudios geológicos oficiales en Colombia, tomo 5, p. 496, 1942.

[17] Trumpy, Daniel, op. cit., p. 1286.

[18] White Uribe, H. E., Informe geológico de Urabá: Bol. minas y ptróleo, tomo 4, nos. 19–20, pp. 66–67, 1930.

[19] Trumpy, Daniel, op. cit., pp. 1287–1297 and 1301–1302.

The Ordovician, together with some Cambrian, according to Trumpy, is represented by micaceous sandstone and quartzite, gray-black shale, brown and green micaceous shale, and limestone north of the Garzón massif and along the flank of the Cordillera Macarena; these strata grade laterally northward into the "Quetame series," composed mainly of phyllite and very fine grained schist. Arkosic and nonfossiliferous strata probably of the same age occur locally on the northwest flank of the Sierra de Perijá, and black shale containing Ordovician graptolites has been found near Cristalina, Antioquia. Nonred sandstone and shale, locally with minor amounts of limestone, represent the Devonian along the northwest flank of the Sierra de Perijá, near Floresta (lat. 5°52′ N., long. 72°55′ W.), and elsewhere; and brick-red shale of Upper Devonian or early Carboniferous age has been found at several places. The Carboniferous is represented by limestone with sandstone and gray, green, and pale-red shales near Gachalá (lat. 4°41′ N., long. 73°31′ W.); by gray, black, and red shales with sandstone and limestone near Bucaramanga; by gray and green shale with limestone along the northwest flank of the Sierra de Perijá; and by prevailingly red sandstone with shale and some limestone near Labateca (lat. 7°18′ N., long. 72°29′ W.). The Permian is represented by dolomitic limestone along the northwest flank of the Sierra de Perijá and perhaps by the uppermost parts of the Gachalá and Labateca sections.

Descriptions of rocks designated as Cambrian or Ordovician in the Cordillera Central to the east of Popayán, in Antioquia (apart from the shale near Cristalina), and along the north border of the Santa Marta range, as shown by the 1946 geologic map of Colombia and the GSA geological map of South America, were not available to the writer.

Very tentatively, and without fossil evidence, Grosse[20] assigned a Paleozoic age to a sequence that he named the Chita beds, which are prevailingly gray slate and locally phyllitic but contain minor amounts of quartzite and chert as well as interbedded basic volcanic tuffs and breccias. These beds, which crop out on both sides of the valley of the Río Patía in Cauca and Nariño, are assuredly pre-Cenozoic.

MESOZOIC SEDIMENTARY ROCKS

CORDILLERA OCCIDENTAL SUBPROVINCE

The Cordillera Occidental is shown by the 1944 geologic map of Colombia as a continuous belt of Mesozoic rocks which enclose several small massifs of basement complex, are intruded by half a dozen

[20] Grosse, Emil, Acerca de la geología del sur de Colombia, II: Compilación de los estudios geológicos oficiales en Colombia, tomo 3, p. 152 and areal geologic map, 1935.

stocks and batholiths of post-Jurassic igneous rocks, and are locally covered by very small areas of late Cenozoic volcanic rocks; the Mesozoic rocks are in part undifferentiated, in part assigned to the Cretaceous. The apparent simplicity of the range is not due to uncomplicated geology, however, but to an extreme dearth of information. Actually, the bedrock probably includes (1) scattered areas of pre-Cretaceous basement complex, (2) one or more sequences of pre-Cenozoic sedimentary rocks, which at places are interbedded with basic sills, flows, and pyroclastic rocks, (3) cross-cutting igneous bodies of different sizes, types, and ages, and (4) scattered cappings of late Cenozoic volcanic rocks.

The cross-cutting igneous rocks occur as stocks and batholiths and also as dikes and other hypabyssal forms. Not only acidic rocks, but also basic rocks that probably range in composition from gabbro to pyroxenite abound. The basic intrusive rocks doubtless are the source of the platinum which, at least in small quantities, accompanies gold in many streams that drain the western slope of the Cordillera Occidental all the way from northern Chocó to Nariño.

The sedimentary strata, together with interbedded igneous rocks, apparently accumulated in a geologic trough which extended eastward as far as the lower western slope of the present Cordillera Central from Antioquia to Cauca and, at least locally, still farther east in southwestern Colombia. Some of the sedimentary strata have few or no interbedded igneous rocks. Grosse [21] has mapped the Chita beds (Paleozoic?) at several places in southern Cauca and Nariño; Stutzer [22] reports dark shale, siliceous shale, and phyllite along the middle and lower western slope of the Cordillera Occidental at latitudes 3°40′ to 3°50′ N.; and Hubach [23] reports quartzite, shale, and chert, which locally exhibit evidence of slight metamorphism, at places in the western fork of the Cordillera Occidental north of latitude 7° N. and also in the Serranía de Baudó.

Sedimentary beds intercalated in an abundance of igneous rock occur at places. A sequence described by Stutzer [24] as diabase, diabase tuff, and diabasic sandstone prevails along the narrow eastern slope of the Cordillera Occidental in Valle del Cauca and northern Cauca and also crops out locally along the eastern border of the Cauca Valley in the same departamentos. Rocks presumably similar have

[21] Grosse, Emil, Acerca de la geología del sur do Colombia II: Compilaciôn de los estudios geológicos oficiales en Colombia, tomo 3, pp. 152–154, 1935.

[22] Stutzer, Otto, Acerca de la geología de la Cordillera Occidental entre Cali y Buenaventura: Compilación de los estudios geológicos oficiales en Colombia, tomo 2, pp. 42 and 48–51, 1934.

[23] Hubach, Enrique, Informe geológica de Urabá: Bol. minas y petróleo, tomo 4, nos. 19–20, pp. 65–66, 1930.

[24] Stutzer, Otto, Contribución a la geología del foso del Cauca-Patía: Compilación de los estudios geológicos oficiales en Colombia, tomo 2, p. 135, 1934.

been reported by Botero Arango [25] along the upper western slope of the Cordillera Central about at latitude 5°50′ N. Rocks that Grosse [26] assigned to his "porphyrite formation" crop out along the narrow eastern flank of the Cordillera Occidental in southern Cauca and Nariño, on both flanks of the Cordillera Central in Cauca, Nariño, and Putumayo, and along the western flank of the Cordillera Central in Antioquia.

The "porphyrite formation" of Antioquia is described by Grosse as epidotized and fractured flows, tuffs, and agglomerates of spilite, diabase, augite porphyrite, melaphyre, and keratophyre interbedded with subordinate amounts of dark shale, slate, and calcareous sandstone; scarce fossils found at two places were doubtfully assigned a middle Cretaceous age. The "porphyrite formation" of Cauca, Nariño, and Putumayo is described by Grosse as greenstones, consisting mainly of basic flows, tuffs, and agglomerate with intercalated chert and siliceous slate, whereas Royo [27] describes it as an epidotized and fractured sequence of very fine grained sandstone, locally having a pseudoporphyritic aspect, with intercalated chert, limestone, and porphyritic andesite. The rocks contain sparse and poorly preserved *Foraminifera.* Although believed by Grosse to overlie fossiliferous middle Cretaceous strata, the "porphyrite formation" of southwestern Colombia was assigned by the Servicio Geológico Nacional in 1946 to the Jurassic and Triassic. It may or may not be essentially equivalent to Stutzer's diabase sequence and to the "porphyrite formation" of Antioquia.

Along both sides of the Atrato Valley, Cretaceous strata may represent the earliest deposits of the Bolívar geosyncline (see "Tertiary sedimentary rocks"), inasmuch as ammonite fragments, alleged to be Cretaceous, were found by Hubach [28] at approximately latitude 6°36′ N., longitude 77°18′ W.

CORDILLERA ORIENTAL SUBPROVINCE

Concerning Triassic and Jurassic strata of the Cordillera Oriental and the Magdalena Valley, Trumpy [29] states:

> Marine Upper Triassic with strong affinities with the Peruvian Triassic has been found in the upper Magdalena Valley, but may have extended to the Caribbean coast. Marine Lower Jurassic is known only from the El Banco district.

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[25] Botero Arango, Gerardo, and Garces G., Hernán, Informe geológico del camino Bolívar-Quibdó: Rev. minería (organo de la Asociación Colombiana de Mineros), año 3, no. 28, pp. 1885–1886, 1934.

[26] Grosse, Emil, Acerca de la geología del sur de Colombia, I and II: Compilación de los estudios geológicos en Colombia, tomo 3, pp. 66–71 and 154–157, 1935; El Terciario carbonífero de Antioquia, pp. 53–55, Berlin, Dietrich Reimer (Ernst Vohsen), 1926.

[27] Royo y Gomez, José, La cuenca hidrográfica del Juanambú, Departamento de Nariño: Compilación de los estudios geológicos oficiales en Colombia, tomo 5, pp. 225–226, 1942.

[28] Hubach, Enrique, op. cit., p. 67.

[29] Trumpy, Daniel, op. cit., p. 1302.

Triassic and Jurassic are chiefly red beds with variable amounts of effusive and intrusive igneous rocks.

Marine Upper Triassic is represented southwest of Payandé (lat. 4°18′ N., long. 75°06′ W.) by gray limestone with intercalated brown, partly tuffaceous chert; the limestone is conformably overlain by red beds consisting mainly of porphyritic flows, tuffs, and volcanic breccias. Fossils from the black shale above red beds near the Boyacá-Santander border north of Tunja may also be Upper Triassic. Marine Lower Jurassic is represented by black shale and thin limestone in the lower part of a 2,600-meter sequence of red beds, containing interbedded acid flows, tuffs, and agglomerates, 45 kilometers south of El Banco (lat. 9° N., long. 73°59′ W.). Either Upper Triassic or Lower Jurassic is represented by black shale, which underlies greenish sandstone and shale interbedded with red and green porphyry and tuff, on the southwest border of the Santa Marta range.

A thin sequence of red beds, which constitutes a prominent and widespread stratigraphic unit in northern Colombia, commonly is called the "Girón series," a name that has recently been redefined by Dickey [30] and other authors. At the type locality, near Girón (lat. 7°04′ N., long. 73°11′ W.), is 2,000 meters of red and green sandstone, conglomerate, siltstone, and shale with no interbedded igneous rock. To the west and to the north of Girón, however, the "series" normally contains interbedded flows, tuffs, volcanic breccias, and perhaps sills. The amount of volcanic material, according to Trumpy,[31] "is subject to rapid change and is greatest on the flanks of the Santa Marta and the Cordillera Central, but even in the Perijá there are rhyolite and liparite flows." After reviewing the scant fossil evidence, Trumpy concludes that "the red beds of northern Colombia may * * * range from upper Triassic to Lower Cretaceous, but only the Lower Jurassic (Liassic) is well established."

The "porphyrite formation" of southwestern Colombia, as previously mentioned, is now assigned by the Servicio Geológico Nacional to the Jurassic and Triassic. Whether the trough in which it accumulated ever connected with the Girón basin is not yet known. The distribution of Jurassic and Triassic rocks in southern Colombia shown on the GSA geological map of South America is derived from the 1946 version of the geologic map of Colombia, which in turn was taken, in part, from a map by Royo.[32]

Cretaceous sedimentary rocks of the Cordillera Oriental and adjoining areas, including the Magdalena Valley, were deposited in the

[30] Dickey, P. A., Pre-Cretaceous sediments in Cordillera Oriental of Colombia: Am. Assoc. Petroleum Geologists Bull., vol. 25, pp. 1791–1792, 1941.

[31] Trumpy, Daniel, op. cit., p. 1300.

[32] Royo y Gomez, José, La cuenca hidrográfica del Juanambú, Departamento de Nariño: Compilación de los estudios geológicos oficiales en Colombia, tomo 5, map opposite p. 250, 1942.

so-called North Andean geosyncline, which in Colombia was bounded on the east by the Guayana shield, on the west by the Cordillera Central massif, and on the northwest by the Santa Marta massif. Because of uneven topography at the outset and differential subsidence during deposition, in detail the geosyncline was a group of connecting basins, and so the ages and facies of deposits vary from place to place. The stratigraphy has been summarized by Hedberg [33] and by Anderson.[34] Evidence to indicate that the Cretaceous deposition followed a late Jurassic crustal disturbance is summarized by Hedberg.[35]

The early Cretaceous, according to Hedberg,[36] is commonly represented by a thick sequence of shale, sandstone, and conglomerate which may in large part be nonmarine; however, fossiliferous marine shale and limestone persist locally through the entire section. At places, the sequence includes green and even mottled shales. In the central part of the Cordillera Oriental, early Cretaceous strata are referred by the Servicio Geológico Nacional to the Cáqueza formation,[37] which at its type locality is more than 5,000 meters thick and is composed mainly of black shale with subordinate sandstone and other rocks. Farther north, in the vicinity of the Santander massif, which probably remained a land area until late Barremian or Aptian time according to Hedberg,[38] early Cretaceous strata "are extremely variable in thickness and mostly represented by coarse clastics." The so-called Cocui sandstone is an example. North and east of the massif, the Uribante formation is composed of black and green shale, sandstone, limestone, and conglomerate and ranges in thickness from 1,000 meters to the vanishing point. In the Sierra de Perijá is 3,000 meters of feldspathic sandstone with interbedded conglomerate, siltstone, and calcareous beds. The early Cretaceous of southern Colombia remains almost undescribed; Hedberg [39] thinks it may be represented by conglomerate, sandstone, and black shale that crop out near Guadalupe (lat. 2°01′ N., long. 75°36′ W.), and Royo [40] assigns to it the lower part of a black shale, with intercalated chert, near Mocoa (lat. 1°08′ N., long. 76°38′ W.).

The middle and late Cretaceous are represented in Cundinamarca and Boyacá, according to a stratigraphic column published by the

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[33] Hedberg, H. D., Mesozoic stratigraphy of northern South America: 8th Am. Sci. Cong. [Washington, 1940] Proc., vol. 4, pp. 206–216, 218–220, and 222–224, 1942.

[34] Anderson, J. L., Petroleum geology of Colombia, South America: Am. Assoc. Petroleum Geologists Bull., vol. 29, pp. 1084–1091, 1945.

[35] Hedberg, H. D., op. cit., pp. 205–206.

[36] Hedberg, H. D., op. cit., pp. 209 and 211.

[37] Hubach, Enrique, La formación "Cáqueza," región de Cáqueza (Oriente de Cundinamarca): Compilación de los estudios geológicos oficiales en Colombia, tomo 6, pp. 25–26, 1945.

[38] Hedberg, H. D., op. cit., p. 210.

[39] Hedberg, H. D., op. cit., p. 209.

[40] Royo y Gomez, José, Datos para la geología económica de Nariño y alto Putumayo: Compilación de los estudios geológicos oficiales en Colombia, tomo 5, pp. 136–137, 1942.

Servicio Geológico Nacional,[41] by the Villeta formation of Hauterivian to Turonian age, the Guadalupe formation of Senonian age, and perhaps the lower part of the Guaduas formation, which is regarded as mainly Eocene and Oligocene. The Villeta, in places more than 2,000 meters thick, is dark shale with some interbedded limestone and sandstone. The Guadalupe, in places more than 1,000 meters thick, likewise is dark shale with interbedded sandstone and limestone, but along the crest and eastern slope of the range it contains an upper member of somewhat friable sandstone, chert, and cherty shale. The lower part of the Guaduas is a typical coal-measures sequence.

Corresponding rocks in the middle Magdalena Valley have been given a number of names by different oil-company geologists, and the published correlations remain somewhat confused. Wheeler[42] lumped the bulk of the Cretaceous strata under the term "Palmira series," which includes about 2,200 meters of dark shale, limestone, and chert; it may range from early to late Cretaceous in age. Above the "Palmira series" is the Umir formation—of latest Cretaceous age, according to Butler,[43] and composed of 900 to 1,200 meters of dark shale overlain by 300 meters of coal measures.

In northeastern Colombia, according to Hedberg,[44] the middle Cretaceous is represented by the Cogollo limestone, which is a gray, massive, rather coarsely crystalline limestone about 400 meters thick, and the overlying La Luna limestone, which is dark shaly limestone and limy shale about 300 meters thick. The late Cretaceous is represented by the gray fissile Colon shale, the overlying Mita Juan formation composed of sandstone, greenish-gray shale, glauconitic limestone, and ironstone, and the lower part of the Orocue formation, which is mainly a coal-measures sequence. The Cogollo and La Luna facies grade southward, Hedberg[45] states, along the eastern flank of the range in Norte de Santander and along the western flank of the range in Santander, into the Villeta facies. Details of the Cretaceous section in the Barco concession are given by Notestein, Hubman, and Bowler.[46]

In Huila, Cauca, Putumayo, and Nariño, Cretaceous rocks of the North Andean geosyncline crop out in both the Cordillera Oriental and the Cordillera Central. The generalized sequence, as given by

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[41] Informe del Ministro de Minas y Petróleos al Congreso Nacional en sus sesiones ordinarias de 1942, columnar section opposite p. 176, Bogotá, Imprenta Nacional, 1942.

[42] Wheeler, O. C., Tertiary stratigraphy of the middle Magdalena Valley, in Pilsbry, H. A., and Olsson, A. A., Tertiary fresh-water mollusks of the Magdalena embayment, Colombia: Philadelphia Acad. Nat. Sci. Proc., vol. 87, p. 21, 1935.

[43] Butler, J. W., Jr., Geology of the middle and upper Magdalena Valley: World Petroleum, vol. 10, no. 3, p. 97, 1939.

[44] Hedberg, H. D., op. cit., p. 212.

[45] Hedberg, H. D., op. cit., pp. 213–214.

[46] Notestein, F. B., Hubman, C. W., and Bowler, J. W., Geology of the Barco concession, Republic of Colombia, South America: Geol. Soc. America Bull., vol. 55, pp. 1173–1189, 1944.

Hedberg,[47] is (1) shale, sandstone, conglomerate, and tuff, (2) the 200-meter-thick Arabuco sandstone, of Hauterivian age, (3) strata of the Villeta facies, ranging from Barremian to Turonian in age, and (4) green porphyrite, tuff, agglomerate, ash, and some interbedded clay. The last is the green "porphyrite formation" which was originally regarded as post-Villeta but more recently has been assigned by the Servicio Geológico Nacional to the Jurassic and Triassic. In northern Huila, near Tello (lat. 3°04′ N., long. 75°08′ W.), according to Royo,[48] sandstone, chert, and limestone of the Guadalupe formation crop out.

Concerning the close of Cretaceous deposition, Hedberg[49] states that

> retreat of the Cretaceous sea appears to have been accomplished not only as a lateral shrinking in width but also as a gradual regression along the length of the geosynclinal axis northward and eastward to the opening of the basin into the eastern ocean. * * * Thus, in Perú, Ecuador, and southern Colombia, the sea appears to have retired in early Senonian time. * * * In the area of the central portion of the Cordillera Oriental of Colombia, coal swamp conditions were initiated in uppermost Cretaceous time and brackish-water and paludal deposits merge upward into early Tertiary beds of distinctly continental origin. In western Venezuela * * * intermittent marine conditions appear to have continued across the Cretaceous-Tertiary boundary.

TERTIARY SEDIMENTARY ROCKS

Marine Tertiary strata, according to Olsson,[50] extend from Panama eastward across

> the coastal region of northern Colombia to the Venezuelan border and southward along the west coast into Ecuador. * * * Embayments extend up the principal river valleys such as along the Magdalena and the Cauca where the beds pass into brackish- and fresh-water deposits. In the Cauca valley the Vijes limestone, a few miles north of Cali * * * is of probable late Oligocene age. * * * [The Vijes] limestones are marine and show the extent to which marine waters had penetrated southward along the Cauca valley from the coast.

Nonmarine Tertiary strata occur in the Magdalena and Cauca Valleys upstream from the marine embayments and, where not eroded, throughout the northern half of the Cordillera Oriental.

MARINE STRATA

The Tertiary strata of the northern or Caribbean zone, according to Olsson,[51]

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[47] Hedberg, H. D., op. cit., p. 215.

[48] Royo y Gomez, José, Contribución al conocimiento de la geología del valle superior del Magdalena (Departamento del Huila) : Compilación de los estudios geológicos oficiales en Colombia, tomo 5, p. 270, 1942.

[49] Hedberg, H. D., op. cit., pp. 223–224.

[50] Olsson, A. A., Tertiary deposits of northwestern South America and Panamá : 8th Am. Sci. Cong. [Washington, 1940] Proc., vol. 4, p. 250, 1942.

[51] Olsson, A. A., op. cit., pp. 250–251.

are of great thickness and generally strongly deformed. * * * They are in the main similar to those of Panamá, commencing with Upper Eocene foraminiferal limestones * * * followed by shales which may be partly Lower Oligocene. The Middle Oligocene is strongly developed in part of the Sinú valley where it consists principally of sandstones with conglomerates and coals [and] often with limestones. * * * In places * * * faunas * * * have been found which permit close correlation with the Middle Oligocene of Perú. These Oligocene beds are succeeded by [dark] shales * * * [which] at several places contain limestone lenses. The Miocene * * * is extremely thick and comprises several formations, some of which are of local development. * * * They consist generally of alternating sandstones and shales together with some coal. The Middle Miocene of Gatún is extensive and usually is highly fossiliferous. * * * [F. M.] Anderson was the first to show the presence of a stratigraphic break at the base of the Tubara corresponding to the Gatún unconformity of Panamá. * * * The Chorerra of Atlántico is probably Upper Miocene, while coral-reef limestone formations along the coast may be in part Pliocene.

A somewhat less generalized review of the stratigraphic sequence in northern Colombia is given by Anderson.[52]

The Tertiary strata of western Colombia were deposited in the Bolívar geosyncline, which is bounded on the east by the ancestral Cordillera Occidental and extended southward from the present Gulf of Urabá through the Atrato Valley, east of the Serranía de Baudó, and then along the coast as far as Ecuador. Marine deposition in this geosyncline, at least in the northern part, may have begun during Cretaceous time and continued through all of the Tertiary, but details of the stratigraphic sequence remain almost unknown. In the Urabá region, deformed clastic strata aggregate about 4,500 to 5,000 meters in thickness. Locally they contain fossil plants as well as marine faunas. Hubach [53] classifies these strata into five formations, of which one is assigned very tentatively to the Cretaceous, two to the lower Tertiary, and two to the upper Tertiary. The main unconformities are at the base of the lower Tertiary and between the two upper Tertiary formations. Along the coast south of Buenaventura, according to Olsson,[54]

the prevailing Tertiary formation * * * is formed of soft to slightly consolidated sands, and blue sandy shales which [eastward] become coarser and include beds of conglomerates. * * * The beds are lying nearly flat in the coastal section with dips increasing to 15 to 30 degrees in the interior. * * * On the Telembí they overlie, with marked unconformity, a series of hard, sedimentary tuffs and pillow lavas. * * * [The Tertiary formation] is definitely Miocene and * * * is tentatively considered as Upper Miocene.

Olsson also mentions Oligocene sandstone near Tumaco (lat. 1°50′ N., long. 78°46′ W.) and late Eocene or Oligocene rocks on Gorgona Island, off the coast of Nariño.

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[52] Anderson, J. L., Petroleum geology of Colombia, South America: Am. Assoc. Petroleum Geologists Bull., vol. 29, pp. 1092–1097, 1945.

[53] Hubach, Enrique, op. cit., p. 78.

[54] Olsson, A. A., op. cit., pp. 252–253.

NONMARINE STRATA

A thick sequence of fluvial, lacustrine, and estuarine strata which exhibit many lateral variations in lithology occupies the middle and upper Magdalena Valley, whereas marine strata prevail in the lower valley, north of El Banco (lat. 9°N., long. 73°59′ W.). The general stratigraphy of the nonmarine beds has been summarized by Wheeler,[55] Butler,[56] and Anderson.[57]

In the middle Magdalena Valley—that is, between El Banco and Honda (lat. 5°12′ N., long. 74°44′ W.)—the Lisama formation, composed of approximately 1,000 meters of mottled and gray shales, fine-grained sandstone, and a few nonproductive coal seams, overlies the coal measures of the very late Upper Cretaceous Umir formation. The Lisama may be latest Cretaceous or early Tertiary, or both. It is overlain disconformably by a thin, blue-gray, massive shale, which in turn is overlain by 1,000 to 2,000 meters of mottled and blue-green shales interbedded with sandstone, the latter increasing in abundance upward, at the top of which is a zone containing late Eocene fossils. The Oligocene is represented by two "series," each of which contains a fossil zone at the top. The lower "series" is composed of blue-gray and mottled shale and sandstone, the upper "series" of mottled and red shales and sandstone. The aggregate thickness of Oligocene strata ranges from 1,000 meters to 3,000 meters, in general increasing both to the east and to the south. The Miocene is represented by a maximum of 4,000 meters of poorly sorted sandstone, conglomerate, and red to brown mottled shale, which locally contains silicified wood. These beds rest on the top of the Oligocene in some places and on older strata elsewhere. Concerning the entire Tertiary section of the middle valley, Wheeler [58] states:

> The large and consistent increase in thickness of sediments eastward in the basin is clear evidence of deltaic deposition. * * * The chief source of sediments was, therefore, from the east.

Wheeler [59] also states:

> Following the period of Miocene sedimentation * * * the strata were considerably folded, and the overlying Pliocene beds, called the Mesa formation, were deposited nonconformably upon them.

In the upper Magdalena Valley—that is, south of Honda—various names have been applied to Tertiary strata at different places, and detailed correlations remain confused. A proposed stratigraphic

[55] Wheeler, O. C., op. cit., pp. 26–39.
[56] Butler, J. W., Jr., op. cit., pp. 96–100.
[57] Anderson, J. L., op. cit., pp. 1099–1107.
[58] Wheeler, O. C., op. cit., p. 39.
[59] Wheeler, O. C., op. cit., p. 37.

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column, published by Butler,[60] shows the latest Cretaceous and the early Eocene represented by coal measures that grade upward into mottled, maroon, gray, and locally variegated shales, with interbedded sandstone and conglomerate; the late Eocene and Oligocene represented by variable proportions of coarse conglomerate, sandstone, and red, brown, and mottled shales; and the Miocene represented by conglomerate and coarse sandstone, with intercalated maroon and green shales, which locally contain silicified wood. The upper member of the Miocene sequence is characterized by an abundance of detrital andesitic material.

The coal measures, together with the overlying sequence of relatively fine grained clastic rocks, commonly are called the Guaduas formation or group. It crops out, not only along the Magdalena Valley, but also along the crest and eastern slope of the Cordillera Oriental at many places in Cundinamarca, Boyacá, and Santander. The coal measures of the Guaduas formation may be equivalent to the upper member of the Umir formation, and Guaduas beds above the productive coal seams may be equivalent to the Lisama formation of the middle Magdalena Valley. However, the Servicio Geológico Nacional classifies the Guaduas beds of the Bogotá-Tunja savanna as ranging from latest Cretaceous to Oligocene in age.

Prevailingly nonmarine Tertiary beds crop out at many places along the Cauca Valley south of latitude 7° N. Those of central Antioquia have been mapped and described in considerable detail by Grosse,[61] who divides them into an early Tertiary sequence of coal measures and a late Tertiary sequence of coarse conglomerate, sandstone, shale, tuff, and agglomerate interbedded with andesite and basalt flows. The coal measures in turn are divided into a lower member 200 to 1,100 meters thick, a middle member 250 to 350 meters thick, and an upper member 1,000 to 1,900 meters thick; productive coal seams occur only in the middle member, but there are nonproductive seams in the lower member and in the basal part of the upper member. Conglomerates that probably represent the base of the late Tertiary sequence transgress from the upper to the lower member of the coal measures. In the Patía Valley, the rocks are divided by Grosse [62] into (1) an early Tertiary sequence of coal measures, which he correlates with the lower and middle members of the coal measures of Antioquia, (2) a middle Tertiary sequence of gray to green shale and sandstone, with minor conglomerate and variegated shale, which he correlates with the upper member of the coal measures

[60] Butler, J. W., Jr., op. cit., p. 96.

[61] Grosse, Emil, El Terciario carbonífero de Antioquia, pp. 101–228, Dietrich Reimer (Ernst Vohsen), Berlin, 1926.

[62] Grosse, Emil, Acerca de la geología del sur de Colombia, I and II: Compilación de los estudios geológicos oficiales en Colombia, tomo 3, pp. 84–104 and 160–178, 1935.

of Antioquia, and (3) a late Tertiary sequence of tuff, agglomerate, conglomerate, and red sandstone and shale which discordantly overlie the foregoing rocks. All the Tertiary strata of the Cauca Valley have been strongly deformed.

In northeastern Colombia, along the east flank of the Cordillera Oriental, the Tertiary is represented by a thick sequence of deformed beds of Eocene, Oligocene, and Miocene age. Stratigraphic details for the Barco concession are given by Notestein, Hubman, and Bowler,[63] who state:

> The Tertiary rocks, which are characteristically nonmarine but carry a few marine beds, are approximately 2,500 meters thick within the concession. * * * If the remainder of the Guayabo group [Miocene] as known outside the concession is included, the thickness of the Tertiary would be increased 75 per cent.

The productive coal measures are assigned to the Eocene.

POST-JURASSIC IGNEOUS ROCKS

The post-Jurassic igneous rocks of Colombia presumably include a diversity of plutonic, hypabyssal, and extrusive facies, but significant information concerning them is exceedingly scant.

More than a dozen stocks and batholiths, shown as post-Jurassic on the 1944 geologic map of Colombia, are known or inferred to cut rocks to which a Jurassic or younger age has been assigned. The full extent of post-Jurassic plutonic rocks remains undetermined, however, for many occurrences probably have not been mapped, particularly in the Cordillera Occidental, and some of the intrusives now tentatively assigned to the pre-Cretaceous may prove to be younger. Plutonic rocks assigned to the post-Jurassic are equigranular and porphyritic types ranging from granite to gabbro. Acidic facies apparently prevail, but diorite and gabbro occur even in the Cordillera Oriental.

Hypabyssal rocks, commonly called intrusive porphyries, are absent in most sedimentary-rock areas, except where sills along with flows constitute a part of the sequence. However, they may be abundant in the Cordillera Occidental, and they range from scarce to abundant at some places within massifs of basement complex. They are not shown on most areal maps, and they remain almost unstudied.

The only extrusive rocks known to postdate the ones associated with the "Girón series," the "porphyrite formation," and the diabase sequence of Stutzer are of late Cenozoic age. Volcanism began during Miocene time and continued until Recent. The earliest materials are found, in the Magdalena and Cauca Valleys, in bedded rocks that were folded and faulted during the Andean revolution. Later materials formed the flows, tuffs, and volcanic breccias that cover scattered areas shown by the 1944 geologic map of Colombia. All are prevailingly andesitic, with only minor amounts of dacite, basalt, and trachyte.

[63] Notestein, F. B., Hubman, C. W., and Bowler, J. W., op. cit., pp. 1173 and 1190–1205.

COLOMBIAN MINING LAW

GENERAL STATEMENT

The mining law of Colombia is founded on the general concept, inherited from ancient Spanish law, that all mineral deposits belong to the Nation. The most important exception is the constitutional right given to the poor to work placer ground by panning or other relatively simple methods in any locality, regardless of ownership. Another noteworthy exception is that in most instances the holders of land titles antedating October 28, 1873, own the subsoil rights to minerals not specifically excepted in the national constitution; this applies throughout the country except in departamentos whose legislatures, during the period in which they were sovereign states, specifically eliminated rights to certain or all minerals from land titles within their domain.

From the standpoint of foreign mining interests, the most important types of mineral deposits belonging to the Nation include the following:

1. Gold, silver, platinum, copper, and precious stones anywhere. Deposits of these minerals (except along navigable rivers) may be acquired by "adjudicación." Deposits of these minerals in the beds of navigable rivers and in adjacent land to a distance of 1 kilometer on each side of the channel, except ground for which title was granted prior to 1937, may be worked by "contract"—that is, a concession—from the National Government.

2. Iron, lead, mercury, coal, mica, and "other similar" minerals discovered (a) in the public domain, (b) in private terrain whose original title postdates October 28, 1873, or (c) in private terrain (regardless of the date of the original title) within departamentos whose legislatures during the period in which they were sovereign states, specifically withheld rights to certain or all minerals from land titles. Such deposits may be worked by "contract"—that is, a concession—from the National Government.

3. Emeralds, beryl, and "comparable" minerals anywhere.

4. Rock salt, marine salinas, and saline springs, except springs whose concentration of salt does not exceed 6° Baumé.

5. The gold and silver deposits of Marmato, Supía, Santa Ana, and La Manta and the coal deposits of San Jorge and Mongua.

6. Petroleum deposits located (a) in the public domain, (b) in private terrain whose original title postdates October 28, 1873, or (c) in private terrain (regardless of the date of the original title) within departmentos whose legislatures, during the period in which they were sovereign states, specifically withheld rights to certain or all minerals from land titles within the domain.

It is apparent from the above list that the minerals which are the property of the landowner are as follows: iron, lead, mercury, coal, mica, and "other similar" minerals (actually all except gold, silver, platinum, copper, precious stones, beryl and related minerals, salt, and several others specifically mentioned by the constitution), as well as petroleum, in private terrain whose title antedates October 28, 1873, not located within departamentos whose legislatures while they were sovereign states withheld subsoil rights.

As a general rule, the person in regular possession of, especially the one exploiting , a mine is given some preference in the courts.

TITLE BY ADJUDICACION

To acquire title by "adjudicación" (old-fashioned title), there are four necessary steps, each of which must be carefully carried out with attention to the most minute details of the Mining Code. Anyone who is a citizen or a foreigner with citizen's rights in the matter, which includes practically all foreigners, may apply for mining titles in this way.

The first step is the "aviso," a notification to the municipal authority (the alcalde, who keeps a book in which only these notices are set down) of the discovery of the "mina." This is the word used to designate the immediate area where the deposit occurs; it may be either a placer mine or lode mine. The dimensions of a placer mine may be, at the discretion of the applicant, 2 by 5 kilometers, 3 by 3 kilometers, or less. A lode mine may consist of one, two, or three contiguous claims (called "pertenencias"), each 240 by 600 meters in area; thus the usual lode "mina" measures 240 by 1,800 meters. All measurements are made along the surface, not by horizontal projection. The notification costs 5 pesos and is valid for 90 days, during which time the applicant may examine and exploit freely.

The second step is the "denuncio," which must be filed within the 3-month period following the notification. It consists of certain formulas whereby the applicant alleges claim to the mine by discovery or rediscovery and states its exact location; it is directed to the President of Colombia through his delegate, the secretary of mines of the departamento concerned. If the mine is found in an intendencia or comisaría, instead of in a departamento, the denouncement must be approved by the Ministry of Mines of the Nation. The declaration, which costs another 5 pesos, must be accompanied by a copy of the notification. If it is approved by the appropriate authorities, it is then published in the official organ.

The third step, receiving material possession of the mine, may be taken supposedly—and more by usage than by law—within a year

after filing the declaration. The Governor designates some person, usually the alcalde, to make delivery. Before doing so, this functionary is obliged to publish his intention by written notice in a public place in the municipio for 3 weeks and to make vocal proclamation in the public square on three successive weekdays, all in order that interested persons may offer any opposition to which they feel entitled. If there is no opposition, or if it can be properly overcome, the applicant is notified as to what day he should receive his mine or mines. On that day he should provide transportation, food, and other comforts for the official party which is required to go to the site, measure the ground, and deliver it to the applicant by vocal and written proclamation. Opposition may also be offered at the moment just before possession is given.

The fourth and last step, which should be taken within 60 days after receiving possession, is the application for title. This costs 50 pesos and consists of presenting before the proper authorities, in proper form, all documents so far acquired. If the three preliminary steps have been carried out correctly and no valid opposition is offered, title to the mine is granted and it becomes the property of the applicant. This does not include surface rights but implies means of access and, with some new restrictions, water rights. A mine thus titled is in the class of "semimovables" and does not become real property. In the case of several claims, it is necessary to carry out the whole procedure individually for each.

Mines in this class are subject to what is called a "stake tax," which is payable annually and which reserves the title. On lode mines this tax is 5 pesos per year. Since 1932, placer mines have been taxed 20 pesos per year and, if the mine is not actively worked, 40 pesos per year during the fourth and fifth years; if the mine has not been actively worked by the end of the fifth year, it is considered abandoned and further payments will not save it. Active work on placer mines is defined as that of 10 men for 4 months each year; on lode mines, that of 6 men for 4 months each year.

"CONTRACTS" (CONCESSIONS)

"Contracts," in English more commonly known as concessions, may be acquired for (1) precious metal deposits (including those of copper and precious stone), located in the beds of navigable streams and in adjacent land to a distance of 1 kilometer on each side, and (2) nonprecious mineral deposits, aside from those of beryl, salt, and several other commodities specifically mentioned by the constitution as belonging to the Nation.

In general, prior to 1905, placer deposits along navigable streams could be acquired by "adjudicación." Beginning that year, a series

of decrees and laws culminated in Law 13 of 1937 and its complementary laws, which declared such areas exploitable only by "contract," with due regard to prior titles. Considered as navigable is "any stretch of river not less than 15 kilometers long that serves or may serve in an effective manner habitually and in both directions as a means of communication with craft of mechanical traction," which latter obviously includes dugout canoes with outboard motor. The National Government may grant a concession along a navigable river for an area up to 15 kilometers in length; moreover, depending on his ability to exploit them, the concessionaire may be granted one or two additional and contiguous concessions at the discretion of the Minister of Mines and Petroleum. In no case will more than three concessions be awarded to one operator.

A proposal for a concession must be accompanied by certain valid information such as location, proximity of nearest well-known mines, sketch of ground desired, ownership of surface rights, if any, geologic and topographic conditions, and other general details. Before the request may be presented for the approval of the President, a bond of 2,000 to 10,000 pesos must be posted, because from its incipience a contract implies certain obligations upon the proponent. During the 2 years following the date of contract, the proponent is obligated to appraise the mine, map it, and locate it in relation to geographical coordinates. The resultant information, along with other data, must be furnished to the ministry; failure to meet this requirement is cause for forfeiture of part or all of the bond. In certain circumstances, the 2-year period may be extended by 6 months. Royalties stipulated in the latest law range from 2 percent, for a gold content up to 150 milligrams per cubic meter, to 20 percent, for 800 milligrams per cubic meter.

Opposition to concessions may be offered by other holders of titles and may be based upon (1) a sustained title antedating Law 13 of 1937, (2) alleged nonnavigability of the river, or (3) agricultural activities of surpassing importance to the region.

"Contracts" or concessions for working deposits of nonprecious metals (except copper) and of nonmetallic minerals may be obtained in a manner similar to that employed for river concessions. The principal differences are: (1) Agreements are limited to a period of 30 years. (2) The terms and stipulations concerning capacity and the like are arranged individually, and (3) the required bond varies in amount between 1,000 and 10,000 pesos.

COMMENT

The general consensus in Colombia is that the laws and procedures pertaining to acquisition of mines by "adjudicación" are reasonably

satisfactory. However, even these include pitfalls through which a person may become involved in extended litigation.

Certain features of the laws pertaining to "contracts" are undesirable from the miner's viewpoint. Most deposits are discovered by local peons lacking both the resources and the knowledge needed to acquire a concession, which involves dealing directly with the ministerio in Bogotá instead of with the local mayor, the hiring of a lawyer to prepare the petition in such a form that it will not be thrown out by the ministerio, the hiring of an engineer to make a map, and the posting of a bond of 1,000 pesos or more. As a result, the discoverer is likely to keep the secret to himself. At the other extreme are provisions undesirable to a large mining company seeking a concession, particularly placer ground along a navigable river. Most undesirable are the provisions (1) that all equipment and improvements upon the property revert to the Colombian Government when the contract expires and (2) that the Government may send one or several engineers to interfere in any manner they desire with the mining operations.

ANTIMONY

An intermittent output aggregating 30 to 50 metric tons of stibnite was derived during the period 1939–45 from three mines in Caldas. Most of it was sold in small lots over the counter to druggists, but 13 tons were exported in 1940 to the United States. According to Fetzer,[64] the price received for the exported ore, after deducting transportation costs, was about $80 per ton, American currency, which was less than half the price received in the Colombian domestic market and was inadequate to defray operating costs.

Numerous stibnite occurrences, unprospected and for the most part even unverified, have been reported in Caldas, Tolima, and Cauca (pl. 6). Among them at least a few deposits that could be worked on a small scale may be found, provided intensive scouting followed by the requisite soil stripping at the more promising localities is done. Probably the most promising area is the municipio of Villa María, immediately to the southeast of Manizales in Caldas, where two of the mines and a relative abundance of alleged prospects exist.

All in all, reasonable hope could be entertained for a future output up to several metric tons of stibnite per month, given adequate demand and price.

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[64] Fetzer, W. G., Investigación del yacimiento de antimonio de "La Gloria" (Municipio de Villa María) : Compilación de los estudios geológicos oficiales en Colombia, tomo 5, p. 519, 1942.

CALDAS

LA GLORIA MINE

La Gloria mine (pl. 6), located approximately 12 kilometers south-southeast of Manizales in the municipio of Villa María, has been described by Fetzer,[65] whose data follow. The bedrock is "gray argillaceous schist." It is transected by irregular fractures, some of which contain stibnite-quartz veinlets, whereas others contain pyrite-calcite veinlets. The stibnite-quartz veinlets are bordered by 1 centimeter to several centimeters of gouge. At irregular and unpredictable intervals they open into pockets of nearly pure stibnite up to 50 centimeters in width.

Exploitation began in 1939 and terminated in 1942. Mining was done in an open-cut, 15 by 30 meters in area, whose depth is less than the zone of weathering. The rock was loosened by pick, shoveled aside, and then flushed by booming. Soil and brush conceal bedrock outside the open-cut, so that future potentialities remain unknown. La Gloria mine was the source of the 13-ton shipment to the United States.

LA CRISTALINA MINE

La Cristalina mine (pl. 6), located approximately 6 kilometers south-southeast of Manizales in the municipio of Villa María, has been described by Fetzer,[66] whose data follow. The aggregate output at La Cristalina may have been nearly as much as at La Gloria, but in 1941, the time of Fetzer's visit, the mine was shut down and no stibnite was visible in place. The bedrock is "black organic schist." It is transected by a nearly vertical shear zone, 5 to 6 meters wide, in which are a series of parallel veinlets separated from each other by schist. The veinlets, each of which is 1 centimeter to several centimeters wide, are most profuse within a zone 36 centimeters wide but occur in lesser abundance throughout the shear zone. After examining several kilograms of material on the dump, Fetzer concluded that the stibnite probably is intimately intergrown with quartz and schist and that crushing and concentration would be needed to obtain a high-grade concentrate. However, this material may possibly have been inferior to the ore that was shipped.

JESÚS GOMEZ' MINE

Jesús Gomez, dentist in Ríosucio (lat. 5°25′ N., long. 75°42′ W.), in 1945 stated that he owned a mine (pl. 6) from which he currently

[65] Fetzer, W. G., op. cit., pp. 517–519.

[66] Fetzer, W. G., Investigación de los yacimientos de estibina de "La Cristalina," Municipio de Villa María: Compilación de los estudios geológicos oficiales en Colombia, tomo 5, pp. 539–540, 1942.

was selling pure stibnite in both Medellín and Cali. No details were given.

LA PALMA PROSPECT

La Palma prospect, located in the municipio of Quinchía about a kilometer northwest of the junction (lat. 5°23′ N., long. 75°44′ W.) of a spur road from Quinchía with the main Cartago-Medellín highway, was examined in 1942 by W. D. Longan, whose data follow. The prospect also has been briefly described by Fetzer.[67]

At some time prior to 1941, five short adits were driven to prospect for gold. Only one was accessible to Longan. The adit follows a quartz vein containing numerous crystals of pyrite and occasional seams of stibnite. Approximately 800 to 1,000 pounds of stibnite, much of which is intimately mixed with gangue, were recovered by driving the adit a distance of 20 meters. The largest individual ore pockets yielded only a couple of pounds of stibnite each. The wall rock is highly altered quartz monzonite(?).

OTHER LOCALITIES

Carlos Posso, mining engineer of Manizales, has examined several prospects in the municipio of Villa María at which narrow seams of stibnite are visible. Other reported occurrences near Villa María, however, have not been visited by engineers.

Stibnite showings are said to occur (1) in the Salento region (lat. 4°38′ N., long. 75°34′ W.), (2) along the Río Miel southeast of Samaná (lat. 5°32′ N., long. 74°57′ W.), and (3) in several other places.

CAUCA

An excellent specimen of very coarse stibnite, exhibited in Bogotá, allegedly came from a prospect located about 5 kilometers from Lerma (lat. 1°58′ N., long. 76°57′ W.). Stibnite also is said to crop out near El Tambo (lat. 2°25′ N., long. 76°49′ W.) and at other localities.

TOLIMA

EL DIAMANTE ANTIMONY CONCESSION

El Diamante antimony concession, in the municipio of Cajamarca, was examined by the author and Gilberto Botero Restrepo. Prospecting had been restricted to three localities, at only two of which stibnite was visible.

The Pajaritos locality (lat. 4°31′ N., long. 75°28′ W.) includes nine different showings. Stibnite occurs in quartz devoid of other sulfide

[67] Fetzer, W. G., Prospección de los yacimientos de antimonio de La Palma, Municipio de Quinchía: Compilación de los estudios geológicos oficiales en Colombia, tomo 5, pp. 513–515, 1942.

minerals except for pyrite at two places. The quartz, in turn, is within fracture zones, ranging from a meter to more than 10 meters in width, that transect chloritic schist. Only a very small percentage of the stibnite could be recovered without fine grinding and concentration. Exploration has been inadequate to estimate ore tonnages.

The Diamante locality, 2 kilometers south of Pajaritos, is even less promising. Soil stripping over an area 2 by 23 meters revealed thin layers, lenses, and nests of quartz and stibnite in limonite-stained rock. Nearly all the stibnite, which is erratically distributed, is very fine grained.

EL PORVENIR PROSPECT

El Porvenir prospect, located approximately 5 kilometers southwest of Herveo (lat. 5°05′ N., long. 75°10′ W.) has been described by Fetzer.[68] The deposits were entirely concealed by slide debris at the time of Fetzer's visit in 1941.

Specimens said to have been recovered before the slide occurred include pieces of nearly pure stibnite up to a kilogram in weight, as well as fine-grained stibnite imbedded in quartz and schist.

OTHER LOCALITIES

Many people in Ibagué declare that they have seen stibnite in that general region.

ASBESTOS

A deposit of cross-fiber chrysotile asbestos is located at Morro Norizal (lat. 7°04′ N., long. 75°18′ W.), in Antioquia (pl. 6). It was examined in 1944 by J. K. Cathcart, after it had been briefly described by Alvarado.[69] Nine outcrops within an area 40 by 60 meters in extent expose 49 square meters of rock having an average fiber content of 0.81 percent, of which 0.33 percent is fiber more than 2 centimeters long, 0.37 percent is fiber 1 centimeter to 2 centimeters long, and 0.11 percent is fiber less than 1 centimeter long. Outside the 40- by 60-meter area are scattered outcrops revealing only small and spotty patches of asbestos-bearing rock. Thus the deposit probably is small and lean. The asbestos occurs in serpentine as irregularly distributed, unoriented veinlets as much as 10 centimeters in thickness. In most veinlets, the fibers are slightly bent and not quite perpendicular to the walls, but in some veinlets, the ends of the fibers are sharply bent and stony material may be intergrown with the curved parts. Medial partings of serpentine appear in some veinlets. The serpen-

[68] Fetzer, W. G., Prospección del yacimiento de antimonio de El Porvenir: Compilación de los estudios geológicos oficiales en Colombia, tomo 5, pp. 515–517, 1942.

[69] Alvarado, Benjamín, Palau, Climaco, and Paba Silva, Fernando, Los yacimientos de asbesto de Norizal (Antioquia): Bol. minas y petróleos, nos. 121–144, pp. 39–49, 1939–40.

tine, associated with partly serpentinized peridotite, forms a tongue-shaped body that extends northwestward from an apex located 1.5 kilometers southwest of Morro Norizal. It is surrounded by gneiss and schist, which are cut by quartz monzonite and related dikes. The region is one of rugged topography, with a relief of 300 meters, and contains scattered farms.

Within a radius of 15 kilometers to the south and east of Morro Norizal are said to be many asbestos showings which are decidedly less promising than those at the Morro. Six along the Río San José, 5 to 6 kilometers east-northeast of Morro Norizal, were visited by an FEA mineral scout, whose data and specimens confirm the fact that the deposits are leaner than, and inferior to, the one at Morro Norizal.

A few metric tons of serpentine containing cross-fiber asbestos that was utilized in cement are said to have been extracted in Nariño (pl. 6) from talus along the banks of the Quebrada Aguacillas (approximately lat. 1°32′ N., long. 77°02′ W.), 200 meters from the point where the stream crosses the Pasto-La Cruz highway. According to Royo,[70] the asbestos has little tenacity and tends to break readily into small particles. It forms veinlets 6 centimeters in maximum thickness but 2 to 3 centimeters in average thickness. Royo points out that beneath the talus there may be a deposit containing tenacious, flexible asbestos in bedrock.

Amphibole asbestos has been reported at scattered localities, mostly in the Cordillera Central, but none was investigated by FEA personnel.

BARITE

In Colombia barite is used chiefly as a constituent in drilling mud, although minor amounts are used in the manufacture of paint and other commodities. Nearly 3,000 metric tons was consumed during 1944, of which probably half came from domestic mines. The demand may be expected to increase sharply during the next decade, as all oil companies are planning extensive exploration programs.

Because of high transportation costs within Colombia, barite in 1944 cost $50 to $80, American currency, per ton at the points of consumption. Whether domestic or imported barite is used at any given place normally depends on which can be supplied at least cost. Accordingly, only deposits having relatively favorable locations are exploited. As oil exploration spreads to new regions, some deposits that in 1944 were economically inaccessible may become workable.

The output in 1944 came mainly from a mine located 13 kilometers by trail west of Los Santos (lat. 6°46′ N., long. 73°07′ W.), San-

[70] Royo y Gomez, José, La cuenca hidrográfica del Juanambú, Departamento de Nariño: Compilación de los estudios geológicos oficiales en Colombia, tomo 6, p. 237, 1942.

tander (pl. 7). This mine, which began operating in February 1944, was examined by J. K. Cathcart. Two veins were exploited by means of shallow open-cuts, each about 20 meters long, on a 20-degree slope. The veins are nearly vertical, have widths of several meters, and transect nearly horizontal shale and limestone. Float and outcrops indicate that other workable veins may exist on the mine property, with still others in the vicinity.

A minor output during 1944 came from the Ataco region (lat. 3°35′ N., long. 75°23′ W.) of southern Tolima (pl. 7). During preceding years, deposits near Coyaima (lat. 3°48′ N., long. 75°12′ W.) and El Valle (lat. 4°11′ N., long. 75°10′ W.), in southern Tolima, and near Carnicerías (lat. 2°28′ N., long. 75°44′ W.), in central Huila, also were exploited (pl. 7). Many barite occurrences have been found in these regions, but as they are rather distant from markets, their aggregate output to the end of 1944 amounted to less than 3,000 metric tons. Most of the deposits are said to be veins, but a few in Tolima are surface accumulations of barite boulders. Probably no single deposit has reserves of more than a few thousand metric tons that may be recovered by simple open-cut mining.

In 1945, mining began at Naranjos farm (approximately lat. 8°05′ N., long. 73°07′ W.), east of the Río Tarra and about 30 kilometers southeast of Ocaña, Norte de Santander (pl. 7). According to C. E. Dixon, the principal deposit is a nearly vertical barite vein, 1.5 to 2 meters wide, containing small, sparsely scattered nests of galena and sphalerite. At least 5,000 metric tons can be recovered from an open-cut.

The most favorable deposits for future exploitation are located 15 kilometers east-southeast of Chiriguaná (lat. 9°22′ N., long. 73°37′ W.), Magdalena (pl. 7). These deposits, discovered in 1942, are in open, slightly rolling terrain adjoined on the west by the swampy jungle of the Magdalena Valley. Transportation across a series of shallow lakes from Chiriguaná to the Magdalena River port of El Banco is possible with barges having a draft of 3 feet or less. Daniel Trumpy, chief geologist of the Shell Petroleum Co., kindly furnished geologic data obtained from the field work of Enrique Hubach. Within an area of 20,000 square meters (5 acres), more than a dozen veins composed of barite and quartz have been found. The veins range from 0.3 to 0.9 meter in width and from a few meters to as much as 50 meters in exposed length; they trend northward, have a nearly vertical dip, and transect Devonian shale that dips 35° to 45° to the west. Large parts of each vein consist of coarse-grained, gray to pinkish-gray barite, but in places the barite grades laterally into quartz containing barite nests. The reserves in 1943 were estimated as 700 metric tons per vertical meter, and prospecting doubtless will disclose more.

BAUXITE

The only verified occurrence of bauxite in Colombia is in the Cuivá plains, in the Santa Rosa de Osos region (lat. 6°39′ N., long. 75°28′ W.) of Antioquia. According to Botero Arango,[71] the bauxite occurs as irregularly shaped nodules, up to a third of a meter in maximum diameter, scattered through a surface clay that averages 60 centimeters in thickness and nowhere is more than a meter thick. The bauxite-bearing clay is not continuous but forms isolated areas, none of great magnitude. The locality does not constitute an apparent source of bauxite for the manufacture of aluminum.

CEMENT

Cement production in Colombia had increased nearly tenfold during the decade 1935–44, was inadequate to meet the current demand in 1945, and was expected to increase sharply as soon as new equipment became available. In 1945 five companies, each capitalized in excess of 1,000,000 pesos, produced cement from six plants located in four different departamentos (pl. 7). The annual value of their product amounted to about 11,000,000 pesos (in American currency, $6,000,000). The aggregate rated plant capacity of all the companies was 1,040 tons of cement per day, yet because of subcapacity production at Nare, the actual output was only about 950 tons per day.

The current demand, as estimated by cement-company officials, would have been at least 1,500 tons per day if that quantity of cement had been available. Therefore cement was rationed by the companies and sold at ceiling prices fixed by the Government. Nearly all the companies planned to expand as soon as machinery became available.

There follows a brief description of location, capacity, and sources of limestone, fuel and power, and gypsum for each plant, arranged according to departamentos. Clay or clay and sand to mix with the limestone, invariably procured locally, are not considered.

ANTIOQUIA

The plant of the Cía. de Cementos Argos, S. A., is on the southern outskirts of Medellín (pl. 7). The rated plant capacity in 1945 was 100 tons of cement per day, but the actual output had attained 120 tons. The company's limestone quarries are near San José (lat. 6°29′ N., long. 74°49′ W.) and Sabaletas (lat. 6°24′ N., long. 74°34′ W.) stations, 110 and 145 kilometers, respectively, from Medellín on the railroad to Puerto Berrio. Coal is procured from a mine near Angelópolis; the mining company Industrial Hullera is owned and operated by a group consisting of the cement company and more than half a dozen other Medellín concerns. About 80 tons of gypsum per month

[71] Botero Arango, Gerardo, oral communication, September 1942.

was purchased from small producers near Los Santos (Santander); the current price in 1945 was 28 pesos per ton in Bucaramanga and 53 pesos per ton in Medellín. The small output at Los Santos, combined with competitive buying by the Bucaramanga cement plant, was causing gypsum prices to rise. Cement sold in Medellín for 50 pesos ($30, American currency) per ton.

The Memoría de Minas y Petróleos for 1944 published the following data regarding the Argos company's limestone concession:

	1943	*1932–43*
Limestone produced for cement (metric tons)	20,300	182,855
Limestone produced for agricultural and other uses (metric tons)	1,428	8,748
Value of limestone produced for all uses (pesos)	48,464	463,308
Royalty collected by Colombian Government (pesos)	2,721	23,078

The plant of the Cía. de Mármoles y Cementos del Nare, S. A., is at Puerto Inmarco, 3 kilometers north of Nare (lat. 6°11′ N., long. 74°35′ W.), on the Río Magdalena (pl. 7). The rated plant capacity was 240 tons of cement per day, but the actual production was less. The limestone (marble) quarry is on the Río Nare, 15 kilometers upstream from its confluence with the Magdalena. The limestone is ground, made into a sludge, and then transported by pipe line to the cement plant. The company's hydroelectric plant is near the quarry. The kilns are fired by fuel oil from Barranca Bermeja. Gypsum, at 28 pesos per ton plus freight charges from Bucaramanga to Nare, was purchased from small mines near Los Santos (Santander); an alternative source was the Tocaima-Girardot district (Cundinamarca).

The Empresa Siderurigica de Medellín stated that they had purchased equipment for a cement plant having a capacity of 420 tons per day, to be located on a site called El Cairo (pl. 7) at their limestone quarry near Santa Barbara (5°53′ N., 75°35′ W.).

ATLANTICO

In 1945 no cement was manufactured in Atlántico. The Cementos del Caribe company, a subsidiary of Argos, planned to construct a plant with a capacity of 200 tons of cement per day at Barranquilla (pl. 7). Limestone will be quarried at a site already selected.

CUNDINAMARCA

The plant and limestone quarry of the Fábrica de Cemento Samper, S. A., are at La Calera (pl. 7), 17 kilometers in an air line north-northeast of Bogotá. A new quarry located farther east was being planned in 1945. The rated plant capacity and actual output were 240 to 250 tons of cement per day. Cement is transported 9 kilometers by aerial tramway to Contador station, which is 14 kilometers from Bogotá, on the railroad to Tunja. The company's own hydro-

electric plant furnishes power, and coal for the kilns is purchased from the San Vicente mines at Sesquilé. About 7½ tons of gypsum per day is purchased, at prices ranging from 28 to 32 pesos per ton delivered at Contador, from mines near Leiva (Boyacá). The cement was sold in Bogotá at 42 pesos ($24.70, American currency) per ton.

The plant and limestone quarry of the Cía. de Cementos Portland Diamante, S. A., are at Apulo (lat. 4°32′ N., long. 74°36′ W.). (See pl. 7.) The rated capacity, as well as the actual production, was about 200 tons of cement per day in 1945. The company's own hydroelectric plant furnishes power. Coal for the kilns is procured from its own mine near Tocaima. Some 160 tons of gypsum per month, at prices ranging from 21 to 28 pesos per ton delivered at the plant, was purchased from small mines of the Tocaima-Girardot district. The cement was sold in Bogotá at 45.70 pesos ($27.00, American currency) per ton—that is, 40 pesos per ton at the plant plus freight charges.

SANTANDER

The plant and quarry of the Cía. de Cementos Portland Diamante, S. A., are on the outskirts of Bucaramanga (pl. 7). The rated capacity, as well as the actual production, was 80 to 100 tons of cement per day in 1945. This plant was established about 1943 by moving part of the equipment formerly at Apulo. The kilns are fired by oil purchased from Barranca Bermeja. About 2½ tons of gypsum per day was purchased from mines at Los Santos (Santander) or Leiva (Boyacá). The cement sold at the plant at 40 pesos ($23.50, American currency) per ton.

VALLE DEL CAUCA

The plant of Cementos del Valle, S. A., is at Yumbo (lat. 3°35′ N., long. 76°30′ W.), 15 kilometers north of Cali (pl. 7). The rated plant capacity was 150 tons of cement per day in 1945, but the actual production was about 190 tons. The limestone quarries are at Puerto Isacas, 10 kilometers by either highway or railroad from the plant. In 1945 about 60 to 70 tons of coal per day was procured in part from the company's own mine at La Viga and in part by purchase from independent producers. About 170 tons of gypsum per month, at 55 pesos per ton delivered at the plant, was purchased from small mines in the Tocaima-Girardot district (Cundinamarca), near Ibagué (Tolima), and near Castillo and Pubenza (Huila). The cement currently sold at 40 pesos ($23.50, American currency) per ton at the plant and at the same price plus freight charges throughout Caldas, Cauca, and Nariño.

CHROMITE

Chromite has been found in serpentine at several places near Medellín, but all the occurrences are unpromising as ore. The serpentine,

said to crop out over a considerable area, is closely associated with diorite, gabbro, and peridotite. The areal distribution of these rocks in central Antioquia is shown in part by Scheibe's map.[72]

Prospecting has been carried on only in the Santa Elena–Las Palmas area, located about 10 kilometers southeast of Medellín, where there are at least 10 chromite showings within an area of 2 square kilometers. Five of the showings are picayune occurrences in bedrock, the poorest exhibiting a few stringers of chromite and the best a 15-ton pocket of impure chromite. The others are eluvial accumulations found above either decomposed serpentine or soft lateritic clay but beneath surface soil. The eluvial chromite is a mixture of particles and angular boulders that forms lenses ranging from a centimeter to several tens of centimeters in thickness and from a few square meters to several hundred square meters in area. The larger particles and the boulders are intergrowths of coarse chromite and serpentine. Five eluvial lenses were discovered during 1942–44. Intensive prospecting probably would reveal others.

CLAY

Tile, brick, and other products derived from low-grade clays are made at a great many localities scattered throughout the country. In aggregate volume they doubtless represent the most important of the industrial mineral products; yet because the output is divided among so many small units, no production figures are available. There are several brickyards on the outskirts of almost all the cities; and tile, particularly roofing tile, which covers perhaps 80 percent of all houses and other buildings in Colombia, is made at almost every town and village.

Intermediate and fairly high grade clays in Antioquia and elsewhere, in small individual deposits, are exploited to some extent for the manufacture of household ware, electrical insulators, and other products.

The principal ceramic plants, according to Gilberto Botero Restrepo, are located as follows:

Town	*Departamento*	*Coordinates*	
		Latitude	*Longitude*
El Carmen de Viboral (8 plants)	Antioquia	6°05′ N.	75°19′ W.
La Union	do	5°58′ N.	75°21′ W.
Sonsón	do	5°42′ N.	75°18′ W.
Caldas	do	6°06′ N.	75°38′ W.
Itaguí	do	6°11′ N.	75°36′ W.
Medellín (in a suburb, Robledo)	do	6°15′ N.	75°34′ W.
Ráquira	Boyacá	5°32′ N.	73°38′ W.
Bogotá (3 plants)	Cundinamarca	4°36′ N.	74°05′ W.
Arboledas (shut down in 1947)	Norte de Santander	7°39′ N.	72°48′ W.

[72] Scheibe, Roberto, Geología del sur de Antioquia : Compilación de los estudios geológicos oficiales en Colombia, tomo 1, pl. 3, 1934.

COAL

Coal, one of the chief mineral commodities exploited for domestic consumption in Colombia, was specifically studied by the author for several weeks during late 1944. Geologic data were procured by reviewing publications and by conferring with geologists, mainly of the Servicio Geológico Nacional. Statistical, economic, and mining data were obtained from interviews with leading producers and, to a lesser extent, consumers. In addition, visits were made to one or more mines in each productive district.

Ranging in rank from sub-bituminous to bituminous, coal is distributed widely enough in Colombia to assure large resources. The reserves, however, cannot be estimated even with moderate reliability because geologic data are too scant. It now is certain that the reserve estimate made years ago by Gamba [73] must be radically revised. The aggregate coal reserves in Colombia, to a maximum depth of a thousand meters, may very tentatively be regarded as 10 billion metric tons or more. Part of the reserve is coal that will yield inferior grades of coke, but there are no apparent sources of high-grade metallurgical coke.

Coal consumption in Colombia has steadily increased in the past and should continue to increase in the future. Except as the need for superior grades may arise, the demand in localities away from the coast, where foreign coal may be supplied more cheaply than domestic, presumably will be met for many years by increasing mine production. The rate of increase will be determined by the extent of general industrial expansion, modified by the amount of competition from petroleum and hydroelectric power.

The output of coal in Colombia during 1944 may be estimated as 595,000 metric tons, valued at approximately $2,700,000, American currency, at rail or other points of delivery nearest the mines. This estimate, to be regarded as correct within about 10 percent, is derived from records and estimates of informed persons, inasmuch as no statistical record of coal production is maintained by the Government. The output by districts during 1944 was approximately as follows:

	Metric tons
Cundinamarca-Boyacá	300,000
Antioquia	150,000
Valle-Cauca	138,000
Norte de Santander	5,000
Caldas	2,000
Others	Negligible
Approximate total	595,000

[73] Gamba, F. P., Coal resources of Colombia, in Coal resources of the world, vol. 2, pp. 577–578, 12th Int. Geol. Cong. (Toronto, 1913), 1913.

The output of coke during 1944 aggregated only a few thousand metric tons.

Most of the coal being mined probably has a moisture content of less than 10 percent, a volatile-matter content of 25 to 45 percent, and a heat value ranging from 5,500 to 7,000 calories (9,900 to 12,600 B. t. u.), but analyses suggest that composition and heat value vary considerably even in the same field. Some of the coal in each productive district yields coke. The thickness of the seams actually exploited normally ranges from slightly more than half a meter to about 2 meters, although locally a seam may be nearly 4 meters thick. Dips in different mines range from horizontal to vertical; due to relatively complex local structure in most fields, however, steep dips are common.

The minable coal seams in Colombia may all be Eocene in age; if not, none is older than the very latest Cretaceous, and none is younger than Oligocene. In each district, one or more minable seams along with seams too thin to be worked occur interbedded with shale, sandstone, conglomerate, and—locally—limestone in a typical coal-measures sequence, the aggregate thickness of which may range from 75 meters to 900 meters. The coal measures, which may contain minor amounts of reddish-weathering shale, in some districts grade upward into barren strata that weather prevailingly red. Despite general similarity in age and lithology, the coal-bearing strata throughout Colombia were not deposited in a single, continuous basin.

Broadly generalized, the coal-bearing strata crop out intermittently along narrow and complex longitudinal structural belts in which post-Cretaceous rocks remain uneroded. The principal belts, from southwest to northeast and not in order of economic importance, are: (1) along one or both sides of the Ríos Patía and Cauca from latitude 1°30′ N. to latitude 6°35′ N., (2) along the western flank of the Cordillera Oriental from latitude 4° N. to latitude 7°45′ N., (3) along the central part of the Cordillera Oriental from latitude 4°30′ N. to latitude 6°20′ N., (4) along the eastern border of the Cordillera Oriental from latitude 7° N. to latitude 9° N., and (5) in the northeastern part of Magdalena, adjoining the Guajira Peninsula. (See pl. 8.) Each belt includes one or more general areas, or districts, in which are local coal basins. Outcrops of coal also have been reported in northern Antioquia and Bolívar and along the eastern border of the Cordillera Oriental in Cundinamarca. Other areas of post-Cretaceous rocks that are shown on the 1944 geologic map of Colombia are not known to contain coal.

CUNDINAMARCA AND BOYACA

The coal sequence of Cundinamarca and Boyacá (pl. 8) crops out (1) in local areas over much of the altiplano, or savanna, 10 to 40

kilometers wide and 200 kilometers long, that extends along the central part of the Cordillera Oriental north and northeast of Bogotá; (2) in isolated, narrow areas outside of, yet near, the altiplano; (3) in a discontinuous belt along the western flank of the range; and (4) at a few localities along the eastern flank of the range. Exploitation has proceeded where outcrop areas are in close proximity to transportation facilities and markets. Consequently, some 65 percent of the output comes from the altiplano, 30 percent from two areas adjacent to the altiplano on the west, and 5 percent from localities along the western flank of the range where it is crossed by two railroad lines.

Coal occurs in the Guaduas formation, classified by the Servicio Geológico Nacional as mainly Eocene and Oligocene but as probably also including some strata of uppermost Cretaceous age. The Guaduas commonly is divided into two members, whose stratigraphic boundary is the base of the Cacho sandstone—the only sandstone more than 10 meters thick in the Guaduas, at least in the central part of the range. Published data, though meager, indicate that the lower member ranges from 400 to 900 meters and the upper member from 1,000 to 1,700 meters in thickness. Both contain gray, mottled, and maroon shales, sandstones that commonly are ferruginous, and conglomerates, but mottled and maroon shales are much scarcer in the lower member than in the upper. Workable seams of coal are restricted to the lower member.

The altiplano is a major synclinal basin complicated by relatively large longitudinal folds and faults and by minor transverse and oblique structures. Profile sections across the basin at different places would show up to four longitudinal segments of Guaduas strata bounded by older rocks. Each segment would have one or another of four types of structure: (1) simple synclinal, (2) synclinal complicated by minor folds, (3) simple homoclinal bounded on one side by a longitudinal fault, or (4) complex homoclinal bounded on one side by a longitudinal fault. Dips may range from nearly horizontal to nearly vertical. The lengths of individual segments of Guaduas strata range from a few kilometers to nearly a hundred kilometers. Inasmuch as workable coal seams are restricted to the lower member of the Guaduas, certain portions only of each Guaduas segment are underlain by coal, and these constitute the individual local fields.

Outside the altiplano, but near its western border, are several narrow synclines in which the coal measures remain uneroded. Most important from an economic standpoint are one extending 10 kilometers in each direction from Tequendama Falls (lat. 4°33′ N., long. 74°18′ W.) and another that extends 13 kilometers southwestward from Zipaquirá (lat. 5°02′ N., long. 74° W.). To the northeast of the alti-

plano in Boyacá is a complex major syncline, 70 kilometers in length, along the Río Chicamocha, in which are several small coal basins; their output now is negligible but would increase if a proposed steel plant should be constructed at Belencito (lat. 5°46′ N., long. 72°53′ W.).

Along the western flank of the Cordillera Oriental occurs a belt, perhaps discontinuous, of Guaduas strata containing an unknown number of coal basins. In general, at the few localities exploited, coal seams are thinner and fewer in number and individual basins are smaller and structurally more complex than in the altiplano.

Present data suggest that very little coal occurs along the eastern flank of the range.

Additional information concerning the geology of the coal fields of Cundinamarca and Boyacá may be obtained from several publications.[74]

The number, thickness, and stratigraphic position of the coal seams differ from one local basin to another. Moreover, the number of shale partings, as well as the thickness of coal in each seam, commonly varies greatly within a single basin.

The aggregate number of exploitable seams in different basins ranges from one to nine, or possibly more, but the greatest number exploited in a single mine is four. In most basins, a main seam averages 1 meter to 2 meters in thickness, one or more thinner seams are workable, and half a dozen or more seams are too thin for exploitation. Each seam may contain from one to five partings. The minimum thickness exploited in different places varies from about 0.5 meter to 0.8 meter, depending on quality, proximity to thicker seams, and other factors that influence the local economics. At some places seams reach a maximum of 3.5 meters in thickness, but normally they decrease to about 2 meters within relatively short distances.

Available coal analyses indicate a wide range in composition from place to place, even within the same local basin. This in turn suggests that the quality, like the thickness, of each seam varies within relatively short distances. Salient data are set forth in the following table:

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[74] Scheibe, Roberto, Documentos de la Comisión Cientifica Nacional: Compilación de los estudios geológicos oficiales en Colombia, tomo 1, pp. 13–50 and 65–83, 1933; Scheibe, Roberto, Jimenez Jaramillo, J., and Lleras Codazzi, R., Informes y estudios varios: Compilación de los estudios geológicos oficiales en Colombia, tomo 1, pp. 231–275 and 287–329, 1933: Scheibe, E. A., Los yacimientos Terciarios de carbón en Colombia; Compilación de los estudios geológicos oficiales en Colombia, tomo 2, pp. 327–335, 1934; Reichenbach, R., Contribución al conocimiento de los carbones de la Cordillera Oriental: Compilación de los estudios geológicos oficiales en Colombia, tomo 2, pp. 345–419, 1934; Scheibe, E. A., Estudios geológicos y paleontológicos sobre la Cordillera Oriental de Colombia, part 1, pp. 32–38, and geologic map, Berlin, P. K. G. Gariner, 1938.

	21 analyses, published by R Scheibe,[1] of coal from localities in altiplano		30 analyses, published by Reichenbach,[2] of coal from Cundinamarca-Boyacá localities, mostly altiplano		Normal range of Cundinamarca-Boyacá coal, as given by National railways
	Average	Range	Average	Range	
Moisture (percent)	2.4	1.0–9.5	2.5	0.7–9.2	1–9
Volatile matter (percent)	36.6	19–53	31.3	10–55	25–46
Fixed carbon (percent)	54.2	31–70			40–66
Ash (percent)	7.4	3.0–15.0	6.2	2.3–15.1	3–15
Sulfur (percent)			0.9	0.2–2.9	0.5–2.5
Heat value (calories)	5,430	4,200–7,670	7,649	6,640–8,380	6,000–7,500

[1] Scheibe, Roberto, Documentos de la Comisión Científica Nacional: Compilación de los estudios geológicos oficiales en Colombia, tomo 1, p. 83, 1933.
[2] Reichenbach, R., Contribución al conocimiento de los carbones de la Cordillera Oriental: Compilación de los estudios geológicos oficiales en Colombia, tomo 2, pp. 362–363, 1934.

The coking properties of the coal at most localities remain undetermined, because the local demand for coke has been slight. Coal that yields poor to intermediate grades of coke is known to exist and may eventually prove to be fairly widespread.

Reserves have been reliably estimated only in two small areas outside the altiplano. It seems likely that the total reserves of the altiplano and adjacent areas may eventually be estimated at 2 billion to 9 billion metric tons and the reserves of the belt along the west flank of the range at decidedly less. Mere guesses, these estimates are made by considering the aggregate area underlain by coal, as well as the number and thickness of seams in Cundinamarca and Boyacá as compared with Antioquia, Valle del Cauca, and Cauca, where the reserves have been calculated with some reliability. Data are inadequate even to guess the reserves of coking coal.

Approximately 25,000 metric tons of coal per month was produced during 1944 in Cundinamarca and Boyacá. This figure represents a weighted average of estimates, made by informed persons, which ranged from 22,000 to 32,000 metric tons per month. About half the total came from seven mines, each producing 1,000 metric tons or more per month.

The geographic distribution of the output by local fields was approximately as follows:

Field	*Coordinates (center of field)* *Latitude*	*Longitude*	*Percentage of total output*
Cundinamarca:			
Guachetá-Lenguazaque (including Ruhr mine).	5°21′ N.	73°42′ W.	8
Nemocón	5°04′ N.	73°53′ W.	1½
Zipaquirá	5°02′ N.	74°00′ W.	14
Chocontá-Santa Rosita	5°07′ N.	73°41′ W.	17
Suesca-Sesquilé	5°04′ N.	73°48′ W.	28
Guatavita	4°55′ N.	73°51′ W.	4
Tequendama	4°33′ N.	74°18′ W.	16
Tocaima-La Virginia	4°26′ N.	74°42′ W.	3½
All others			5
Boyacá			3

Several hundred tons of coke per month was produced at Guachetá and minor amounts at two other localities. As coke production is limited by market demand, it is possible that noteworthy quantities of coking coal now are being mined and sold for noncoking use.

The railroads consumed about 30 percent of the total coal output, industries about 40 percent, and domestic users about 30 percent (for cooking). The chief industrial consumers were salt refineries, cement plants, breweries, brick and tile plants, glass factories, tanneries, and the Bogotá municipality.

ANTIOQUIA

The main coal district of Antioquia (pl. 8) extends along the eastern slope of the Cauca Valley from Sucre (lat. 6°35′ N., long. 75°48′ W.) nearly to Damasco (lat. 5°48′ N., long. 75°35′ W.). The current output comes chiefly from the district between Amagá (lat. 6°02′ N., long. 75°42′ W.) and Angelópolis (lat. 6°07′ N., long. 75°43′ W.), but minor amounts of coal are produced in the region around Titibirí (lat. 6°04′ N., long. 75°48′ W.), near Heliconia (lat. 6°13′ N., long. 75°44′ W.), and elsewhere. All the coke in Antioquia comes from the Titibirí region. The entire district was mapped and described in considerable detail by Grosse.[75]

Possible coal fields in northern Antioquia, where outcrops have been reported east of the Gulf of Urabá and at several scattered localities along the Nechí and Cauca Valleys, remain wholly unexplored and unstudied; hence they will not be further considered here.

The coal sequence, of "Eotertiary" age according to Grosse, may be divided into three members. Between Heliconia and Amagá and likewise in the vicinity of Titibirí, the lower member is 100 to 250 meters thick and consists of light-gray sandstone and conglomerate, light- to greenish-gray shale, and a few thin, nonworkable coal seams; the middle member is 170 to 250 meters thick and consists of light-gray to grayish-green shale, light-gray sandstone, and coal seams of which one or more may be workable; and the upper member is 1,000 or more meters thick and consists of gray to bluish-green sandstone that weathers yellow to pink, gray to variegated shale, and a few thin, nonworkable coal seams restricted to the lowermost part. North of Heliconia, the lower and upper members increase decidedly in thickness, and conglomerates become more abundant and appear at higher stratigraphic horizons than farther south. For the area south of Amagá, stratigraphic data are inadequate to determine whether the thickness and lithology of the coal sequence change.

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[75] Grosse, Emil, El Terciario carbonífero de Antioquia, Berlin, Dietrich Reimer (Ernst Vohsen), 1926.

Between Sucre and Damasco are a long, narrow eastern belt of "Eotertiary" rocks and a much shorter but somewhat wider western belt; branches at two places connect these belts. The eastern belt includes (1) a group of minor coal fields between Sucre and Ebéjico, which is 26 kilometers to the south-southeast; (2) the Heliconia field, 5 kilometers long, (3) the Amagá-Angelópolis field, some 9 kilometers long; and (4) the coal-bearing terrain south of Amagá, which remains nearly undeveloped except near Fredonia (lat. 5°55′ N., long. 75°40′ W.). The western belt includes several small, closely spaced, structurally complex fields near Titibirí and some nearly undeveloped coal-bearing terrain elsewhere.

The Amagá–Angelópolis field is the northern part of a long synclinal basin that pitches to the south and is bounded on each side by a major fault. Low dips, a scarcity of faults, and proximity to the railroad combine to favor economical exploitation in most of this field. Five potentially workable seams have an aggregate thickness of 6.5 meters within a stratigraphic zone 50 to 60 meters thick. The uppermost seam, which is 2 meters thick, has yielded the bulk of past production, and the second highest seam, which is a meter and a half thick, nearly all the remainder. South of Amagá, the output has been relatively slight, presumably because the coal may be steeply dipping, flexed, and faulted where it is accessible along the limbs of the syncline.

The Heliconia field is narrower and shorter, more complicated structurally by faults and folds, and more distant from the railroad than the Amagá–Angelópolis field. Meager data concerning the fields between Sucre and Ebéjico suggest that the seams there are fewer and thinner and that the structure is even more complex than at Heliconia.

The Titibirí area, comprising several small basins, contains all the coking coal known in Antioquia, yet by no means will all the coal there yield coke. At Sitio Viejo, immediately north of Titibirí, a narrow syncline overturned toward the west contains 7 to 10 workable seams, all of which yield coke. Elsewhere, steeply dipping beds cut by numerous faults include 3 to 6 workable seams, some of which yield coke. Mining in the past has concentrated on the thickest and most accessible seam within each small basin.

The very few available analyses of coal from Antioquia suggest that the normal range in composition is approximately:

Moisture (percent)	3–15
Volatile matter (percent)	25–50
Fixed carbon (percent)	38–48
Ash (percent)	1.5–4.0
Sulfur (percent)	0.3–1.1
Heat value (calories)	5,500–6,500

Grosse [76] estimated the reserves for the entire district as approximately 4,375,000,000 metric tons, of which half is less than a thousand meters deep. He further estimated that 455,000,000 metric tons, two-thirds of which is in the Titibirí, Amagá, Angelópolis, and Heliconia areas, may be exploited.

The reserves of coking coal were not estimated but may be regarded as relatively small, restricted to the Titibirí area, and in general capable of yielding only inferior grades of coke.

Coal production in Antioquia during 1944, according to one of the leading operators, averaged about 12,000 to 13,000 metric tons per month. Three-fifths of this total came from 5 mines, each producing 1,000 to 2,000 metric tons per month, and the remainder from 15 to 20 small mines. By contrast, Grosse [77] reports that 66 mines operated during 1922 to produce 51,600 metric tons of coal per year.

VALLE DEL CAUCA AND NORTHERN CAUCA

A coal series, locally named the "Cauca formation," crops out along the west side of the Río Cauca in a belt 5 to 25 kilometers wide and 120 kilometers long from Yumbo (lat. 3°35′ N., long. 76°30′ W.), in Valle del Cauca, nearly to Tambo (lat. 2°25′ N., long. 76°49′ W.), in Cauca, and also along a discontinuous transverse belt between Buenos Aires (lat. 3°01′ N., long. 76°38′ W.) and Calotó (lat. 3°03′ N., long. 76°25′ W.), in northern Cauca (pl. 8). The productive part of this district is the northern half of the belt along the Río Cauca. Most of the output is derived from the immediate vicinity of Cali, within an area that extends 5 kilometers northward from the city and 10 kilometers to the south. A subordinate output is derived from an area some 15 kilometers long between the railroad stations of Guachinte (lat. 3°10′ N., long. 76°37′ W.) and San Francisco (lat. 3°03′ N., long. 76°40′ W.), minor amounts from the vicinity of La Viga (16 kilometers south of Cali), and insignificant amounts from other parts of the belt. The southern half of the belt along the Río Cauca remains nonproductive mainly because it is not accessible by railroad or highway. The transverse belt is nonproductive because of the extremely poor quality of the coal, the seams being much too shaly for exploitation except possibly near Calotó.

The "Cauca formation," lower Tertiary in age according to the Servicio Geológico Nacional, is 250 to 550 meters thick and consists of gray shale with interbedded sandstone, conglomerate, coal, and

[76] Grosse, Emil, El Terciario carbonífero de Antioquia, pp. 330–331, Berlin, Dietrich Reimer (Ernst Vohsen), 1926.

[77] Grosse, Emil, El Terciario carbonífero de Antioquia, p. 329, Berlin, Dietrich Reimer (Ernst Vohsen), 1926.

perhaps some mottled shale. Hubach [78] divided the series into five members, all of which contain coal, but did not give lithologic details or thicknesses for each member. He regards the "Cauca formation" as equivalent to the coal series of Cundinamarca but slightly older than the coal series of Antioquia, whereas Grosse [79] regards the formation as equivalent to the lower and middle members of the coal series of Antioquia. According to Hubach, the strata comprising the formation were laid down in an intermontane basin that originally extended at least from latitude 1°29′ N. to latitude 4°45′ N. between the ancestral Cordilleras Occidental and Central; in the western part of this basin conditions were most favorable for the accumulation of source materials for coal.

Along the Río Cauca, the coal-bearing strata crop out in the foothills of the Cordillera Occidental. They are bordered on the west by older rocks and on the east by valley alluvium. They may continue beneath alluvium across the wide Cauca Valley, but the geologic structure is imperfectly known and the economic value of any seams that might exist there is questionable.

Two synclines separated by a very narrow, sharp anticline, according to Hubach,[80] exist within the foothills belt between Yumbo and La Viga, a distance of 30 kilometers. The western syncline is narrower and more tightly compressed than the eastern. A reverse, perhaps thrust, fault constitutes the eastern border of the eastern syncline. Coal is mined along both limbs of both synclines—that is, across the entire belt. Dips in the mines range from 40° to vertical, in general being 55° or more. Minor variations in strike and dip are common, but faults are not abundant. South of La Viga, little is known of the major structure; in places there may be only one syncline. Most mines, nevertheless, continue to reveal nearly vertical dips.

The greatest number and greatest aggregate thickness of seams are found in Cerro Golondrinas, immediately northwest of Cali, from which the number and thickness of seams decrease rather abruptly northward but very gradually southward. According to Hubach, there is a very slight decrease in the number and thickness of seams southward as far as the Río Melendez, 8 kilometers south of Cali; then a gradual decrease southward at least to the Río Pance, 18 kilometers south of Cali, and possibly as far as the Río Claro, 28 kilometers south of Cali; then a slight increase as far as the Río

[78] Hubach, Enrique, Geología económica del carbón y existencia de carbón en la región de Cali (private report dated May 11, 1934).

[79] Grosse, Emil, Informe rendido al Ministerio de Industrias sobre un viaje por la cuenca del Patía y el Departamento de Nariño: Compilación de los estudios geológicos oficiales en Colombia, tomo 3, p. 161, 1935.

[80] Hubach, Enrique, Geología económica del carbón y existencia de carbón en la región de Cali (private report dated May 11, 1934).

Asnazú, 30 kilometers southwest of Cali and a few kilometers south of San Francisco; and finally again a progressive decrease southward toward Tambo.

At least 10 different seams, each 60 centimeters or more thick, occur at Cerro Golondrinas, but the number is less at all other places. Individual mines, probably none of which transects all seams locally in the series, throughout the district exploit up to eight different seams separated by stratigraphic intervals ranging from a few meters to nearly 40 meters. Most mines work seams that are from 0.4 meter to 1.5 meters thick, but west and southwest of Cali there is a seam that averages more than 2 meters and locally attains 5 meters in thickness.

Sills and dikes of tonalite in the Cerro Ferriera, located in the eastern part of the Guachinte–San Francisco area, and in other places to the south have "anthracitized" the coal locally. The transformation has resulted in the loss of volatile matter but not in a hardening of the coal.

A great number of partial analyses and fewer complete analyses in the files of the local cement company and those of the railroad indicate the following ranges in composition:

Moisture: Normally 1 to 3 percent; rarely exceeds 4 percent.

Volatile matter: Ranges from 7 to 47 percent. In general, most coal from the Cali area contains 25 to 40 percent, and most coal from La Viga and areas farther south contains 10 to 30 percent.

Fixed carbon: Ranges, in accordance with other constituents, from 37 to 74 percent.

Ash: Ranges from 2.5 to 25 percent. In general, coal from the Cali and La Viga areas contains 10 to 20 percent, whereas coal from the Guachinte–San Francisco area contains 5 to 14 percent.

Sulfur: Normally 0.2 to 1.5 percent, but may be as high as 4 percent.

Heat value: Normally 6,600 to 7,200 calories. However, the extreme range is 6,200 to 8,000 calories.

All the coal has a strong tendency to break into fine particles and thus become "cisco" (powdered coal).

Only a small percentage of the coal yields coke, which is of inferior quality. Because local demands are slight, coke has been manufactured by few operators, and so the precise ratio of coking to noncoking coal cannot be stated. Hubach apparently believes that coking coal is confined mostly to the "coke member," one of his five members of the "Cauca formation." He states that the "coke member" exhibits its maximum aggregate thickness of coal between latitudes 3°06′ N. and 3°15′ N. yet also is exploited in other places.

The reserves of coal have been estimated by Hubach [81] as follows:

	Metric tons
Cali area, north of latitude 3°22′ N. (known and probable)	106,000,000
Between latitudes 3°22′ N. and 3°17′ N. (probable)	84,000,000
Between latitudes 3°17′ N. and 3°13′ N. (probable)	56,000,000
Between latitudes 3°13′ N. and 3°10′ N. (probable)	45,000,000
Between latitudes 3°10′ N. and 3°06′ N. (probable)	40,000,000
Between latitudes 3°06′ N. and 3°03′ (?) N. (probable)	43,000,000
Between latitudes 2°49′ N. and 2°44′ N. (probable)	32,500,000
Other latitudes	Not estimated

The foregoing estimates may be regarded as reasonably conservative, but they were made in the absence of geologic maps of the district. Hubach himself states that data are inadequate for the accurate calculations of reserves south of latitude 3°22′ N.

Of the calculated reserves, 10 percent are above the level of the Cauca Valley, the remainder below. However, the estimates do not include any possible continuations beneath valley alluvium east of the outcrop belt.

The output of coal during 1944 averaged about 11,000 to 12,000 metric tons per month. The railroad consumed two-thirds of the total and the cement plant, breweries, brick plants, other local factories, and domestic consumers nearly all the remainder.

The coke output during 1944 amounted to approximately 400 to 600 metric tons.

NORTE DE SANTANDER

Coal-bearing strata crop out intermittently along the eastern border of the Cordillera Oriental across Norte de Santander (pl. 8), but mining is restricted to the valley of the Río Pamplonita between Cúcuta (lat. 7°53′ N., long. 72°30′ W.) and Pamplona (lat. 7°23′ N., long. 72°38′ W.). The stratigraphic sequence for eastern Norte de Santander is set forth by Notestein, Hubman, and Bowler.[82] The Los Cuervos formation, which is lower Eocene in age and ranges from 250 meters to perhaps more than 500 meters in thickness, commonly contains 8 to 10 coal seams in the lowermost 75 meters. Individual seams range from 0.1 meter to 2.5 meters in thickness, but most are 0.5 to 1 meter thick. The fixed carbon ratio of 22 samples ranges from 49.0 to 58.4 and averages 54.5.

The reserves cannot be reliably estimated, even for the productive area. Along the Río Pamplonita, coal-bearing strata may occur in north-northeastward-trending segments separated by older rocks. The seams probably are considerably folded and faulted; dips at the two principal mines are about 45°.

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[81] Hubach, Enrique, Geología económica del carbón y existencia de carbón en la región de Cali (private report dated May 11, 1934).

[82] Notestein, F. B., Hubman, C. W., and Bowler, J. W., Geology of the Barco concession, Republic of Colombia, South America: Geol. Soc. America Bull., vol. 55, pp. 1165–1216, 1944.

The output of the Cúcuta-Pamplona district in 1944 was not more than 5,000 metric tons. The bulk of this came from two mines located about 18 kilometers north of Pamplona, the remainder from half a dozen scattered small mines. Nearly all the output is sold in Cúcuta, half of it to the Cúcuta–Puerto Villamizar railroad and the other half to the brewery, to the liquor factory, and to domestic consumers for cooking.

CALDAS

In Caldas, coal crops out at various places in the municipios of Ríosucio (lat. 5°25′ N., long. 75°42′ W.) and Quinchía (lat. 5°21′ N., long. 75°43′ W.) and also at scattered localities east of the Río Cauca (pl. 8). Near Ríosucio, half a dozen or more mines, past and present, as well as most of the known outcrops of coal, are within an area of 6 square kilometers located 3 to 4 kilometers west-northwest of the town. Near Quinchía, five or more mines, past and present, are located in different directions from the town.

Presumably the coal sequence of Caldas is a southward extension of the coal sequence of Antioquia, but the general stratigraphy, geologic structure, and areal distribution remain almost unknown. Near Ríosucio, the thickness of productive seams ranges from 1 meter to 2 meters. Two seams, 1 meter and 1.95 meters thick, respectively, are worked in one mine. Four different seams, 0.5 meter, 0.7 meter, 1.75 meters, and 1.6 meters thick, respectively, are known, but only one has been worked at another mine. Dips range from 20° to 40°. Near Quinchía are seams ranging from 1 meter to 3 meters in thickness. Dips in different mines range from moderate to steep, and minor variations in dip may be found within a single zone.

The eight available analyses suggest the following ranges in composition for coals near Ríosucio:

Moisture (percent)	1.4–5.4
Volatile matter (percent)	30–42
Fixed carbon (percent)	50–60
Ash (percent)	1.8–4.5
Sulfur (percent)	0.5–2.4
Heat value (calories)	6,200–8,200

Coke, probably of inferior quality, can be made from some of the Caldas coal.

During 1944 an aggregate output of some 2,000 metric tons was derived from two or three mines near Ríosucio and two mines near Quinchía.

Data are inadequate to calculate reserves, but it is the writer's impression that the reserves of the Ríosucio and Quinchía areas are much less than those of the Valle–Cauca district, that the geologic structure of the coal-bearing areas may be fairly complex, and that only

limited quantities of the coal will yield coke. None of the localities east of the Río Cauca holds promise for commercial exploitation, except possibly a small area northeast of Cartago (lat. 4°45′ N., long. 75°55′ W.).

SOUTHERN CAUCA AND NARIÑO

Coal-bearing strata of "Eotertiary" age, identical in age with the coal series at Cali according to Grosse,[83] form a somewhat complex structural basin that extends from Peñol (lat. 1°29′ N., long. 77°28′ W.), Nariño, nearly to Tambo (lat. 2°25′ N., long. 76°49′ W.), Cauca. These strata crop out on both sides of the Patía Valley, along the margins of the basin, but are buried beneath thousands of meters of younger beds in the center of the basin. Data regarding the number and thickness of the seams are still too meager to outline the potentially productive parts of the district.

The most favorable area for future exploration, according to Grosse, is northwest of Mosquera (lat. 2°19′ N., long. 76°53′ W.), Cauca (pl. 8), where seams may be cut by adits and where possible reserves may amount to 75,000,000 tons. Elsewhere along the outcrop belt west of the river, whatever coal exists must be mined from shafts. In general, the outcrop belt east of the Río Patía seems to have fewer and thinner seams and so holds less promise for eventual exploitation than the belt west of the river. Grosse states that, if the aggregate thickness of workable seams all the way from Peñol to Tambo averages 2 meters, the reserves would be some 5,000,000,000 metric tons; however, in view of the very meager data now available, Grosse's estimate must be regarded as a highly optimistic guess.

Details regarding the thickness of seams in scattered outcrops may be obtained from Grosse's paper.

SANTANDER

Coal-bearing strata in Santander crop out (1) within a belt along the western slope of the Cordillera Oriental from about latitude 5°50′ N., longitude 74° W., to latitude 7°35′ N., longitude 73°20′ W., and (2) in a narrow tectonic basin along the Río Servitá from latitude 6°35′ N., longitude 72°44′ W., to latitude 6°55′ N., longitude 72°42′ W. Geologic data are fragmentary and meager for both districts, and so the coal potentialities are only vaguely known.

Coal along the western slope of the Cordillera, according to Royo,[84]

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[83] Grosse, Emil, Informe rendido al Ministerio de Industrias sobre un viaje por la cuenca del Patía y el Departamento de Nariño: Compilación de los estudios geológicos oficiales en Colombia, tomo 3, pp. 139–231, 1935.

[84] Royo y Gomez, José, Los carbones del Departamento de Santander: Informe del Ministro de Minas y Petróleos, 1942, tomo 1, pp. 148–157, 1942.

occurs in the basal part of the Lisama formation, of lower Eocene (?) age, and in the Umir formation, of uppermost Cretaceous age. The geologic structure presumably is complex, and the coal may be restricted to local basins. The dip ranges from moderate to steep at the few localities where seams have been exploited to a small extent. Royo's meager data suggest that the number and thickness of seams may decrease progressively northward from the municipio of Landázuri (lat. 6°13′ N., long. 73°48′ W.), where one seam is 1.4 meters thick, another 0.95 meter, several others 0.8 meter, and still others 0.6 meter or less (pl. 8). His few analyses suggest an ash content of 10 to 30 percent and a heat value of 5,000 to 6,800 calories (9,000 to 12,000 B. t. u.)

Coal in the Servitá Basin is in the lower part of the Guaduas formation, which is regarded as mainly Eocene and Oligocene but may also contain strata of uppermost Cretaceous age. Data regarding the number, thickness, and quality of seams are wanting.

MAGDALENA AND GUAJIRA

A coal sequence, called the Cerrejón formation, crops out in the Barrancas (lat. 10°57′ N., long. 72°47′ W.), region of Magdalena and perhaps in adjacent parts of Guajira (pl. 8). Oppenheim [85] has made a reconnaissance study of the area in which known outcrops of coal are most numerous. This area is about 80 kilometers by air line, across a plain having slight relief, from the seaport of Riohacha (lat. 11°33′ N., long. 72°55′ W.).

The Cerrejón formation, of lower Tertiary age according to Oppenheim, is about 1,000 meters thick and consists of pale-yellow to pink sandstone and shale, with coal seams as well as intercalated thin limestones restricted to the lower part. Individual seams, as revealed by 17 outcrops, range from 0.3 meter to 3.5 meters in thickness. Oppenheim's profile sections show from three to five different seams, but additional ones that do not crop out may be present. Arango [86] believes that six seams, aggregating 16.4 meters in thickness, occur locally.

Within the area mapped by Oppenheim, a belt of Cerrejón strata 2 to 3 kilometers wide extends 20 kilometers northeastward from Barrancas along the southeast side of the Río Ranchería. The southeast border of this belt probably is a major fault zone, for Oppenheim depicts Cerrejón strata everywhere dipping toward Cretaceous and Jurassic strata to the southeast. However, Cerrejón strata continue

[85] Oppenheim, Victor, La cuenca carbonifera del Cerrejón: Bol. minas y petróleos, nos. 121–144, pp. 67–80, 1939–40.

[86] Arango, Roberto (former chief of mining department, Ministerio de Minas y Petróleos), oral communication, 1945.

to unknown distances northeastward, northwestward, and southwestward from the mapped area, though additional coal outcrops have been reported at only two places to the northwest.

The rank and quality of coal in the Barrancas region remain very imperfectly known. Weighted averages, computed by Arango, of 9 to 29 analyses of seams at each of six localities range as follows:

Moisture (percent)	5.3–9.8
Volatile matter (percent)	36.3–39.8
Fixed carbon (percent)	50.8–53.7
Ash (percent)	1.05–2.42
Sulfur (percent)	0.38–0.94
Heat value (calories)	6,600–7,370

Reserves of coal in excess of some 50,000,000 metric tons are not assured by the present meager data. However, reserves of several hundred millions of metric tons, or more, may possibly be calculated when the number, thickness, and areal extent of seams become better known. There was practically no output prior to 1945.

MINING METHODS

With very few exceptions, the mines are worked either from inclined shafts less than 300 meters long or from adits less than 866 meters long. In the inclined shafts, coal is handled by power-operated cars with a capacity of 1 metric ton or less in the larger mines and by men carrying fique baskets with a capacity of about 50 kilograms in the smaller mines. Along a level, coal may be transported in cars having a capacity of 1 metric ton or less, in wheelbarrows, or in fique baskets or gunny sacks; cars are pushed by hand except in a few mines where there are mules. At the mine portal, coal may be dumped directly into 25-ton gondolas, but more commonly it must be transported by truck, by oxcart, or on muleback either to the railroad or to the consumer. Only two aerial tramways, both in the Cali region, have been constructed to transport coal from mine to railroad.

Mining is done by overhand stoping where dips are moderate to steep. From drifts along the strike of a seam, raises are driven normally at intervals of 6 to 20 meters and to heights of 50 to 100 meters along the dip. Sublevels then are driven from each raise, normally at intervals of 10 to 20 meters measured along the dip. The actual spacing of the raises and sublevels varies according to the thickness of the seam, the condition of the roof, and the like. Finally, the coal blocked out by raises and sublevels is partly or wholly removed in systematic order while the roof is supported by fill or by timbers.

A system of room and pillar mining is employed where dips are at low angles. From an inclined shaft or adit, a main haulageway is driven up or down the dip of a seam for a distance rarely exceeding 100 meters. Then rooms having 2 to 7 meters of front are driven to

distances ranging from less than a hundred meters to as much as several hundred meters along the strike. As the rooms advance, interconnections are made so as to leave pillars from about 5 by 5 meters to more than 10 by 10 meters in area. In retreating, these pillars commonly are partially removed by quarters.

Coal is removed by pick, and rock by hammer and moil, except in a very few mines equipped with air or electric hammers, drills, or shovels. Dynamite is used for rock only, and almost no mines use black powder. Candles, kerosene torches, carbide lamps, or, at several mines, electric lamps furnish light. Water from shaft mines may be removed either by power pump or by hand. Nearly all mines are free of gas.

In nearly all the medium-sized and larger mines, wages are paid in accordance with a contract by which a stipulated minimum wage is augmented in accordance with the actual amount of work done. During 1944–45, miners averaged about 750 to 1,000 pesos ($430 to $540, American currency) per year, muckers and trammers somewhat less, and surface laborers about 400 to 500 pesos ($230 to $290) per year. The price of lump coal at the railroad siding in different parts of Colombia was 7 to 10 pesos ($4 to $5) per ton, and that of "cisco" (fine-grained coal) was less.

COPPER

Although areas of copper mineralization are widespread in Colombia (pl. 9), no copper ore was mined during the period of 1942–45 or had been mined for many years previous. The alleged production during colonial times and later probably came from very small ore shoots which may have been worked primarily for precious metals.

The present outlook for finding large tonnages of copper ore that can be mined for export is discouraging. On the other hand, reasonable hope may be entertained for developing small tonnages, at several localities, which might be mined profitably for domestic consumption. Moreover, systematic and detailed scouting and geologic mapping in several areas—for example, northeastern Magdalena and the Natagaima area of Tolima—might yield clues to ore deposits more promising than any examined to date.

The best-known copper deposits in Colombia include bedded replacement deposits in limestone, pyrometasomatic deposits, veins in intrusive rocks, and perhaps deposits of the "red bed" type in Mesozoic sedimentary rocks that contain interbedded sills.

ANTIOQUIA

At Cerro de Plateado (lat. 6° N., long. 76°07′ W.), a paramo 2,000 to 3,000 meters in altitude along the crest of the Cordillera Occidental,

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are veins said to be less than half a meter in width that contain chalcopyrite and minor gold (pl. 9). Data from second-hand sources suggest that none is a promising showing of commercial ore.

Copper minerals have been reported (1) at a locality 3.5 kilometers north-northwest of Santa Barbara (lat. 5°52′ N., long. 75°35′ W.) and (2) at several places in general proximity to Dabeiba (lat. 7°01′ N., long. 75°35′ W.), but no tangible data concerning them even remotely suggest commercial possilibities.

BOYACA

About 4 kilometers south of Moniquirá (lat. 5°52′ N., long. 73°36′ W.) is a mine said to have been operated from 1892 to 1900 by an English company (pl. 9). W. D. Longan examined the locality in 1942. Only two of the former adits could be found; and only one was accessible, for a distance of 22 meters. There are several small stopes along a vein, 10 to 30 centimeters wide, of iron-stained quartz with specks of malachite and azurite. The wall rock is sandstone.

CALDAS

LA DIAMANTINA PROSPECT

La Diamantina prospect (pl. 9), located 3 kilometers north of Marquetalia (lat. 5°17′ N., long. 75°04′ W.), was examined by W. D. Longan. A quartz vein heavily impregnated with sphalerite, galena, chalcopyrite, bornite, and chalcocite is exposed at one place only. The vein probably is 2 meters wide, and the wall rock is schist. Soil stripping is needed to determine the surface dimensions and tenor of this deposit.

LA TASCON PROSPECT

La Tascon prospect (pl. 9), located about 5 kilometers northeast of Anserma (lat. 5°13′ N., long. 75°48′ W.), was examined by W. D. Longan. In the bed of a small ravine is an outcrop, 2 meters long and 0.2 to 0.5 meter wide, exhibiting chalcocite, bornite, chalcopyrite, pyrrhotite, and copper carbonates. The wall rock probably is monzonite. The copper minerals comprise about 3 percent by area of the outcrop. Soil stripping is needed to appraise the deposit.

CUNDINAMARCA

CERRO DE COBRE PROSPECT

The Cerro de Cobre (pl. 9), examined by the author in 1942, is along the Guavio Valley, 15 kilometers east-northeast of Gachalá (lat. 4°41′ N., long. 73°30′ W.), in a sparsely settled region. The bedrock is massive limestone, several hundreds of meters thick, that may be either Carboniferous or Cretaceous in age. Copper mineralization is distributed irregularly as replacements of the limestone, mainly

within two stratigraphic zones that are 4 to 10 meters thick and about 130 meters apart. The mineralization seems to be concentrated near the crest of a plunging anticline, particularly where cut by relatively open fissures. The hypogene ore mineral is chalcopyrite, which is erratically scattered in aggregates having great diversity of form and ranging in size from mere specks to masses larger than one's fist. The gangue is almost entirely limestone, calcite, and limonite, but pyrite occurs in two places. Malachite and minor amounts of azurite are widespread. The absence of visible chalcocite suggests that most of the copper leached during weathering was carried down the steep slope to the Río Guavio. If limonite in present exposures of partly oxidized ore came mainly from chalcopyrite, some hypogene ore was richer than any of the samples that have been analyzed. The geological details of the prospect adits are shown by plate 24 and the locations of the adits by plate 26 of Suarez' report.[87]

The ground best explored is a central block in which some 120,000 metric tons of the lower ore horizon from the covering shell, so to speak, of a topographic nose whose crest and steep slopes nearly coincide with the attitude of the strata. The copper content of the ore horizon where now exposed ranges from less than 1 percent to nearly 7 percent. However, the bedrock is mostly covered by a thin mantle of soil, and prospect adits are not spaced systematically enough to determine the average tenor of the ground.

South of the central block but geographically within the boundaries of known mineralized ground is an area containing 600,000 to 1,000,000 metric tons of unprospected lower ore horizon beneath barren limestone. Part, all, or none of this may be ore. In addition, some 350,000 metric tons of upper ore horizon remain uneroded within known limits of mineralization.

Possibilities north of the central block, across the Río Guavio, seem less promising than elsewhere.

SAN RAFAEL PROSPECT

The San Rafael prospect (pl. 9), examined in 1942 by the author, is 1 kilometer east of Ubalá (lat. 4°44′ N., long. 73°32′ W.). One stope, said to be a mine working of colonial times, is 20 meters long by 1 meter to 2 meters high, dips 20° to 25° into the hillside, and is nearly filled by water. The ore apparently was a chalcopyrite replacement body, conformable with the dip, in limestone of Cretaceous age. No copper-bearing float nor other clues to ore bodies that might be concealed by soil exist in the vicinity.

[87] Suarez Hoyos, Vicente, Reconocimiento geológico de la región del Guavio, Gachalá (Cundinamarca): Compilación de los estudios geológicos oficiales en Colombia, tomo 6, pls. 24 and 26, 1945.

COCUNCHE PROSPECT

The Cocunche prospect (pl. 9), located in the municipio of Nocaima at latitude 5°05′ N., longitude 74°26′ W., was examined in 1945 by J. K. Cathcart. The bedrock is of the Villeta formation (middle or late Cretaceous). An open-cut, 10 meters long, exposes a vein that is 0.8 to 1 meter wide and conformable with the nearly vertical bedding. The vein contains quartz with included shale fragments and sparse pyrite, siderite(?), small masses of chalcopyrite, and copper-stained limonite. Similar material, with chalcopyrite constituting less than 1 percent of the vein, is on the dumps of two short, inaccessible adits. However, only vuggy quartz and calcite were found in the lowest adit, 35 meters vertically below the vein outcrop.

OTHER LOCALITIES

Vague rumors exist of copper showings at scattered localities along the lower western slope of the Cordillera Oriental between latitude 5°03′ N., longitude 74°25′ W., and latitude 5°25′ N., longitude 74°20′ W. At one locality, allegedly worked during colonial times, almost no copper showings were seen by W. D. Longan in 1942.

Alleged showings of widespread, rich chalcocite deposits of the "red bed" type within Girón (Jurassic or Triassic) strata in the Farallones region (lat. 4°25′ N., long. 73°35′ W., to lat. 4°40′ N., long. 73°25′ W.), an extremely inaccessible part of southeastern Cundinamarca, remain unconfirmed.

CHOCO

Chalcopyrite-bearing veins, ranging from 0.3 meter to 4 meters in width, are alleged to exist within a group of claims (pl. 9), in aggregate 20 kilometers long and several kilometers wide, along the Río Andágueda upstream from Bagadó (lat. 5°25′ N., long. 76°25′ W.). The terrain, accessible by canoe over difficult rapids, is covered by dense jungle, and so outcrops are to be expected only along stream banks.

MAGDALENA

Malachite, azurite, chalcocite, cuprite, and perhaps other copper minerals are found along the flanks of both the Sierra de Perijá and the Sierra Nevada de Santa Marta where these ranges face one another for 150 kilometers in northeastern Magdalena. The best known localities (pl. 9) are in proximity to the towns of Barrancas (lat. 10°57′ N., long. 72°47′ W.), Conejo (lat. 10°52′ N., long. 72°49′ W.), Molino (lat. 10°39′ N., long. 72°56′ W.), Villa Nueva (lat. 10°36′ N., long. 72°59′ W.), San Diego (lat. 10°18′ N., long. 73°09′ W.), and Camperucho (lat. 10°08′ N., long. 73°38′ W.). However, persistent rumors allege that copper showings abound elsewhere.

The copper minerals have generally been regarded as restricted to the Girón formation (Jurassic or Triassic), whose distribution is shown by Oppenheim's map,[88] but oil-company geologists have found them in strata both above and below the Girón. Composed of red beds with intruded sills, the Girón is more than a thousand meters thick.

Only a few copper showings, all of which proved to be unpromising, have been examined by geologists or engineers. To verify or disprove the rumors of widespread mineralization, systematic scouting along and adjoining the Girón strata shown by Oppenheim's map would be needed.

SANTANDER

Rumors of widespread copper deposits along the Chicamocha and Sogamoso Canyons to the west and northwest of Los Santos (lat. 6°46′ N., long. 73°07′ W.) remain unconfirmed. At two of the localities, geologists and engineers have described copper showings as exceedingly unpromising. The difficulties of access into the canyons would make systematic exploration for new localities formidable.

About 3 kilometers east of Coromoro (lat. 6°18′ N., long. 73°03′W.) is an outcrop, 0.6 meter by 4.5 meters in area, of limestone heavily impregnated with galena, chalcopyrite, and sphalerite. Soil conceals the bedrock in all directions from this outcrop.

Chalcopyrite is a constituent of some of the gold veins in the California, Baja, Angostura, Alta, and Vetas districts, located east, northeast, and southeast of the town of California (lat. 7°21′ N., long. 72°58′ W.).

TOLIMA

NATAGAIMA DISTRICT

The Natagaima district (lat. 3°38′ N., long. 75°07′ W.) has been investigated by Reymond,[89] who states that "surface indications do not justify any hope of the deposits having economic value." Reymond examined 29 veins, most of them on the eastern slope of the divide between the Ríos Magdalena and Saldaña, the remainder in the foothills of the Cordillera Oriental, east of the Río Magdalena. The veins range from 10 centimeters to several meters in width but are very short and nonpersistent; they contain quartz, pyrite, chalcopyrite, limonite, covellite, chalcocite, malachite, and azurite, carry very minor amounts of gold and silver, and cut intrusive dacites.

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[88] Oppenheim, Victor, Geología del Departamento del Magdalena: Compilación de los estudios geológicos oficiales en Colombia, tomo 5, map opposite p. 498, 1942.

[89] Reymond, Edouard, abstract in Memoría del Ministro de Minas y Petróleos, 1943, pp. 196–198, 1943.

MINA VIEJA, EL SAPO, AND VENECIA PROSPECTS

In the municipio of San Luis, on the eastern slope of a mountain range that, between latitude 4°20′ N., longitude 75°07′ W., and latitude 4°13′ N., longitude 75°12′ W., rises some 1,000 meters above a plain to the north, east, and southeast to form an outlier of the Cordillera Central, are two ancient mines said to have been worked during colonial times and other scattered showings of mineralization. Prevailing bedrock of the range is limestone, probably Mesozoic in age, which has been intruded by stocks and smaller bodies of quartz-poor monzonite and overlapped by younger beds. Copper mineralization, apparently not accompanied by either molybdenum or tungsten, occurs both in pyrometasomatic deposits and in lower-temperature replacement bodies in limestone. Little hope for the discovery of large copper deposits can reasonably be entertained.

At Mina Vieja de Payandé (lat. 4°17′ N., long. 75°07′ W.), which was examined by the author, one may see the remnants of an ancient furnace, fragments of slag, and seven mine workings whose aggregate output apparently was 5,000 to 8,000 metric tons of ore (pl. 9). Other ancient mine workings may be concealed by soil and thick brush. Pyrometasomatic ore was mined from small, pockety shoots within a mineralized zone that is about 30 meters in outcrop width and 120 meters in exposed length. The bedrock in the mineralized zone ranges from recrystallized limestone to skarn rock composed of calcite, garnet, epidote, vesuvianite(?), and other contact silicate minerals. Float and scattered outcrops suggest that monzonite lies no more than 100 meters to the south. Malachite and minor azurite, along with limonite, are very irregularly distributed, locally coating nearly all the rock surfaces but elsewhere being exceedingly scarce within the mineralized zone. Pyrite and chalcopyrite are erratically distributed in grains and in aggregates rarely larger than one's thumb. A chip sample collected from an ore face assayed 3.3 percent copper, 3.5 ounces of silver per ton, traces of gold, and no molybdenum nor tungsten. To appraise the potentialities adequately the brush must be cleared, the rock faces cleaned, and trenches dug outside the 4,000 square meters now exposed. Data at hand, however, suggest that shoots exceeding a few thousand metric tons of ore containing 2 to 5 percent copper and minor silver and gold are not reasonably to be anticipated.

At El Sapo (lat. 4°13′ N., long. 75°10′ W.), ancient workings include two groups of small, shallow open-cuts and several adits (pl. 9). Data from secondhand sources suggest that a zone of pyrometasomatic ore is 1 meter to 3 meters wide, dips steeply, and is locally exposed over an outcrop length of about 100 meters. Small, pockety shoots apparently were exploited. Prospecting is needed to determine

whether this zone continues laterally or in depth and whether ore bodies exist outside the zone. The ore now in sight is insignificant. Specimens from El Sapo contain malachite, limonite, and minor azurite, with sphalerite, pyrite, chalcocite, and perhaps other sulfide minerals, in a gangue of contact silicate minerals. A sample of ore "sand"—that is, material ground up, presumably by the Spaniards, in preparation for smelting—assayed 3.04 percent copper, 27 ounces of silver per ton, an insignificant amount of gold, and no molybdenum nor tungsten.

The Venecia tract, about 3 by 3 kilometers in area, located directly north of El Sapo, was visited briefly by the author. Thirteen showings contain one or more of the following metals: copper, molybdenum, lead, zinc, gold, and silver. Appreciable copper occurs only at one locality, named El Salitre; there a small shoot of high-grade malachite ore, containing minor gold and silver, occurs as a replacement body in limestone. Other malachite showings may be seen in the vicinity.

SHOWINGS IN MUNICIPIO OF ROVIRA

Copper showings have been reported at La Fortuna prospect (approximately lat. 4°15′ N., long. 75°20′ W.), the Tuamo prospect (approximately lat. 4°09′ N., long. 75°17′ W.), and the San Antonio prospect (approximately lat. 4°05′ N., long. 75°20′ W.), all in the municipio of Rovira. No tangible data suggest that any of these is worth an examination.

EMERALDS

Emeralds have long been an important and famed mineral product of Colombia. The ensuing information about them is derived almost entirely from publications by Scheibe,[90] Pogue,[91] and Rainier, Mentzel, and MacFadden.[92] The FEA mission did not concern itself with emerald deposits, partly because none were being mined during 1942–45 but mainly because they are not an apparent source of raw material for beryllium. A nontransparent green beryl called "morralla" accompanies the emerald but is too scarce to be procured in significant quantities for sale as commercial beryl.

More than 150 emerald localities have been reported. They are scattered in two general regions which, together with an intervening barren region, comprise a belt some 70 kilometers wide that extends southeastward across the Cordillera Oriental from northwestern

[90] Scheibe, Roberto, Informe geológico sobre la mina de esmeraldas de Muzo: Compilación de los estudios geológicos oficiales en Colombia, tomo 1, no. 4, pp. 169–198, 1933.

[91] Pogue, J. E., The emerald deposits of Muzo, Colombia: Am. Inst. Min. Eng. Trans., vol. 55, pp. 910–933, 1917.

[92] Rainier, P. W., The Chivor-Somondoco emerald mines of Colombia, with appendixes by Charles Mentzel and C. K. MacFadden: Am. Inst. Min. Met. Eng. Tech. Pub. 258, 1930.

Boyacá (pl. 10). Only the Muzo (lat. 5°33′ N., long. 74°10′ W.), Cosquez (approximately lat. 5°39′ N., long. 74°10′ W.), and Chivor or Somondoco mines (approximately lat. 4°52′ N., long. 73°22′ W.) are believed ever to have been important producers, however, and only a few others anything more than mineralogic occurrences.

The principal emerald deposits had long been worked by aboriginal Indians prior to the colonial period. The first mines discovered by Spaniards, in 1538, were those of the Chibcha Indians at Chivor. Not until 1558, however, did the Spaniards locate any workings in the land of the hostile Muzo Indians, and the site of the present Muzo mines may not have been found until 1594.

The Muzo mines, which have been consistently outstanding as to both quality and quantity of the stones produced, have been intermittently worked ever since the Spaniards found them. The last operations (prior to 1947) terminated in 1938 in order to permit the disposition of an accumulated stock pile. The Chivor mines were exploited on a large scale until about the close of the sixteenth century, when they became lost, but they were rediscovered early in the twentieth century. There the last operations (prior to 1947) terminated about 1935. The Cosquez deposits, according to Scheibe, yielded large, fine emeralds, but because they are relatively difficult to mine, they have not been exploited since early in the nineteenth century.

Concerning the output at Muzo, Pogue [93] states:

> The pre-Spanish output, undoubtedly significant, is of course not open to any measure. In historic times, the output was so irregular and the records so incomplete, that a fair basis for judgment is entirely lacking. Nevertheless, it is certain that the total output may be estimated in terms of tens of millions of dollars, and that in many single years the production has run in value from $1,000,000 to perhaps $2,000,000, or more.

Even less is known of the output at other localities.

All emerald deposits are the property of the Nation. Moreover, it is illegal for any individual to possess uncut emeralds or to ship them except under Government seal. Mining rights in Muzo, Cosquez, and four other emerald preserves in northwestern Boyacá are assigned to the Banco de la República, whereas mining rights at Chivor are retained by an American group that acquired them in 1925. Exclusive rights to supervise the sale of emeralds are assigned to the Banco de la República. When the stock pile of emeralds became exhausted in 1946, the Banco began seeking a mining group willing, not only to reopen the Muzo mines, but also to establish a cutting industry in Colombia.

Mining is done by the open-cut method, after the surface has been stripped of its jungle growth. A steep slope, 50 to 150 meters long and

[93] Pogue, J. E., op. cit., p. 932.

15 to 20 meters high, which may be the side either of a mountain or of an artificial V-shaped cut, is worked by terraced benches not more than a meter deep. Rows of peons stand on the benches and attack the rock with long iron crowbars. The emerald-bearing veins are carefully removed by hand, but the rock debris slides down the slope and is washed away by water. Diverted from streams, the water is stored in "tambres," excavations with wooden gates which may be emptied rapidly. From time to time the emeralds, after hand picking, cleaning, and grading, are transported under seal and by a Government official to Bogotá.

MUZO MINES

GEOGRAPHY

The Muzo mines (pl. 10) are located 8 kilometers by trail west of the small town of Muzo (lat. 5°32′ N., long. 74°06′ W.), which in turn is 84 kilometers by one-way auto road southwest of a railroad and a main highway at Chiquinquirá (lat. 5°37′ N., long. 75°50′ W.). On excessively steep mountain slopes, at a mean altitude of about 800 meters above sea level, open-cuts at different times have extended over a total area of at least 300,000 square meters (74 acres), but they have been nearly obliterated by the rank growth of tropical vegetation, which quickly covers abandoned mine workings. The climate is hot and humid, and the population of the region is moderately sparse.

BEDROCK

A geologic sketch map of the Muzo mine area has been published by Scheibe.[94] Sedimentary strata of Cretaceous age constitute the bedrock. Locally recognized are two lithologic divisions named the "Capas Esmeraldíferas" and the "Cambiado." The former is uneroded over an irregularly shaped area of approximately 450,000 square meters (111 acres), where it has a maximum thickness of about 50 meters. Its basal contact is exceedingly uneven, being characterized by abrupt changes in inclination, and is discordant with the underlying "Cambiado"; Scheibe and Pogue regard it as a tectonic boundary along which the "Capas Esmeraldíferas" have been shoved across truncated strata of the "Cambiado." The "Capas Esmeraldíferas" are a very thinly bedded sequence of soft, black shale and subordinate hard and dense shaly limestone in beds that average 2 to 5 centimeters in thickness. At a few places these strata are nearly horizontal, but elsewhere they are flexed, contorted, and ruptured. The "Cambiado," according to Scheibe, is mainly black to bluish-black shale, in which bedding planes are obscure, but it contains intercalated zones of nodu-

[94] Scheibe, Roberto, Informe geológico sobre la mina de esmeraldas de Muzo: Compilación de los estudios geológicos oficiales en Colombia, tomo 1, no. 4, pl. 4, 1933.

lar limestone and of pyrite concretions. Its prevailing dip is 60° to the south.

Two pegmatites in the "Cambiado" near the mine area were mapped by Scheibe, who describes them as composed of quartz, potash feldspar, sericite, and accessory albite, apatite, and other minerals.

HYPOGENE ALTERATON PRODUCTS

"Roca albitica," "cama," and "cenicero" are local names for products of hypogene alteration. In the order named from base to top, they normally occur as discontinuous layers or lenses having variable thicknesses of less than a meter to several meters directly beneath the "Capas Esmeraldíferas"; these relations are illustrated by Pogue.[95] However, the "cenicero" may extend as tongues into or as outlying nests in either the "Capas Esmeraldíferas" or, less commonly, the "Cambiado," and the "cama" may curve abruptly into carbonate veins in the "Cambiado." The "cenicero" is more widespread and continuous than the other two, according to Scheibe's map, yet is absent over much of the district. The "cama" is present throughout nearly half the area in which the "cenicero" has been mapped. The albite rock is much less continuous but more widely scattered than the "cama" and may occur independently even of the "cenicero."

The typical albite rock, according to Scheibe, ranges from a black, friable rock containing an abundance of disseminated albite granules to a nearly white rock composed of large and small albite crystals whose interstices are filled by tiny remnants of black shale. The original bedding normally is preserved in the former but not in the latter. Some varieties of albite rock contain calcite, which may become the chief constituent. In places the albite rock grades downward or laterally into unaltered "Cambiado" strata, but elsewhere the contact is sharp. Veins containing calcite, dolomite, albite, pyrite, and quartz may adjoin the albite rock. Scheibe states that the albite rock occurs at many places in isolated lenses, having an "extensión" of several meters, but that the aggregate area of these lenses is only a fraction of the area in which albite rock is absent at the top of the "Cambiado."

The "cama" is composed of rhombohedrons and rhombic twins of calcite, 5 to 10 centimeters in diameter, with accessory quartz. It pinches and swells abruptly. Locally it may be represented by a few isolated crystals. According to Pogue, the calcite crystals are unit rhombohedrons. Barite may appear in the "cama" as crystals in druses or as veinlets. Very rarely is the "cama" unaccompanied by "cenicero."

Typical "cenicero" is gray and composed of dolomite rhombs, calcite, quartz, and pyrite in a calcareous matrix that, according to Scheibe,

[95] Pogue, J. E., op. cit., figs. 7, 8, and 9.

may contain either barite or talc (or pyrophyllite?). At places, barite becomes the chief constituent, appearing as nodules or layers up to 40 centimeters in thickness. A red-weathering facies, which may interfinger with the gray "cenicero" but more commonly is beneath it, is composed mainly of dolomite, albite, and pyrite; this facies may contain lenses of nearly pure pyrite up to 0.4 square meter in area. Included in the "cenicero" are fragments of black shale, albite rock, light-colored shale, and veins derived from the "Capas Esmeraldíferas." At some places, particularly where the "cenicero" is absent, masses of breccia up to 2 meters in thickness underlie the "Capas Esmeraldíferas."

VEINS

The "Capas Esmeraldíferas" are crossed at random by many veins composed of calcite, with or without dolomite and minor accessory minerals, including emeralds. According to Olden,[96] the veins range from less than a centimeter to 60 centimeters in thickness. Where they cross ruptured strata, the veins themselves are ruptured. The paragenesis given by Scheibe for veins in the "Capas Esmeraldíferas" is: (1) calcite and pyrite; (2) calcite, dolomite, quartz, emerald, parisite, albite, apatite, and fluorite; (3) calcite and barite.

Calcite, calcite-dolomite, and albite-dolomite veins that are no more than a few meters long nor more than 25 centimeters thick are moderately abundant in the "Cambiado" near its boundary with the "Capas Esmeraldíferas." Accessory minerals of these veins include pyrite, barite, quartz, apatite, talc, and allophanite, but not emerald.

OCCURRENCE OF EMERALDS

Most emeralds and "morralla" are found in calcite veins in the "Capas Esmeraldíferas," but a few are embedded within those strata or within the "cenicero." According to Olden,[97] the best stones commonly are in veins less than 15 centimeters thick. The emeralds occur as six-sided prisms, few of which are larger than one's thumb. Many are broken. Choice specimens display a rich green color surpassed by the product of no other locality. A crystallographic study of Muzo emeralds has been published by Bernauer.[98]

CHIVOR MINES

The Chivor mines (pl. 10), near the junction of the Río Rucio with the Río Guavio, are approximately 9 kilometers by air line (7 hours by trail) southeast of the town of Somondoco (lat. 4°58′ N., long.

[96] Olden, Charles, Emeralds: Their mode of occurrence and methods of mining and extraction in Colombia: Inst. Min. Met. Eng. [London] Trans., vol. 21, p. 196, 1912.

[97] Olden, Charles, op. cit., p. 196.

[98] Bernauer, F., Las llamadas maclas multiples de esmeralda de Muzo y sus anomalías ópticas: Compilación de los estudios geológicos oficiales en Colombia, tomo 1, pp. 199–221, 1933.

73°26′ W.), which is some 110 kilometers by auto road southeast of Bogotá. The region is moderately cool, rather sparsely populated, and extremely rugged, with a relief of more than 1,000 meters within a single square kilometer. Production data are available only for the period from January 1, 1926, until June 30, 1929, when the output aggregated 119,147 carats.[99]

According to Mentzel,[100] the bedrock is a sequence of gray calcareous shales, which are capped by a hard, gray, fossiliferous limestone. They strike N. 30° E., dip 35° NW., and are transected by two sets of faults, the one striking nearly east and dipping steeply to the north and the other, which is slightly younger, striking N. 30° E. and dipping 35° to 40° SE. The fault throws range from a few centimeters to 20 meters.

The emeralds occur in veins, very few of which are more than 8 centimeters thick, 30 meters deep, or 60 meters long. Pockets or shoots, each of which may yield from a few to several hundred emeralds, may extend the entire strike length of a vein but rarely have a vertical range of more than a meter. Several shoots, one above the other, may be found in the same vein. The paragenesis given by Mentzel for the principal vein minerals is: quartz, pyrite, emerald, albite. The quartz, in clear crystals up to 10 centimeters in diameter and 20 centimeters in length, is restricted to the northeastward-trending faults. According to J. R. Balsley, who examined the locality in order to determine its quartz crystal potentialities, quartz is more abundant in pyrite-rich veins than in albite-rich veins.

The bulk of the emeralds lie within a stratigraphic zone, ranging from 30 to 130 meters in thickness, above a horizon of thin-bedded, hard, blue, limy shale or limestone and below a series of "iron bands." The latter are described as "large veins and masses or beds" of limonite, with some hematite, which are derived from pyrite and enclose quartz crystals and remnants of unaltered pyrite. The "iron bands" are not displaced by faults. The shale above the "iron bands" is irregularly silicified.

GOLD[101]

The total value of gold produced in Colombia since the Spanish conquest has amounted to nearly a billion dollars. This includes an estimated $639,000,000 worth (Spanish and Colombian currencies, approximately equivalent to United States currency), which together with $33,000,000 worth of silver, according to Restrepo,[102] was pro-

[99] Rainier, P. W., op. cit., p. 4.

[100] Rainier, P. W., op. cit., appendix by Charles Mentzel.

[101] Reproduced, with slight modification, from a summary report written by J. K. Cathcart for FEA.

[102] Restrepo, Vicente, Estudio sobre las minas de oro y plata de Colombia, 2d ed., pp. 156–157, Bogotá, Silvestre y Cía., 1888.

duced from 1537 until 1886. Prior to the Spanish conquest, the aborigines produced and used gold for ornaments and utensils. Fishhooks crudely fashioned of native gold, rarely alloyed with copper, are still found when some of the stream beds are dredged.

The silver content of Colombian gold varies greatly from place to place. Assays published by Restrepo [103] show the parts per thousand of Antioquian gold alone as ranging from 634 to 965 in 50 placer deposits and from 343 to 919 in 50 lode deposits. Fetzer [104] states that the gold-silver ratio by weight in mines at Marmato, Caldas, averages 1:2.8. Nevertheless, in very few lode mines and probably in no placer mines throughout Colombia is the gold-silver ratio less than 1:1 by weight.

In the years the gold output has fluctuated from about 300,000 ounces per year during 1915–20 to a low of 136,576 ounces in 1929 and a peak of 656,028 ounces in 1941. The output by years, 1931–45, as published [105] by the Colombian Government, is given in the section entitled "Silver." The output by departamentos during 1940 and 1944 was:

Gold production in Colombia, 1940 and 1944

Departamento or intendencia	1940		1944	
	Ounces	Percent of total	Ounces	Percent of total
Antioquia	417,069	66	329,008	59.3
Chocó	64,264	10	49,127	8.7
Caldas	39,308	6	40,787	7.2
Nariño	32,119	5	51,635	9.2
Tolima	30,111	5	24,070	5.3
Cauca	27,861	4	47,447	8.3
Valle del Cauca, Putumayo, Santander, Huila, and Bolívar	21,195	4	11,456	2
Total	631,927	100	553,530	100

Placers yielded about 60 percent of the gold produced in 1940 and about 66 percent in 1944. The remainder came from two large lode mines at Segovia and Berlín, both in Antioquia, and a host of medium-sized to small lode mines. The Berlín mine, however, shut down in 1946. A list of names and locations of the principal gold producers, both placer and lode, was published [106] in 1942. At that time companies with foreign capital produced 55 percent of the gold, large domestic companies 15 percent, and small domestic companies and hand panners 30 percent. Operating at placers were 17 dredges, 2

[103] Restrepo, Vicente, op. cit., pp. 41–43.

[104] Fetzer, W. G., Contribución al estudio de las minas de Supía y Marmato: Rev. minería (organo de la Asociación Colombiana de Mineros), año 7, no. 81, p. 7244, 1939.

[105] Memoría del Ministro de Minas y Petróleos al Honorable Congreso Nacional, 1946, p. 10, Bogotá, Imprenta Nacional, 1946.

[106] Informe del Ministro de Minas y Petróleos al Congreso Nacional en sus sesiones ordinarias de 1942, pp. vii–ix, Bogotá, Imprenta Nacional, 1942.

draglines, about 120 hydraulic elevators, some 400 monitors, and thousands of hand panners.

Rarely is a new gold mine discovered in Colombia. When it is remembered that the Spaniards and their immediate descendants explored intensively for gold during 300 years, using their typical courage and tenacity together with all of the skill and knowledge the world had accumulated up to that time, it would seem that no region could have escaped them. Nevertheless, the Spaniards could not successfully contend with large volumes of water or with refractory ores. Most of the larger modern developments have been located in placer deposits where the gold was mainly below water level or in lodes where the gold was mechanically combined with other minerals to the extent that cyanidation was necessary to recover it. New developments can be expected, in most cases not as a result of new discoveries, but at known deposits that become available because modern techniques, transportation facilities, and ample capital now make their exploitation practicable and profitable.

With one important and several minor exceptions, all the gold-bearing regions found so far are in the central and western ranges of the Andes. The only important gold mines of the eastern range are those of the so-called Alta, Baja, California, and Vetas subdistricts in Santander. There, within an area of some 50 square kilometers, to the northeast, east, and southeast of the town of California (lat. 7°21′ N., long. 72°58′ W.), and to the west of the range crest, at altitudes ranging from 2,000 to 4,000 meters, are a multitude of veins that have been intermittently exploited since early colonial times. The veins range from a few centimeters to 6 meters in width and from 25° to vertical in dip. They are composed of quartz, minor pyrite, and limonite—with or without traces of chalcopyrite, covellite, arsenopyrite, and galena or their oxidation products. According to Gilberto Botero Restrepo, the veins in the northern (Alta) subdistrict are fissure zones in which the rock has been partly replaced by vein minerals, though retaining its original texture. The ore bodies range from mere pockets to shoots as much as 200 meters long and 100 meters deep. The wall rock is aplitic igneous rock in the eastern part of the district and gneiss in the western part. During the early 1940's these mines had an output of 2,000 to 3,000 ounces per year.

ANTIOQUIA

PRODUCTION SUMMARY

Antioquia produced 329,008 ounces of gold during 1944; of this, about 71 percent was produced by five companies with foreign capital, about 13 percent by medium-sized companies with Colombian capital, and about 16 percent by small operators and hand panners. The

1938 census showed that 14,000 persons, 10 percent of whom were women, were engaged in gold mining. A map showing the locations of 16 placers and 98 lodes in Antioquia is published opposite page 7272 of Revista Minería, the organ of the Asociación Colombiana de Mineros, for March 1939.

The principal gold operators during 1944 were:

Name	Nationality	Method	Municipio	Approximate production, 1944, in ounces
Pato	Canadian	Dredge	Zaragoza	105,000.
Frontino	British	Lode	Segovia	65,000.
Timmins-Ochalí	Canadian	do	Yarumal	50,000.
Cuturú	American (?)	Dredge	Zaragoza	6,000 to 10,000.
San Andrés	Colombian	Hydraulic	Yolombó	8,152 (average of 11 years).
Caramanta and Providencia	do	do	San Roque and Yolombó.	6,000 (estimated by J. K. Cathcart).
Porcecito	do	Dredge and hydraulic.	Santa Rosa	6,000 (estimated by Cathcart).
Viborita	British	Hydraulic	Amalfi	3,000 to 5,000.
Gallinazo	Colombian	Dragline	San Roque and Yolombó.	3,000 (estimated by Cathcart).

PLACER MINES

PATO DISTRICT

In the municipio of Zaragoza, in the valley of the Río Nechí at about latitude 7°28′ N. and longitude 74°54′ W., occurs what is probably the richest gold-mining region of Colombia, as judged by production in both colonial and modern times (pl. 10). Some of the first mining laws of the country, vestiges of which are still evident in the Mining Code, were enacted in 1587 to regulate activities in this district. The town of Remedios, 80 kilometers to the south, was founded in 1547 as a rest camp, it is said, for miners from the more unhealthy lower Nechí.

The Ríos Porce and Nechí, which contain detrital gold throughout their lengths, converge at a point called Dos Bocas. Above Dos Bocas they have swift courses through mountainous regions. Just below Dos Bocas, the Río Nechí loses gradient and becomes sluggish as it reaches the base level of the Bolívar plain. The slowing up of the stream resulted in gold deposition, and meandering resulted in the spreading of the deposits over a considerable width. Naturally, the coarse gold was dropped first; at Pato, just below Dos Bocas, gold is said to average some 10 colors per milligram, whereas 30 kilometers farther downstream, at Cuturú, important values are reported in dust of 200 colors per milligram. Besides the placers found along the present stream valley, there are rich high-bench deposits, several of which were worked extensively during colonial times.

The Nechí is navigable by small river boats from the Río Magdalena to Dos Bocas. Pato also has air service, formerly by pontoon planes

which made landings on the river, later by land planes that use a field built by the company. The climate is exceedingly hot, and malaria and other tropical diseases abound. A large item of the initial investment was for adequate housing, hospital facilities, sanitation, and water supply.

Dredging has been carried on successfully at Pato since 1913. The British firm of Pato Gold Mines, Ltd., developed hydroelectric power on a side stream below Pato and operated two dredges on the flood plains of the Nechí near Pato until 1934. When one of these dredges was dismantled in 1935, it was reputed to have recovered the record amount of $50,000,000 in gold.

In 1934 the company was reorganized and became the Canadian firm of Pato Consolidated Gold Dredging, Ltd., of Vancouver, B. C., capitalized at $5,000,000, Canadian currency, under the management and technical direction of Placer Development, Ltd., of San Francisco. Additional hydroelectric power was developed on the nearby Río Anorí; one dredge was dismantled, one was rebuilt, and three new ones were erected. Much new adjacent ground was acquired by purchase and lease, and a considerable area of dredged ground was reworked; the latter was made practicable by using better technique in scraping bedrock, by dredging at greater depth in some areas, and especially by recovering fine-grained or float gold. It was stated in 1936 that gold up to 14 cents, American currency, per cubic yard was recovered from the areas being reworked. One of the new dredges, which can work 90 feet below water level, was designed to dredge the channel of the Río Nechí, where it has recovered extraordinarily high values. During the fiscal year ended April 30, 1944, the Pato company operated three dredges; the fourth was tied up because of the scarcity of replacement parts during the war. The results of dredging operations were as follows:

Cubic yards handled	9,735,000
Ounces of fine gold recovered	90,097
Total value, with gold at $35, American currency, per troy ounce	$3,153,400
Average value per cubic yard, American currency	$0.3239

In addition to dredging, the new company has successfully carried on hydraulicking on the high-bench gravels near Pato, although at a slightly higher unit cost. The results of hydraulicking operations during 1944 were:

Cubic yards handled	1,651,000
Ounces fine gold recovered	14,715
Value of gold recovered, in American currency	$513,014
Average value per cubic yard, American currency	$0.31194

The average direct operating cost for both dredging and hydraulicking during 1944 was about 16.4 cents, American currency, per cubic yard.

CUTURU PROPERTY

On the Río Nechí, 30 kilometers below Zaragoza, at about latitude 7°45′ N. and longitude 74°48′ W., a small dredge is operated by the Cuturú Gold Dredging Co. on property of the associated Nechí Valley Gold Mining Co. (pl. 10). Pato Consolidated Gold Dredging, Ltd., owns a proprietary interest in both companies. No records are available, but Cuturú production during 1944 is estimated by J. K. Cathcart to have been between 6,000 and 10,000 ounces per year. The dredge has been operating since late 1939 or early 1940.

VIBORITA PROPERTY

In the municipio of Amalfi, about 4 kilometers northwest of the town at about latitude 6°57′ N. and longitude 75°04′ W., extensive beds of old gravel occur in basins devoid of a natural drainage outlet about 1,000 meters above the level of the Río Porce.

In one of the basins, the "Viborita," an American company began operating in 1911. They first drove a short tunnel to drain the basin, then for several years mined by hydraulicking with indifferent results. Since about 1930, the British firm of Viborita Gold Mines, Ltd., which bought the property, has driven a second tunnel at a lower level and continued mining by the same system with, it is claimed, a modest profit. The lower tunnel is some 1,000 meters long, has a steep grade, and is used as a sluice as well as for drainage. Water under working head is brought to bear from above by a series of ditches and pipe lines. The working depth of the deposit at places is more than 50 meters.

No records of production or costs have been released. It is estimated by J. K. Cathcart that 3,000 to 5,000 ounces of gold per year were being produced during the early 1940's.

EAST-CENTRAL ANTIOQUIA PLACERS

In certain respects east-central Antioquia is unlike any other part of the country. The region may be defined geographically as being between latitudes 6° N. and 6°55′ N. and longitudes 74°30′ W. and 75°30′ W. It includes the valleys of four important gold-producing rivers: the Nare, Porce, Nus, and San Bartolomé. All have their headwaters at altitudes of about 2,500 meters, their outlets at about 300 meters, and their productive placer areas between 700 meters and 1,500 meters above sea level. Each of these rivers has stretches where low gradients and wide valley floors across relatively soft and evenly eroded bedrock have provided ideal conditions both for the deposition and for the recovery of placer gold.

A distinctive feature of the region is the presence at many places, particularly along the Río Nare, of granitic boulders of rather unusual origin. These boulders, ranging in size from less than a meter

to more than 100 meters in diameter, result from inherited structures. In unweathered rock, the presence of incipient boulders is not apparent until blasting reveals their stubborn resistance to fracture, as J. K. Cathcart has observed in the solid granites of railroad tunnels at depths of more than 1,000 feet in both Antioquia and California. Similarly, resistance to surface jointing reveals the incipient boulders before decomposition sets in. As weathering proceeds, the boulders tend to remain unaltered or eventually to become reduced in size by sloughing off concentric shells. Finally, huge resistant boulders remain nearly in place while distintegrated and decomposed material between them is eroded away. In east-central Antioquia, numerous belts of boulders so derived cross the valleys and continue up the slopes on each side. At two places on the lower Nare, named "Puente de Humo" and "Puente de Tierra," the entire stream flows through the interstices between huge boulders. The boulders influence mining because they cannot be dredged. Accordingly, numerous stretches of rich placer ground are unworkable because the whole valley is covered with piles of boulders which are 5 to 10 meters in diameter.

Although some tributaries of the Ríos Porce and Nare originate in areas of schist and phyllite, the rivers in general originate in and flow across the Antioquia batholith, a huge body of tonalite and related facies. Within the batholith are innumerable quartz veins ranging from a few millimeters to tens of meters in width. At many places, groups of quartz stringers, lenses, or gash veins are sufficiently rich in the zone of weathering to permit small lode-mining operations. Nevertheless, most of the veins and veinlets cannot be exploited and so have economic importance only insofar as they have furnished gold for placers. Several dozen unexploited veins and veinlets examined by J. C. Cathcart yielded samples assaying from $1 per ton in the large veins to $100, American currency, in the stringers. Furthermore, extensive areas of bedrock probably contain not less than 1 milligram of gold per cubic meter.

In the east-central Antioquia region, the physiographic conditions most favorable for the accumulation of placer gold seem to have been (1) a straight valley, (2) a stream gradient of 0.13 to 0.15 percent, with a stream velocity of 5 to 6 kilometers per hour, (3) a relatively smooth and even floor, and (4) a slight inclination of the bedrock floor against the stream. A stream with a velocity of less than 5 to 6 kilometers per hour is likely to be sandy and low-grade, and a swifter one is likely to have scoured gold from the bedrock. Very little gold is found on the outermost side of the stream curves; moreover, this leanness is not compensated by any excessive enrichment on the concave side.

Depth to bedrock below the water level of the Ríos Nare and Porce is 20 to 30 feet. Depth to bedrock on the flats adjacent to the Río Nus averages about 15 feet below water level. Depth to bedrock on the San Andrés Creek, a tributary of the Río San Bartolomé, in many places is as much as 50 feet, but this is the abandoned channel of an ancient river.

Mining methods for east-central Antioquia were developed during the period 1905 to 1930. The tract of ground normally available has contained 1,000,000 to 5,000,000 cubic yards; larger tracts normally are not available either because of ownership differences or because of physiographic conditions. With few exceptions, mining has been carried on by hydraulic excavation combined with hydraulic elevation, formerly with only a natural head of water; but lately, at several places where the transportation of heavy equipment has been feasible, mining has utilized an artificial head of water. The desirable head is 200 to 300 feet, according to the depth worked. Each elevator unit, with its respective giants, requires 7 to 15 cubic feet of water per second and will move, in ideal ground, 600 to 1,200 cubic yards of material per 24 hours. The power input, therefore, is 6 to 7 horsepower-hours per cubic yard, which would be unreasonably high in any other kind of operation.

The actual mining is done by sinking a hydraulic elevator through the gravel into bedrock, constructing a sluice directly above, and excavating to a radius of 150 feet with giants. Flats usually are mined systematically, and tailing is piled at strategic points, where it is used as a protection against the stream. After a flat has been worked out, the river is diverted to flow through the worked-out area, and then the channel is mined. Recovery has been reckoned at 70 to 87.5 percent, according to the shape of the gold particles. The method requires such a large volume of water flowing over the sluices that much flake gold is carried over the end. Various attempts to save part of this gold have impeded operations and have been generally unsatisfactory. Some of the older engineers express their drill findings in terms of "recoverable" instead of "total" unit values. The cost of developing and equipping one of the mines has ranged from $5,000 to $300,000; ditches more than 20 kilometers long, pipe lines up to 9 kilometers in length, and tunnels 300 meters long have been built.

In 1938, more than 50 different workings were listed. Since then many have failed, have worked out their ground, or are in the last stages of depletion. Their combined output in 1944 may be estimated at 5,000 ounces per month. All the mines are approaching exhaustion, and new discoveries are not to be expected. Further activities will depend on the miners' ability to work economically areas heavily

strewn with large boulders, narrow canyons without flood plains, or material too coarse to be handled with the accustomed equipment. Further ventures doubtless will be undertaken, and much of their success will depend on engineering initiative and adequate financing.

The three leading gold-mining localities of east-central Antioquia—(1) San Andrés Creek, a tributary of the Río San Bartolomé, (2) the Río Nus near the village of Providencia (Caramanta, Providencia, and Gallinazo mines), and (3) the Río Porce (Porcecito mines)—are described in the paragraphs that follow.

San Andrés mine.—The San Andrés mine (lat. 6°40′ N., long. 74°51′ W.) is on San Andrés Creek, a tributary of the Río San Bartolomé (pl. 10). The small creek flows in the valley of an ancient river that was much larger. Depth to bedrock averages about 50 feet. Overlying the bedrock is a layer of quartz gravel, 1.5 to 2 feet thick, which contains all the gold values; above it are silt, sand, and decomposed granite boulders. Large areas have been worked where gold was so abundant in the lower stratum as to give an average of 50 cents, American currency, per cubic yard for the full depth.

Mining is by the usual method of hydraulic excavation and elevation. Water power with a suitable head was developed by driving a tunnel to the upper San Bartolomé; the discharge enters two channels that feed 30-inch penstocks.

During the 11-year period from 1934 to 1944, the aggregate value of gold recovered amounted to $3,138,500, American currency; thus, production averaged about 8,152 ounces per year. The mine had been about half worked out. The reserves in 1944 were reported to be somewhat lower-grade than the ground hitherto worked.

Providencia, Caramanta, and Gallinazo mines.—The properties of the Providencia, Caramanta, and Gallinazo mines (pl. 10) are contiguous, extending downstream along the Río Nus in the order named on both sides of the village of Providencia (lat. 6°31′ N., long. 74°53′ W.) The Providencia mine utilized a side stream to procure 300 feet of head and some 30 second-feet of water in order to work two to four No. 2 hydraulic elevators. The Caramanta mine develops hydroelectric power on the lower Río Nus and uses an artificial head of water developed at the mine for hydraulicking. The Gallinazo mine is worked with a large dragline and a floating washing plant.

Porcecito property.—Near Porcecito (pl. 10), in the municipio of Santa Rosa de Osos at about latitude 6°33′ N. and longitude 75°13′ W., the firm of Minas de Oro de Porcecito has been operating at the junction of the Río Grande and Río Porce since 1930. This company originally was partly owned by Belgian interests but is probably all Colombian now. A 3-cubic-foot dredge and a large hydraulicking plant with three or four elevator units have been working continuously.

Hydraulicking has been more successful and economical than dredging, chiefly because of the great number of large boulders on the bedrock. It is understood that the reserves were approaching depletion in 1945.

LODE MINES

SEGOVIA DISTRICT

Segovia is the most important lode-gold district in Colombia (pl. 10). Although some small mines are being worked by individuals and by companies, the only large-scale operation is that of Frontino Gold Mines, Ltd. This company formerly was named the Sociedad Minera Frontino y Bolívia, S. A., and operated the Bolívia mine at Segovia and several small mines at the town of Frontino. The present company operates the Silencio and Marmajito mines at Segovia and in 1944 was developing the Solferino mine near Anorí, about 50 kilometers to the west.

During 1940 and 1941, the Frontino company each year milled about 120,000 tons of ore, which yielded 65,000 ounces of gold and 55,000 ounces of silver. In 1943, because of war restrictions on materials and a shortage of staff, production declined to 96,000 tons of milled ore, whose grade was similar to that of the ore during 1940–41. Thus the daily output was about 300 tons of ore carrying 0.58 ounce per ton in gold (including silver in terms of its value in gold). Costs reported for 1943 were approximately 22 Colombian pesos per ton, about half of which was the direct cost of mining, milling, and development and the remainder was "general overhead" exclusive of taxes and several other large items.

The terrain is rolling to rough, at altitudes of 700 to 900 meters above sea level. Agriculture has been neglected, despite the large local demand for food, and so virgin forest or jungle covers most of the area. Until recently there was no means of access except by mule-back. Since 1939, however, the company has built a motor road which extends about 80 kilometers from the Río Nechí port of Zaragoza to Segovia and some 12 kilometers southward from Segovia through Remedios to Otú. There is now air service by the Avianca line from Medellín to Otú.

The rocks at Segovia are chiefly tonalite and related facies of the Antioquia batholith, cut by numerous dikes of rhyolite or dacite porphyry and, more rarely, of basalt.

Silencio mine.—The Silencio mine works two roughly parallel veins that converge just south of the main shaft. The single (combined) vein has been worked some 1,000 meters southward from the junction, and both forks have been exploited an equal distance northward. The average dip is 32° E. The lowest level is about 900 meters along the incline, giving a vertical depth of about 475 meters.

Both the "main" vein and its underlying branch, called the "Manta," range in width from a mere film to 3 meters but average about 40 centimeters. The distance between the two veins reaches more than 100 meters. A porphyry dike 1 meter or less in thickness commonly lies along the footwall of the ore but in places is next to the hanging wall.

The gangue is quartz with minor calcite. The quartz is massive to crystalline, but visible crystals are common and occasional vugs contain crystals as much as 5 centimeters in length. The ore minerals, in the order of their abundance, are pyrite, sphalerite, pyrrhotite, galena, and rare scheelite. Pyrrhotite seems to increase with depth. Scheelite was only recently identified; it was found in the lowest levels but may also have been present higher up. Commonly, but not everywhere, it is accompanied by calcite. Only occasionally is a suggestion of irregular banding noticed. The best gold ore is considered to be a nearly pure, friable, fine-grained pyrite which may carry up to 6 ounces of gold per ton. Much of the gold is visible.

The mine is served by a three-compartment inclined shaft, which follows the vein downward for some distance and then continues in the hanging wall, where the dip of the vein becomes slightly steeper. There are levels every 30 meters. Raises are driven along the ore at frequent intervals, and the small intervening blocks are stoped. Later, masonry walls to retain waste filling are built above the level pillars, which are recovered. Masonry for this purpose is said to cost less than adequate timbering. Much wall rock is removed along with the ore, as the veins commonly are narrower than the stoping width; the hanging wall at many places has joints parallel to the vein, to a distance of 30 to 60 centimeters above it, and so breaks free from the ore. Much of the waste is sorted underground, where it is used for filling. Tramming is by hand, and hoisting is with two 1.5-ton skips. The mine is relatively dry; some 300 gallons per minute of surface water, varying with the season, is pumped from the eighteenth level.

Marmajito mine.—The Marmajito mine is approximately 3 kilometers southeast of the Silencio and has its own shaft and primary mill. The Marmajito vein is shorter and slightly narrower than the Silencio vein and strikes obliquely to it, but the two veins are similar mineralogically and have about the same angle of dip. At the end of 1941, an ore shoot 170 meters long was reported betwen the twelfth and thirteenth levels.

At the Marmajito mill, 70 to 100 tons of ore per day are crushed and given a primary grinding with stamps. A table concentrate is removed and trucked to the María Dama mill for treatment; the sands are cyanided at the mine by percolation.

The María Dama mill is just below the Silencio shaft collar and west of it; 300 tons of ore per day from the Silencio mine is delivered by animal-drawn trains. The grizzly oversize is hand-picked on a rotating table, and waste amounting to 13 percent of material hoisted is rejected; the remainder of the oversize is crushed and then ground in twenty-five 1,050-pound stamps. The grizzly undersize is ground in a 6-foot ball mill. The two ground products are reunited and concentrated on Wilfley tables, and the sand tailings are given cyanide treatment by percolation. The table concentrates, together with those from Marmajito, are reground in a ball mill, after coarse gold has been removed with a jig. The jig concentrate is barrel-amalgamated; the sulfide pulp is cyanided in a series of agitators and thickeners with countercurrent decantation. The pregnant solutions are passed through the sand percolation vats, where they are clarified and then precipitated with zinc shavings. A 97-percent recovery is claimed. Bullion from amalgam assays some 0.600 fine; that from precipitates, smelted separately, some 0.500 fine.

Power for all operations is furnished by the company's hydroelectric plants, both of which are near Segovia.

BERLIN MINE

The Berlín mine of the Timmins-Ochalí company is approximately at latitude 7°01′ N. and longitude 75°34′ W. in the municipio of Yarumal (pl. 10). It is reached by a tractor road, about 40 kilometers long, which branches from the main Medellín-Valdivia highway north of Yarumal. The mine, found in 1929, is the only important lode discovery in Antioquia in recent years. It was bought in January 1935 by the N. A. Timmins Co., of Montreal, for a reputed price of 1,400,000 pesos, following an 18-month option during which 229,000 tons of 0.58-ounce ore was developed. Full development was reached in 1938. The following data are derived from Wilson and Darnell.[107]

The main vein strikes about due north and dips 50° to 80° E. along or near the contact of two varieties of schist: black, carbonaceous chlorite schist above and gray quartz-sericite schist below. This vein, which is predominantly quartz, ranges from a few inches to 80 feet in width. It tends to be emplaced, guided by old fractures, on the hanging-wall side of the schist contact. Inclusions of schist within the quartz body range in size from mere specks up to lenses 50 feet long; they have been broken by subsequent movement, and ore has formed by deposition in the openings as well as by replacement of the

[107] Wilson, F. K., and Darnell, B. F., A lode gold mine in Colombia: Eng. and Min. Jour., vol. 143, no. 4 (April), pp. 62–65, and no. 5 (May), pp. 58–62, 1943.

inclusions. Ore shoots are localized where the inclusions are abundant, and gold concentration occurs along the schist walls or in the quartz adjacent to them. The solid quartz invariably is below commercial grade. The gold is both free and mechanically combined with pyrite, galena, and sphalerite; minor amounts of pyrrhotite and arsenopyrite are present, as well as traces of chalcopyrite.

Exploration has extended over a length of 4,000 feet and to a depth of 1,600 feet. The main ore body is about 800 feet deep and long, and it averages about 15 feet in width. Development has been by horizontal adits, as the topography is very rugged.

The mill is at the mine, and ore is delivered from the 1,860-foot level. The process consists of fine grinding in cyanide solution in closed circuit followed by table concentration. Concentrates and tailings are treated separately, both by agitation. The first unit started work in 1936 with a daily capacity of 100 tons. In 1938, two additional units increased the mill's capacity to 300 tons; later, with new arrangements of the flow sheet, it was further increased to 390 tons per day. Operations for the 5-year period ending in 1940 were as follows:

Year	Tons milled	Ounces per ton	Percent recovery	Gold produced, in ounces
1936	17,447	0.855	88.27	13,301
1937	35,224	.632	95.39	22,011
1938	75,945	.453	94.95	33,180
1939	115,486	.380	96.24	43,930
1940	128,533	.408	96.65	51,501

Ore carrying less than 0.22 ounce per ton was not mined. The cost per ton for mining and development was stated by Wilson and Darnell as $2.902, American currency; for milling, $1.099; and for management and overhead, $1.959—that is, a total cost of $5.96 per ton.

This mine shut down in 1946, presumably because the ore was exhausted.

SMALL-SCALE LODE MINES

Small-scale mines are characteristic of Antioquia. In most of the departamento, but especially in the east-central part on the eastern slope of the Cordillera Central, small veins are mined by open-cut and by underground methods. The veins occur in igneous rocks of the Antioquia batholith and, to a lesser extent, in crystalline schists that surround the batholith and form islands in it. The veins range from a few millimeters to several meters in width and from $1 to more than $100 per ton in gold content.

Often the decomposed bedrock is sluiced away, and the broken quartz, so released, is gathered and milled. Usually, however, small veins are mined by ordinary methods, such as cut-and-fill stoping.

Most are abandoned when hard rock is reached at 10 to 20 meters because values diminish and the cost of mining increases.

Milling is done with a wooden stamp mill, called an "Antioquian mill," which consists of an overshot water wheel turning a wooden camshaft 30 to 40 centimeters in diameter. The number of stamps varies from 2 to 12; they have wooden stems. No dies are used, and the mortars are lined with blocks of quartz. Chrome-iron stamp shoes weighing about 125 pounds, cast in Medellín and other centers, are the only replacements needed. Otherwise, as the mill is constructed entirely of wood, repairs are made locally. In 1935, such a mill cost 800 to 1,200 pesos for 8 to 10 stamps. One of its advantages is that it needs no constant feeding; it is simply filled to the top of the mortars at intervals and allowed to grind.

Commonly, a single family works as a unit in mine and mill while still continuing its normal agricultural pursuits; the man of the house or the older boys customarily mine the ore, and the women feed the mill and make small repairs. Often the owner of a mine builds a mill, leases small mining tracts to different individuals, and allots each lessee a battery of two or three stamps in the mill. The owner takes half the free gold and all the tailings, which are crudely treated with cyanide by percolation.

More than a hundred such operations in Antioquia were listed in 1937. Their production ranged from less than half an ounce to 350 ounces of gold per month. The mills usually are built without thorough examination of the mines, and failures are more common than successes. Small pockets commonly are taken out in a few months; then the operators turn the mill over to one of their men or to a local farm tenant, who continues in a small way. Some of the mills have been running more than 40 years.

CALDAS

PRODUCTION SUMMARY

Gold is mined in many parts of Caldas, but half the output comes from the northern part, in the municipios of Marmato, Supía, and Ríosucio, near the Antioquia border. During 1944, the Government-owned lode mines of Marmato, operated by lessees, produced some 12,000 ounces of gold; the Supía Gold Dredging Co., the only operator with foreign capital in the departamento, produced 6,600 ounces; and the Vendecabezas lode mine, near Ríosucio, produced 2,000 to 2,500 ounces. The Guayaquil lode mine, in the municipio of Pensilvania, which in 1935 produced 3,600 ounces of gold, may have ranked fourth during 1944. In the municipios of Florencia and Samaná several important lode mines, including the Britania, operated until 1915-20 but

have been suspended or abandoned, probably because the ore was exhausted.

In 1943 Carlos Posso, of the Gutiérrez-Posso "fundición" of Manizales, Government-authorized gold buyers for Caldas, listed for the author the leading lode gold mines of Caldas; besides those mentioned above, they include:

Mine	*District*	*Principal owner*
Farallones	Manizales	Francisco Botero.
Tolda Fría	do	Antonio J. Londoño.
Coqueta	do	Carlos Orta.
Cascada	do	Heliodoro Restrepo.
La Morena	Salento	Roberto Vélez.
Crucero	Mistrató	Salazar Brothers.
San Rafael	do	Rosendo Quicero.
Guarinó	Manzanares	Francisco Botero.

MARMATO MINES

The Marmato mines (lat. 5°28′ N., long. 75°36′ W.), property of the Colombian Government, are 6 kilometers northeast of the town of Supía, on the west slope of the canyon of the Río Cauca and very near the Antioquia boundary (pl. 10).

The principal deposits lie within an area of 600 by 800 meters. According to Fetzer,[108] they are localized in proximity to a discontinuous roof pendant in the northern part of a cupola of diorite porphyry which is 3 by 6 kilometers in outcrop area. The roof pendant, 400 meters long, is composed of graphitic and chloritic schists. The deposits are veins and replacement veins along a group of eight or more (?) major fissures and many associated minor fissures and branches. Nearly all have dips exceeding 80°. The width of the veins now being mined ranges from 0.25 meter to 2.5 meters, the average being about 0.8 to 0.9 meter; however, lodes up to 20 meters in width are said to have been found. The wall rock is diorite in all except the Echandía mines, at the extreme northern end of the productive area, where both diorite and schist are cut.

Pyrite constitutes 98 percent or more of the sulfide minerals. It normally is accompanied by black sphalerite (marmatite) and minor galena. The gangue, which comprises about 80 percent of the ore sent to the mill, is mainly bedrock, although much quartz and minor carbonate occur in a few of the narrower veins. Fetzer estimates (p. 7244) that the gold-silver ratio by weight in Marmato veins ranges from 1:1 to 1:10 and averages 1:2.8. However, the ratio of gold to silver actually recovered[109] during 1941 and 1942 in seven different

[108] Fetzer, W. G., Contribución al estudio de las minas de Supía y Marmato: Rev. minería (organo de la Asociación Colombiana de Mineros), año 7, no. 81, pp. 7241–7248, March 1939.

[109] Informe del Ministro de Minas y Petróleos al Congreso Nacional en sus sesiones ordinarias de 1942, anexo al tomo 1, table opposite p. 132, 1942; Memoria del Ministro de Minas y Petróleos al Congreso Nacional en sus sesiones ordinarias de 1943, table opposite p. 66, 1943.

mills ranged from 3:2 to 1:2, the latter being at Echandía. During that 2-year period the output averaged 114.3 metric tons of mill ore per day, from which 0.235 ounce of gold and 0.250 ounce of silver, aggregating in value 13.52 pesos ($7.73, American currency) per ton, were recovered.

Milling is done in several small plants with an aggregate daily capacity of less than 150 tons. All of these are crude, rudimentary, and antiquated, so that a recovery of only 60 to 65 percent is obtained. About half the recovered gold is in the free state; the remainder is obtained by inadequate cyaniding. Efficient treatment of these ores would require a modern cyanide plant and a long-range mining program.

Marmato has been worked for more than a hundred years, for a time intensively. The potential ore reserves are assumed to be large, but no extensive development nor prospecting is under way. The mines are under the direct administration of the Ministerio de Minas y Petróleos, whose policy in 1945 was to give concurrently several small, short-time leases. The lessees are working on a "hand-to-mouth" basis.

SUPÍA MINE

The Supía Gold Dredging Co., a subsidiary of the International Mining Co., operates one 8-cubic-foot dredge on the Río Supía, at about latitude 5°26′ N. and longitude 75°38′ W., in the municipio of Supía (pl. 10). The Río Supía is a small stream; its valley, where it can be dredged, is 200 to 300 meters wide and approximately 8 kilometers long. Depth to bedrock is 5 to 6 meters. The amount of ground originally developed was about 12,000,000 cubic yards, with values averaging 40 cents, American currency, per cubic yard. The bedrock is soft red shale, and the stream gravel is extremely coarse and tightly packed. Many boulders of 10 to 15 tons are moved to the bank for breaking; also, occasional huge rocks, as much as 3 meters in diameter, are broken by blasting in the dredge pit.

The recovery has never agreed with drill findings, and much gold is presumed to be lost from the sluices because of the violent pitching of the dredge when hard digging is encountered. The monthly production during 1944 was about 90,000 cubic yards, which rendered 500 to 1,200 ounces of gold. Operations began in mid-1940; 11,000 ounces of gold were reported in 1942 and 6,600 ounces in 1944. The reserves supposedly were sufficient for another 5 years. Eventually this enterprise will be regarded as a test case for dredging, as compared with some other method of recovery, in very coarse gravel.

Power is furnished by the company's hydroelectric plant on the lower Río Supía.

VENDECABEZAS MINE

The Vendecabezas mine is high up in the western range about 1.5 kilometers north of the town of Ríosucio (lat. 5°25′ N., long. 75°42′ W.). The ore occurs as replacement veins of pyrite, sphalerite, and stibnite along tight fissures in red and gray shales and sandstones. The mine is worked by small lessees and prospectors, and the ore is milled by the owners (Medellín interests) in California-type stamp mills. Some 20 to 25 tons are treated daily. The production is variable; in 1944 it was estimated by J. K. Cathcart to average 2,000 to 2,500 ounces per year.

GUAYAQUIL MINE

In the municipio of Pensilvania, on the southeast side of the Río Dulce at about latitude 5°30′ N. and longitude 75°05′ W., the Guayaquil mine has been working since the early 1930's. One or more small quartz veins occur in crystalline schists, and the ore is said to be fairly rich. In 1934–35, some 300 ounces of gold per month was produced. Operations still continued in 1945, presumably at the same rate.

CAUCA

PRODUCTION SUMMARY

Besides the present departamento, Cauca formerly included Valle del Cauca, most of the Chocó, and Nariño—that is, nearly all the Pacific coast belt of Colombia; in early colonial times it may have equaled Antioquia in gold production.

In 1944, 69.4 percent of the gold output of Cauca was listed as derived from operations of foreign companies, of which the Aznazú Gold Dredging, Ltd., is the only important one. The rest came from such small operations as the Munchique and California lode mines in the western range and hand placer operations along the rivers flowing to the Pacific Ocean, such as the Micay, Saija, Timbiquí, and Guapí.

Several serious attempts have been made to mine the gravels of the upper Río Patía valley with large-scale methods. A dredge operated by a British company got under way in 1937 but failed almost immediately because, it is reported, of low gold content. Some hydraulic developments have met with a similar fate. Beginning in 1946, the Cía. Aluviones Selectos, S. A., was expected to dredge a concession downstream from the 1937 locality.

AZNAZU MINES

In the municipio of Buenos Aires, at about latitude 3° N. and longitude 76°40′ W., the Aznazú Gold Dredging, Ltd., operates two dredges, one of 6-foot and the other of 12-foot capacity (pl. 10). The smaller one was started in 1937, the larger in 1941. The mines consist of the flats of the upper Río Cauca and are operated under

concessions from the Colombian Government and leases from private owners. The concessions have a total length of 30 kilometers along the river. The values are reported to be in an alluvial stratum approximately 25 feet deep; the bedrock lies much deeper, out of dredging range, and the material just above is said to carry little gold.

Aznazú, like Pato, is technically directed by Placer Development, Ltd., of San Francisco, Calif. During the fiscal year ended April 30, 1944, about 5,569,400 cubic yards, with an average value of 21.1 cents, American currency, per cubic yard was handled, producing 33,578 ounces of gold. The operating cost, including royalties aggregating about 8.6 percent of the gross production, was about 15 to 16 cents per cubic yard. The reserves at the end of the period were reported as 67,927,000 cubic yards having an average value of nearly 17 cents. The total output to the end of 1944 amounted to 194,540 ounces of gold.

The company produces its own power in two hydroelectric plants. The Cali–Popayán railroad passes through the property. The elevation above sea level is approximately 1,100 meters. The climate is good, and food supplies are abundant. The land is of high value for agricultural purposes.

MUNCHIQUE AND CALIFORNIA MINES

In the municipio of Tambo, on the east slope of the highland called "Alto de Munchique" (lat. 2°28′ N., long. 76°58′ W.), are gold-bearing quartz veins, commonly associated with dacite dikes in granite. The most important are the Mina Tapada de Munchique and—evidently an extension of it—the California mine.

The main vein at Munchique strikes north, dips 80° E., and has several ore shoots, including one about 150 meters long that may be 1.2 meters wide but averages 0.4 to 0.6 meter in width. The values are in finely divided gold mechanically combined with pyrite. The total sulfides, including rare galena and sphalerite, do not exceed 6 percent. Much ore carrying more than 1 ounce per ton was found, but the mill-head average probably was less than 0.5 ounce. The Swedish Diamond Drilling Co., of Stockholm, explored and partly developed the mine and, about 1936, built a 30-ton, all-sliming, countercurrent mill with a cyanide plant, said to have been a pilot mill. When it became apparent that the amount of ore was limited, the mine was abandoned, but later it was taken up by other Swedish interests. In 1943 operations were suspended, whether because of war restrictions on materials or for other reasons is not known.

The California mine is a National enterprise. The veins are similar to those of the Munchique mine and are on land immediately adjacent to the north. The equipment comprises two Antioquian stamp mills and a percolation cyanide plant. There are no data regarding the

mine's production, but it is known to be steady and high in relation to the investment.

CHOCO

In 1940, the Chocó (pl. 10) ranked second among Colombian departamentos, intendencias, and comisarías in the production of gold with 64,264 ounces; in 1944, it ranked third with 49,127 ounces. Practically all the gold is from placer mines: about 50 to 70 percent came from dredges of the Chocó-Pacífico company and nearly all the remainder from small native mines, most of which are simply hand panners. These mines are described in the section "Platinum."

There is a lode mine, said to employ more than a hundred persons in 1944, near a place named Dabeiba (lat. 5°40′ N., long. 76°05′ W.?) in the uppermost headwaters of the Río Andágueda. Access is by foot trail from the town of Andes, in Antioquia.

NARIÑO

In 1940, Nariño ranked fourth among Colombian departamentos, intendencias, and comisarías in the production of gold, with 32,119 ounces; in 1944, it ranked second, with 51,635 ounces. Foreign capital produced 64 percent, small operators the remainder.

In the municipio of Barbacoas (pl. 10), on the Río Telembí, some 35 kilometers above the town of Barbacoas at about latitude 1°37′ N. and longitude 78° W., the Cía. Minera de Nariño operates one 12-cubic-foot dredge, which was started in 1937. The Nariño company is an associate of Chocó–Pacífico and a subsidiary of the South American Gold & Platinum Co.

Gustavo Arbeláez Hurtado [110] states that the average values are 12 to 15 cents, American currency, per cubic yard, that the annual yardage is over 4 million, and that the reserves are adequate for 20 years. It seems more probable that the values are slightly higher and the annual production is about 20,000 ounces. The dredge began operations in the channel of the Telembí, near Chapira, and later moved down river to work the flats of a mine called Santa Ana. According to Arbeláez, power is supplied by Diesel engines and fuel oil is brought from Panama to the port of Tumaco, from which it is towed in barges up the Ríos Patía and Telembí to the dredge. The company's headquarters camp is at Mongón, 12 kilometers upstream from Barbacoas. The dredge works in ground about 24 kilometers farther up the Telembí.

The second principal mining enterprise in Nariño is the Tábano (pl. 10), which ranks third among lode mines in Colombia. It is in the municipio of Santa Cruz, at about latitude 1°25′ N. and longitude

[110] Arbeláez Hurtado, Gustavo, Monografías mineras, pp. 21–29, Bogotá, 1940.

77°40′ W. It was originally developed about 1933 by Medellín interests. A local company, including the Leland family and other American shareholders, has operated it since 1941. The mine is reported to work a nearly horizontal vein of quartz 1.5 to 2 meters thick, containing pyrite, chalcopyrite, and about 1.3 ounces of gold per ton. It is provided with a mill and cyanide plant having a daily capacity of 50 tons, which in 1941 replaced a smaller and less efficient mill that had been running since about 1935. Current production in 1945 was reported at 1,200 ounces per month or 14,000 ounces per year. Developed and probable reserves are reported to be large.

The small gold mines of Nariño are most abundant in a region extending from Mallama (lat. 1°05′ N., long. 77°49′ W.) to Sarmaniego (lat. 1°20′ N., long. 78°35′ W.). The Porvenir and Concordia mines, leading producers in this region, have been described by Miller and J. T. Singewald, Jr.[111] A characteristic of many veins is the presence of arsenopyrite, which has made the ores relatively difficult to treat for gold.

TOLIMA

In 1940 Tolima produced 30,111 ounces of gold; in 1944 the output was only 24,070 ounces, which placed it sixth among the departamentos. Nearly all the gold is derived from veins. The deposits are scattered along the central-eastern slope of the Cordillera Central, mainly in the northern half of Tolima.

Most of the gold lodes, except those of the Líbano and Fresno districts, are briefly described by White-Uribe,[112] and a detailed geologic study of the Recreo mine, probably the largest producer in Tolima, has been published by Rintisch.[113] According to information given to the author by the "fundición" of Ibagué, the leading producers in central Tolima during the early 1940's were, in alphabetical order:

		Location (from White-Uribe map)	
Mine	*Municipio*	*Latitude*	*Longitude*
Bolívar	Cajamarca	4°28′ N.	75°25′ W.
Golondrinas	Ibagué	4°34′ N.	75°14′ W.
Las Animas	Santa Isabel	4°43′ N.	75°06′ W.
Norcacia	Ibagué	4°22′ N.	75°23′ W.
Recreo	Cajamarca	4°24′ N.	75°25′ W.
San Sebastián	Anzoátegui	4°32′ N.	75°07′ W.
Socorro	Anzoátegui (?)	4°33′ N.	75°12′ W. (?)

[111] Miller, B. L., and Singewald, J. T., Jr., Mineral deposits of South America, pp. 377–378, New York, McGraw-Hill Co., 1919.

[112] White-Uribe, H. E., Departamento del Tolima, Estudio minero practicado en los Municipios de Ibagué, Anzoátegui, y Quesado [Cajamarca] and Informe minero del Municipio de Santa Isabel: Bol. minas y petróleos, vol. 13, pp. 281–333, 1935.

[113] Rintisch, Willy, Contribución al conocimiento de los yacimientos de oro en Colombia: Los filones auríferos de El Recreo: Compilación de los estudios geológicos oficiales en Colombia, tomo 1, pp. 407–470, 1933.

GYPSUM

In 1944 Colombia consumed approximately 13,000 metric tons of gypsum, of which 10,000 to 10,500 metric tons was used as a retarder for cement and 2,500 to 3,000 metric tons for the manufacture of calcined products. Manufactured chiefly in Bogotá and Girardot, the calcined products were plasters for walls, moldings, and interior decorations; for dolls, statuettes, and ornaments; and for dental and surgical uses. Only this relatively small amount of gypsum was calcined because lime is used instead of plaster for facing walls, except in cathedrals and other edifices where artistic appearance is more important than cost. Crude gypsum for cement manufacture sold at or near the mines at prices ranging from $17 to $25, American currency, per metric ton and gypsum for calcining at a slightly higher price.

Domestic mines supplied essentially all the gypsum consumed in 1944. The productive districts (pl. 7), in the order of their importance, were (1) Girardot, in southwestern Cundinamarca, (2) Leiva, in west-central Boyacá, (3) Los Santos, in east-central Santander, (4) Rovira, in central Tolima, and (5) scattered localities in southern Tolima and northern Huila. In 1945, according to Gilberto Botero Restrepo, mining began near Zambrano, which is on the Río Magdalena in northeastern Bolívar. In all except the Rovira district, gypsum occurs in shale as narrow veinlets and seams ranging from about a centimeter to several centimeters in width; the aggregate gypsum content of mined ground averages about 5 percent. Near Rovira, a gypsum lens 5 meters in maximum width is being exploited. Sedimentary gypsum beds that would permit large-scale and cheap mining have not been found.

In Cundinamarca, gypsum is found in a belt along the Girardot-Bogotá railroad for a distance of 23 kilometers northeastward, as far as Tocaima (lat. 4°27′ N., long. 74°38′ W.), from a point 3 kilometers northeast of Girardot (lat. 4°18′ N., long. 74°49′ W.). Production comes almost entirely, however, from the southwesternmost 7 kilometers of the belt. The district was examined early in 1945 by J. K. Cathcart. The local climate is semiarid. The gypsum occurs as conformable seams and also as veinlets oblique to the bedding in mottled reddish-gray shale, presumably of the Barzalosa formation (upper Oligocene). All the mines in the southwestern part of the district may be in the same shale bed, which is 1 meter to 3.5 meters thick and locally is capped by sandstone. Most of the seams and veinlets are 0.5 centimeter to 2.5 centimeters thick, though a few seen by Cathcart were as much as 10 centimeters thick and even thicker seams have been found. The gypsum content of mined ground is said to average about 5 percent, but some of the working faces

showed as much as 10 percent. The deposits are mined by the room-and-pillar system from inclined shafts extending down the dip, which is 8° to 12° to the southeast. The longest incline extends 280 meters, to a vertical depth of about 60 meters. A few of the mines have vertical raises to the surface for ventilation. Excavating is done by hand tools and, at times, explosives. Back filling is common. Normally a miner will excavate the rock and remove the waste with a wheelbarrow while a woman or children in the mine sort, clean, and pack the gypsum. A product containing about 75 percent gypsum is thereby procured.

In Boyacá, gypsum is erratically distributed in an area of some 5 by 20 kilometers which extends southward from the town of Leiva (lat. 5°38′ N., long. 73°32′ W.). The district was examined in 1944 by J. K. Cathcart. The local climate is semiarid. Restricted to small, disconnected areas, gypsum occurs in veinlets along fractures and between the laminae of steeply dipping shale. Slabs as much as 1 centimeter by 10 centimeters in volume were observed in stock piles. The gypsum-bearing ground is whitish in contrast to the generally brown land surface. Mining is done by pick and shovel in pits, in most of which relatively soft ground persists to depths not exceeding 5 meters. The gypsum content of the pits seen by Cathcart was about 4 percent, but according to the operators, the general average is slightly higher. A product containing about 60 percent gypsum is obtained by hand sorting.

Gypsum veins not currently exploited crop out in the vicinity of Las Juntas, Boyacá, where the climate is not semiarid. Two prospects were examined in 1944 by C. E. Dixon. At the Peñas Blancas prospect (lat. 5° N., long. 73°15′ W.) are two vertical veins, 20 meters apart. One vein is 3 meters wide, the other 2 meters wide where exposed. At La Vega prospect (lat. 4°58′ N., long. 73°20′ W.) is a vertical vein 3 meters wide. All three veins exhibit mixtures of clay and gypsum, from which the latter must be hand-sorted. Other veins have been reported in the area.

In Santander, gypsum is erratically distributed within an area of 40 by 60 square kilometers which extends westward from a point 5 kilometers west of Los Santos (lat. 6°46′ N., long. 73°07′ W.). The district was examined in 1944 by J. K. Cathcart. The local climate is semiarid. Gypsum occurs as lenticular seams and veinlets, mostly less than a centimeter thick, in weathered shale. Mining is done in pits, which are a few meters to several hundred meters apart, less than 2 meters in depth, and not more than a few square meters in area. The gypsum content of the ground mined is about 4 to 5 percent.

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In central Tolima, gypsum is mined on La Arenosa farm (lat. 4°17′ N., long. 75°15′ W.) in the municipio of Rovira. The climate is not semiarid. The mine was examined in 1944 by Gilberto Botero Restrepo. Gypsum occurs as lens-shaped bodies in variegated shale, presumably of post-Eocene age. An open-cut partly exposed two gypsum lenses that contained about 30 percent admixed shale. The lenses, which have an echelon arrangement, trend N. 60° E., 40° SE., conformably with the shale. The larger lens has a maximum width of 1.5 meters where exposed, but it is alleged to be 4 meters thick where covered by landslide debris. Three adits, now caved, exploited one or more gypsum bodies 200 to 300 meters northeast of the open-cut. Other deposits may be concealed by soil. Besides shale, intensely altered dacitic rock, perhaps a sill, is exposed at the top of the cut face.

In the semiarid valley of the Río Magdalena in southern Tolima and northern Huila are numerous localities at which gypsum has been exploited to a slight degree. Most of the gypsum reaches the railroad at Castilla (lat. 3°49′ N., long. 75°04′ W.), but small amounts have been brought to other stations located between latitude 3°13′ N., longitude 75°13′ W., and latitude 4°02′ N., longitude 74°58′ W. The principal deposits were visited early in 1945 by an FEA mineral scout. His data indicate that gypsum occurs as seams, veinlets, and very narrow lenses in shale(?) bedrock. Mining is done in small, shallow open-cuts. The gypsum content of the mined ground is about 3 to 6 percent.

In Bolívar, exploitation of a gypsum deposit located southwest of Zambrano (lat. 9°45′ N., long. 74°47′ W.) began in 1945. The owner informed Gilberto Botero Restrepo that the gypsum occurs as very thin seams in shale.

IRON

Sizable deposits of high-grade iron ore have not been found in Colombia. The most promising deposits, which were discovered in 1942, are the siliceous oolitic ores of the Paz del Río district of Boyacá (pl. 6); doubtless the ore reserves there greatly exceed 20 million metric tons. Siderite ore, at the surface oxidized to limonite, has at times been exploited to a small extent for very small pig-iron furnaces in Cundinamarca, but the reserves are negligible. Iron-rich laterite occurs near Medellín, in Antioquia (pl. 6), and hematite boulders, the supply of which soon became exhausted, were utilized about 1911 for a very small furnace at Amagá, Antioquia. Some magnetite veins, 1.5 to 7 meters wide, seen by José Royo y Gomez, of the Servicio Geológico Nacional, in the Mocoa region of Putumayo about 60 kilometers east of Pasto, remain unprospected. No data whatsoever are

available concerning an alleged occurrence of iron ore near Rosario, in Bolívar.

PAZ DEL RIO DISTRICT

Paz del Río (lat. 5°59′ N., long. 72°46′ W.) is a small town located in Boyacá on the Río Chicamocha (pl. 6). The walls of the Chicamocha canyon rise 1,000 to 1,500 meters above the river and exhibit the usual steplike aspect caused by alternating hard and soft layers of superbly exposed sedimentary strata. Behind the immediate canyon walls, yet still within the drainage of the Río Chicamocha, is rugged mountain terrain in which outcrops are scarce.

The geology of the Paz del Río district has been mapped in detail by personnel of the Servicio Geológico Nacional, under the direction of Benjamín Alvarado and Roberto Sarmiento. Their published data [114] are supplemented herewith by two items from data kindly furnished in advance of publication when the author visited the district as their guest in October 1944.

A major thrust fault, whose trace is about 2 kilometers west of the Río Chicamocha near Corrales (lat. 5°50′ N., long. 72°51′ W.) and 7 kilometers west of the river near Sativanorte (lat. 6°07′ N., long. 72°42′ W.), separates Cretaceous and Tertiary strata to the east from pre-Cretaceous rocks to the west. The Cretaceous and Tertiary strata are folded into a broad arch whose limbs are complicated by faults and folds. The Río Chicamocha more or less follows the crest of this arch.

The iron ore is a single bed of oolitic hematite within the Tertiary sequence. It ranges from 2 meters to 6.5 meters in thickness over most of the district and therefore crops out on both limbs of the arch—that is, on both sides of the Río Chicamocha—but it pinches out southwest of Paz del Río. The ore averages about 46 percent Fe, 6 percent Al_2O_3, 1 percent P_2O_5, and less than 0.2 percent S, and it ranges from 6 to 20 percent in SiO_2 content.

Reserves in terrain mapped and prospected prior to 1944 were some 20,000,000 metric tons of ore. Much larger reserves may eventually be calculated. Approximately 5 million tons of ore could be mined by open-cut methods.

MEDELLIN DISTRICT

Iron-rich laterite, according to Cock,[115] overlies serpentine that extends discontinuously (pl. 6) from Envigado (lat. 6°10′ N., long. 75°35′ W.), on the outskirts of Medellín, Antioquia, to Belmira (lat.

[114] Alvarado, Benjamín, and Sarmiento, Roberto, Los yacimientos de hierro en Colombia: Rev. "Colombia" (organo de la Contraloría General de la República), año 1, nos. 3 and 4, p. 28, March–April 1944.

[115] Cock A., Julian, La empresa siderurgica de Medellín: Dyna (revista de la Escuela Nacional de Minas), epoca 2, no. 3, pp. 142–173, March 1938.

6°39′ N., long. 75°38′ W.). Two varieties of laterite are found—"oolitic agglomerate" and "earthy." The former is consistently the richer in iron. An analysis of "typical ore" gave 46.7 percent Fe, 1.26 percent Cr_2O_3, 6.10 percent SiO_2, 13.62 percent Al_2O_3, 14.30 percent H_2O, and traces of S and P_2O_5. Mn and Ni, probably present, were not included in the analysis. In the absence of either detailed geologic mapping or systematic prospecting, Cock estimates that laterite containing 44 to 48 percent Fe locally occurs as a layer 0.2 to 1 meter thick, with reserves aggregating 800,000 metric tons; that laterite containing 30.6 to 42 percent Fe locally occurs as a mantle 0.5 meter to 10 meters thick, in places overlain by barren soil 4 meters or less thick, with reserves aggregating 80,000,000 metric tons; and that reserves of laterite containing 22 to 28 percent Fe aggregate 300,000,000 metric tons.

CUNDINAMARCA LOCALITIES

Most of the data which follow have been abstracted from the previously mentioned publication by Alvarado and Sarmiento.[116]

At La Pradera (lat. 5°01′ N., long. 74°08′ W.), two beds of siderite, each 2 to 4 meters thick, occur in the Villeta formation (Cretaceous); the siderite probably is a replacement of original limestone. At the surface, the beds are oxidized to limonite ore that averages about 50 percent Fe, 13 percent SiO_2, and 0.5 percent P_2O_5. The siderite ore averages about 40 percent Fe. The deposits were exploited for local pig-iron production intermittently between 1858 and 1900. The reserves are estimated as 1,500,000 metric tons.

At various localities (pl. 6) in the vicinity of Pacho (lat. 5°08′ N., long. 74°10′ W.), siderite lenses and beds occur within the Villeta formation (Cretaceous). One bed is 1.5 kilometers long, but other occurrences are short lenses, commonly admixed with original limestone. At the surface the siderite is converted to limonite and earthy hematite. The deposits furnish ore for a pig-iron furnace, having a capacity of 5 tons per day, which started operating in 1942 at Capitanes, 9 kilometers west of Pacho. The deposits also were exploited to a small degree during 1823–27 for a local furnace. The exploitable reserves probably do not exceed 100,000 metric tons.

About 5 kilometers north of La Calera (lat. 4°43′ N., long. 73°58′ W.), limonite concretions occur in a bed of ferruginous sandstone that crops out for a distance of about 2 kilometers. The concretions average 45 to 50 percent Fe and 15 percent SiO_2 and are fairly high in P_2O_5. The reserves are estimated as about 300,000 metric tons.

[116] Alvarado, Benjamín, and Sarmiento, Roberto, op. cit., pp. 24–27.

At a rural locality named La Caldera, 5 kilometers northwest of Zipaquirá (lat. 5°02′ N., long. 74° W.), a discontinuous mantle of limonite up to 2.5 meters in thickness overlies ferruginous sandstone. The richest portions of the mantle contain 40 to 55 percent Fe, a variable amount of SiO_2, and a P_2O_5 content above bessemer grade. The reserves are estimated as 50,000 metric tons.

About 2 kilometers east of Nemocón (lat. 5°04′ N., long. 73°53′ W.), a mantle of concretionary limonite 1.8 to 3 meters thick overlies a bed of ferruginous sandstone. The reserves are estimated as about 50,000 metric tons of ore averaging approximately 54 percent Fe, 8.5 percent SiO_2, and a moderately high P_2O_5 content.

LEAD

Lead consumption in Colombia was locally estimated, in 1944, to exceed 1,000 metric tons per year. Lead was used chiefly for building construction, for water pipes, and for the manufacture of gunshot, toys, and novelties. To supply the domestic market, a small smelter was planned at Tipacoque, Boyacá, but the adequacy of the ore supply there is questionable.

As a possible source of ore for the domestic market, the Coromoro lead-copper prospect and Las Nieves lead prospect in Santander, as well as La Diamantina copper-lead-zinc prospect in Caldas (pl. 9), warrant soil stripping in order to determine their potentialities. None of these prospects is near enough to tidewater or now shows enough promise of containing large ore bodies to be considered a possible source of lead ore for export. Other galena showings in Colombia are even less promising.

About 1 metric ton per day of galena concentrate could be recovered at the Segovia mine and lesser amounts from other lode gold mines in Antioquia, given adequate financial inducement.

ANTIOQUIA

Lead possibilities in Antioquia were investigated in 1945 by J. K. Cathcart.

The gold mine at Segovia (lat. 7°06′ N., long. 74°41′ W.) in 1945 was milling about 300 metric tons of sorted ore daily, the table concentrate from which consisted mainly of pyrite, pyrrhotite, sphalerite, and galena. This was reground for cyaniding. About 1 metric ton per day of galena could be recovered by selective flotation of the cyanided concentrate tailings, given adequate economic inducement. Many other lode gold mines of Antioquia produce ore containing galena, but the quantities are too small at current production rates to

deserve consideration. Several alleged galena prospects were found to be worthless.

BOYACA

TIPACOQUE (MOCHANCUTA) PROSPECT

The Tipacoque prospect (pl. 9), located 13 kilometers north of Soatá (lat. 6°20′ N., long. 72°41′ W.), along the Bogotá-Cúcuta highway, was examined by J. K. Cathcart in December 1944. At that time, plans had been formulated for a smelter designed to produce about 5 metric tons of metallic lead per day for consumption within Colombia; however, not enough ore was found.

Sandstone, shale, and limestone, which perhaps are part of the Villeta formation (Cretaceous), comprise the bedrock. The ore is associated with a reverse fault trending N. 20° E., 78° to 83° NW., about normal to the bedding. The hanging wall in the immediate vicinity of the mine workings is sandstone, the footwall sandy shale that curves sharply upward against the fault.

Galena occurs as small masses distributed irregularly between shale laminae in the footwall drag zone of the fault. Concentration normally is greatest adjacent to the fault, and in general the quantity of galena gradually diminishes throughout a distance of 2 to 4 meters away from the fault to where the beds resume their normal dip. No other ore nor gangue minerals were observed by Cathcart, but the Servicio Geológico Nacional reports [117] antimony, together with traces of iron and arsenic, in an ore sample analyzed.

The mine workings in 1944 were at two levels, 20 meters vertically apart on a 10° hillside. The upper level had been extended 30 meters along the footwall of the fault, the lower level 70 meters. Another level, about 100 meters vertically below these two, was projected in order to explore at greater depth. About 70 metric tons of hand-sorted galena had been derived from development work and from "gouging" out small pockets of ore. Because of the spotty distribution of galena, the reserves cannot be closely estimated even in developed ground. Probably 100 to 200 metric tons of galena remained in the small block between the two levels. Much more prospecting was needed to determine the ore potentialities.

SHOWING IN MUNICIPIO OF RÁQUIRA

Galena is alleged to occur at scattered localities in southern Boyacá; two localities were visited by an FEA mineral scout. At El Alisal farm, about 5 kilometers by trail from Ráquira (lat. 5°33′ N., long. 73°38′ W.), are the vestiges of mine workings and of a small furnace

[117] Written communication dated March 20, 1947.

said to have been worked by an English company about 1870. (See pl. 9.) The workings included an open-cut, 20 by 70 meters in area, and an adit, both of which now are nearly obliterated by slide debris. Galena was seen in a piece of slag and also in an 8-pound sample donated by the owner of the farm. Hundreds of man-days of labor would be needed to clean out the workings.

At La Candelaria farm, 10 kilometers by trail from Ráquira, a vein 20 to 30 centimeters wide, containing quartz, limonite, and stringers and nests of galena, is exposed.

CALDAS

La Diamantina prospect, described in the section entitled "Copper," reveals a moderately promising outcrop of copper-lead-zinc minerals in quartz. This prospect is 4 kilometers north of Marquetalia (lat. 5°17′ N., long. 75°04′ W.).

Two other prospects in the municipio of Marquetalia were examined early in 1945 by C. E. Dixon. At La Bella farm, south of the Río Miel, some 10 kilometers from Marquetalia, an irregular seam of galena averages 20 centimeters in width along the hanging wall of a quartz vein some 80 centimeters wide. At La María farm, south of the Río Miel, about 5 kilometers from Marquetalia, pyrite, sphalerite, and galena are minor, erratically distributed constituents of a lenticular quartz vein.

Rumored lead occurrences in general proximity to Ríosucio (lat. 5°25′ N., long. 75°42′ W.), Marmato (lat. 5°29′ N., long. 75°36′ W.), and Pensilvania (lat. 5°31′ N., long. 75°06′ W.) were scouted early in 1945 by J. K. Cathcart, who concluded that the chances for obtaining galena concentrates either from small gold mines or from "raw" lead prospects were negligible. The best prospect appears to be the Guayaquil mine (approximately lat. 5°35′ N., long. 75°05′ W.), said to be producing, in 1945, some 4 metric tons per month of gold-rich galena concentrates.

CAUCA

The most widely known lead prospect of Cauca is the Esmeralda (Sonrisa), located about 12 kilometers north-northeast of Florencia (lat. 1°41′ N., long. 77°05′ W.), in the municipio of Mercaderes (pl. 9). This prospect, examined in 1945 by J. K. Cathcart, is decidedly unpromising. Sphalerite, subordinate galena, and minor pyrite and chalcopyrite occur irregularly as small, lens-shaped masses comprising less than 10 percent of a gouge zone, 0.6 meter to 1.5 meters wide, along a nearly vertical fault. The bedrock is sandstone, probably of middle Tertiary age.

CUNDINAMARCA

EAST-CENTRAL SECTION

Galena has been reported at places within an area of 20 square kilometers along the valley of the Río Guavio in the municipios of Gama, Gachalá and Ubalá. Nine of the localities have been described by Suarez.[118] Least unpromising is the Cuevo Oscuro prospect (pl. 9), located 2 kilometers south of Ubalá (lat. 4°44′ N., long. 73°32′ W.), which was examined in 1942 by the author in company with Suarez.

The best ore showing at Cuevo Oscuro is an outcrop face, 50 square meters in area, of limestone pervaded by interlacing, branching, and anastamosing veinlets of galena accompanied by minor calcite and quartz. The galena content of this face is about 20 percent. Twenty meters diagonally down the slope to the north is a smaller and leaner outcrop of limestone pervaded by galena. Elsewhere, the limestone is either barren or contains very sparsely and erratically distributed galena. All the visible galena is confined to an area, 30 meters wide and 75 meters long, that adjoins a limonitic zone 1 meter to 3 meters wide and is 30 meters distant from a prominent fault containing limonite gouge. The geologic age of the limestone has not been established.

NORTH-CENTRAL SECTION

Galena prospects (1) on Sucre farm (pl. 9), formerly named Socota, about 10 kilometers north of Carmen de Carupa (lat. 5°21′ N., long. 73°54′ W.), (2) on La Betania farm, 3 kilometers northeast of San Cayetano (lat. 5°18′ N., long. 74°06′ W.), and (3) along the Río San Miguel, downstream from the Yayatá bridge (approximately lat. 5°10′ N., long. 74°08′ W.), were examined late in 1944 by C. E. Dixon; and a fourth prospect on the Cajetas farm, east of the Río Salta about 8 kilometers north of Carmen de Carupa, was visited by an FEA mineral scout. At Sucre farm galena was collected in times past from a ravine and mixed with water, the scum being used for glazing pottery.

At all four prospects picayune quartz-galena veins, singly or in groups, are enclosed in dark shale of Cretaceous age. None is associated either with evidence of general mineralization or of igneous activity. Although systematic scouting doubtless would disclose many picayune occurrences in northern Cundinamarca, the chances for developing sizable ore bodies now seem unpromising.

NORTE DE SANTANDER

Three galena prospects, examined by C. E. Dixon, are located in the valley of the Río Tarra, several kilometers north of the Abrego–La

[118] Suarez Hoyos, Vicente, Reconocimiento geológico de la región del Guavio, Gachalá (Cundinamarca): Compilación de los estudios geológicos oficiales en Colombia, tomo 6, pp. 169–172 and pl. 25, 1945.

Victoria trail crossing (lat. 8°04′ N., long. 73° 08′ W.). At a locality named La Sierra, (pl. 9), a caved adit is said to have cut a quartz vein about a meter wide; along one wall of the vein is a zone of galena that pinches and swells from mere stringers to lenses 25 centimeters thick along a drift 10 meters in length. No galena float could be found along the projected trace of the vein. At localities named Loma de Tara and Paves there are mere stringers of galena. The country rock is monzonite(?).

SANTANDER

In Quebrada La Mina, approximately 3 kilometers east of Coromoro (lat. 6°18′ N., long. 73°03′ W.) is a lead-copper prospect examined in 1942 by W. D. Longan. (See pl. 9.) Galena, subordinate chalcopyrite, and minor sphalerite heavily impregnate limestone in an outcrop, 1 meter by 4 meters in area, surrounded by soil and thick brush. Soil stripping is needed to determine the prospect's potentialities.

Las Nieves prospect (pl. 9), on Huerta del Caballo farm 10 to 12 kilometers from Tona (lat. 7°12′ N., long. 72°59′ W.), was visited early in 1945 by an FEA mineral scout. A vein 0.5 meter to 2.5 meters wide, composed of quartz, barite (?), and small, irregularly shaped nests of galena, is exposed for an outcrop length of 13 meters. Soil stripping is needed to determine the potentialities of this prospect.

MANGANESE

In Caldas, there are two manganese prospects which at high cost might yield small quantities of hand-sorted ore averaging about 40 percent Mn. In Meta, manganese veins reported but unverified are remote from transportation facilities. Prospects in Huila and Nariño, as well as a few others not described in this report, are even less promising.

CALDAS

PROSPECTS IN MUNICIPO OF APIA

Manganese oxide minerals may be found at many places in the Apía region (pl. 6), but prospecting has been restricted to two localities: (1) El Naranjo farm, 3 kilometers east of the town of Apía (lat. 5°06′ N., long. 75°58′ W.) and (2) Estambul farm, 2 kilometers southwest of the town of Viterbo (lat. 5°03′ N., long. 75°53′ W.). The two localities are 5 kilometers apart. The deposits have been described by Fetzer,[119] whose data follow.

Steeply sloping hillsides, along which the deposits are located, are extensively cultivated. The bedrock, which is rarely exposed, con-

[119] Fetzer, W. G., Estudio de los yacimientos de manganeso de Apía y Viterbo (Municipio de Apía): Compilación de los estudios geológicos oficiales en Colombia, tomo 5, pp. 507–513, 1942.

sists of poorly stratified, brown to red, somewhat sandy shales of early Tertiary age that locally are intruded by andesitic porphyries. The deposits are in siliceous shale at El Naranjo and in interbedded siliceous and clayey shale at Estambul. At both localities the shale is transected by quartz-adularia veinlets ranging from 0.1 centimeter to 8 centimeters in thickness.

Erratically distributed lenses containing from less than a ton to as much as a hundred tons of manganese ore are exposed by the prospect pits and adits at both localities. The ratio of psilomelane to pyrolusite is about 4:1; these are the chief ore minerals. Part of the ore would have to be crushed and concentrated in order to be utilized.

Fetzer concludes that the deposits cannot be economically exploited on a significant scale because of their small size and irregular distribution but that an output of 10 to 15 tons per month for domestic consumption perhaps could be attained over a considerable number of years. Data from other sources suggest that the grade of several hundred metric tons of hand-sorted ore extracted prior to 1943 did not exceed 40 to 42 percent Mn.

PROSPECTS IN MUNICIPIO OF MANZANARES

Manganese prospects located approximately at latitude 5°12′–13′ N., longitude 75°11′–12′ W., in the municipio of Manzanares (pl. 6), were examined by the author in 1943. About a dozen different stringers and lenses of low-grade manganese ore have been found, but the owners consider only four of them worthy of exploration and have done a small amount of work at only two. The manganese showings occur within a siliceous facies of fine-grained micaceous and chloritic schists prevailing in the region. At the best showing, named La Cumbre, a 7-meter adit exposes a conformable manganese zone, 3.5 meters wide, composed of soft black manganese minerals irregularly permeated with limonite and interfingered with hard cherty material. A chip sample of 15 to 20 metric tons of stock-piled ore assayed 36.4 percent Mn, 4.6 percent Fe, and 25.8 percent SiO_2; slightly better material could be obtained by carefully picking out the cherty waste.

Despite the unpromising outlook, these deposits would merit some soil stripping if manganese production in that section of Caldas were urgently needed.

HUILA

Manganese prospects at El Tabor farm, 5 kilometers northwest of Garzón (lat. 2°12′ N., long. 75°38′ W.), were examined in 1942 by William Burns in company with Benjamín Alvarado.[120] The man-

[120] Alvarado, Benjamín, Exploración del yacimiento de manganeso de "El Tabor," Municipio de Agrado (Huila): Compilación de los estudios geológicos oficiales en Colombia, tomo 6, pp. 75–88, 1945.

ganese minerals, according to Alvarado, occur in three different beds, within a stratigraphic zone 25 meters thick, of the Honda formation (Miocene), which is composed of red and green shale and subordinate sandstone and conglomerate. The strata dip 20° to 40° southward. Four channel samples, collected by Burns, assayed less than 10 percent Mn each.

META

In proximity to the Río Cabra (pl. 6), 15 kilometers upstream from its confluence (lat. 2°36′ N., long. 72°53′ W.) with the Río Guayabero, 20 or more manganese veins are alleged to transect nearly horizontal sandstone of early Tertiary age. Other manganese showings in the llanos of eastern Colombia have been reported by oil-company geologists. However, even if considerable quantities of ore were found, the region is so remote from tidewater that excessive transportation costs, either across Colombia or down the Río Orinoco, almost certainly would preclude profitable manganese mining in the near future.

NARIÑO

At least two outcrops reveal black manganese minerals in the Piedrancha region (lat. 1°08′ N., long. 77°53′ W.), but no showing of high-grade ore has yet been verified. Specimens brought to Bogotá by an oil-company geologist and examined visually consisted merely of limonite and chert with a low manganese content. Intensive scouting for float, supplemented by soil stripping, apparently would be needed to locate ore if any exists.

MERCURY

Prospecting for mercury has been carried on only at the Quindío (pl. 6), or Bermellón, deposits (lat. 4°26′ N., long. 75°33′ W.), located in the municipio of Cajamarca, western Tolima. A geologic study of the locality, made in 1943 by the author, is summarized herewith. The locality also has been described briefly by Scheibe.[121]

The Quindío deposits have yielded a small production in the past and, if prospected in accordance with certain geologic possibilities here set forth, offer reasonable hope for a modest production in the future. According to Cajamarca residents who claim a knowledge of Quindío history, exploitation took place (1) in ancient times, presumably by the Spaniards, (2) during 1889–90, and (3) intermittently from 1910 until 1914. Production figures are not available, but indirect information suggests that the total output may not have exceeded 5,000 to 10,000 metric tons. Most of this came from the "area said to have been placered" shown by figure 2, but a minor production

[121] Scheibe, Roberto, Anotaciones sobre un yacimiento de cinabrio en el Tolima: Compilación de los estudios geológicos oficiales en Colombia, tomo 1, pp. 90–96, 1934.

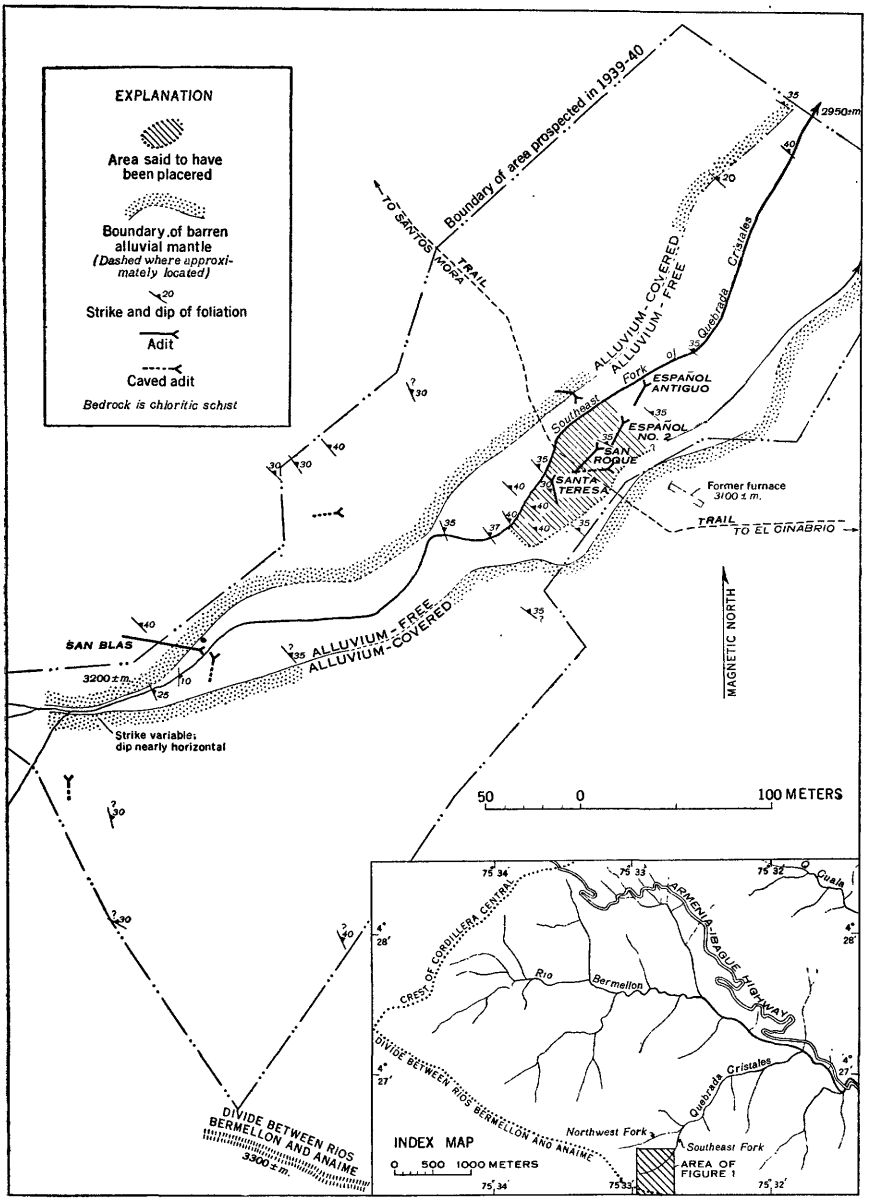

FIGURE 2.—Sketch of the Quindío mercury mine area, municipio of Cajamarca, Tolima, Colombia.

probably came from the San Blas adits and perhaps elsewhere. The grade of the ore is not known, but a few fragments remaining near the former furnace are rich in visible cinnabar. Mining was done mainly from adits and from one or more open-cuts. Toward the close of the 1910–14 period, however, so-called placer mining was done merely by

removing weathered ore found beneath topsoil. In 1939–40, nearly 150 shallow pits were dug and the main adits were cleaned out by a prospecting party working on behalf of an American firm. This party sampled superficial material but did not consider either the geologic occurrence or the geologic possibilities of ore in the bedrock. The pits, even though partly caved, were used by the author to procure information concerning the thickness and distribution of unconsolidated materials at many places and to gain access to concealed bedrock at a few places.

Located at the very head of the Quebrada Cristales, in a broad amphitheater that slopes 25° to 35° northeastward, the Quindío deposits are at altitudes ranging from 3,000 to 3,300 meters. A dense tangle of brush and small trees covers nearly all the amphitheater, but a strip of cleared land 200 meters wide adjoins it and locally makes small reentrants into the prospected tract.

The bedrock is chloritic schist. The prevailing foliation is N. 35° to 55° W., 30° to 50° NE., nearly parallel with but slightly steeper than the slope of the land surface. Zones of shear, represented by numerous films and very thin seams of gouge, dip northeastward either conformably with the prevailing foliation or at a lesser angle; however, the foliation rolls into the low-angle shear zones to form structural benches, and so the gouge almost everywhere remains parallel with the foliation. Other fissures are moderately abundant but inconspicuous. Scheibe [122] states that volcanic rocks occur near the Quindío deposits, and White Uribe's map [123] shows a granitic stock several kilometers to the northwest.

The unconsolidated materials are (1) topsoil, (2) alluvium, and (3) clay-rock eluvium. The topsoil ranges in thickness from a few centimeters to more than a meter, yet throughout most of the area it maintains a fairly uniform thickness of 35 to 50 centimeters. The term "alluvium" is here applied to a layer of buff-colored to medium-brown, fairly well stratified sand, sandy clay, pebble gravel, and—rarely—sand containing cobbles that underlie topsoil at most places. Its distribution is empirically depicted by figure 2; within the area labeled "alluvium-free" this material is entirely absent in 34 pits, is less than half a meter thick in 6 pits, and is a meter thick in 1 pit, whereas within the area labeled "alluvium-covered" the material is more than a meter thick in all but four pits. The maximum thickness is more than 12 meters. The alluvium is barren, and it effectively conceals any ore that may exist beneath it.

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[122] Scheibe, Roberto, Anotaciones sobre un yacimiento de cinabrio en el Tolima: Compilación de los estudios geológicos oficiales en Colombia, tomo 1, p. 91, 1934.

[123] White Uribe, H. E., Departamento del Tolima, Estudio minera practicado en los Municipios de Ibagué, Anzoátegui, y Quesada: Bol. minas y petróleo, tomo 13, nos. 73–78, map opposite p. 280, 1934.

The clay-rock eluvium, which forms a discontinuous layer up to 2 meters in maximum thickness directly above the bedrock, is a mixture of soft, sticky clay and unoriented, more or less "rotten" rock fragments. The size, abundance, and firmness of the rock fragments commonly increase downward, so that clay predominates near the top and rock near the base. The mixture in places seems to grade downward into weathered and slightly dislocated bedrock and so must be in place, whereas elsewhere it is separated from the bedrock by a well-defined, abrupt contact. The mercury content of the clay and rock eluvium ranges from several percent to zero, but throughout most of the prospected area it is far below commercial placer grade. A relatively high mercury content may occur in proximity to the ore in the bedrock. Neither thickness nor mercury content at any given place can be predicted in advance of prospecting.

Ore zones, as exposed by adits, commonly comprise alternating layers of weathered and unweathered ore; the weathered layers probably were rendered permeable to superficial solutions by fracturing along the foliation surfaces. In the unweathered ore, the cinnabar is readily visible as specks and very small masses within stringers of milky quartz and white carbonate; rarely is cinnabar seen within the schist itself. The myriad of quartz-carbonate stringers are in part conformable with the foliation and in part crosscutting. Very few are more than a centimeter thick or more than a few tens of centimeters long. Pyrite (or marcasite) commonly is a minor constituent of the ore, yet it also occurs in barren areas. No effort was made to determine the other mineralogic constituents.

The weathered ore consists of slightly decomposed schist permeated by innumerable seams and veinlets of limonite-stained clay. Residuals of quartz-carbonate stringers may or may not be present. Cinnabar is much less commonly seen in the weathered than in the unweathered ore, yet apparently it can readily be detected by panning.

The ore occurs, at least within the very limited areas of past production, in definite zones or "beds" that are 2 to 7 meters thick and either conformable or nearly conformable with the schist foliation. This is well illustrated by plate 11, which shows the distribution of ore in the Santa Teresa, San Roque, and Español No. 2 adits. However, more prospecting is needed to determine the lateral and vertical distances to which cinnabar may be contained in such a "bed" and to determine whether the ore shoots are small and spotty or of substantial size. The ore shoots may possibly be associated with structural benches, where the foliation rolls into low-angle zones of shear.

Exploration has been almost entirely confined to the immediate vicinity of exposed ore within the alluvium-free area. For example, the ore "bed" depicted in cross section by plate 11 crops out to the

south and southeast of the Santa Teresa adit, where the land surface locally flattens to 10° to 15°. Apparently, another ore "bed" was worked in an open-cut located a few meters above the Español No. 2 adit and immediately to the east of it; the upper "bed" also crops out over parts of the "area said to have been placered." Similarly, an ore "bed" or lens crops out directly across the ravine and only a few meters above the ore "bed" found in the San Blas adit. The alluvium-covered area has been explored only where gulleys happen to expose a few square meters of bedrock from which cinnabar may be panned.

The chances of finding ore within the alluvium-free area have not been exhausted. The inclined longitudinal section of plate 11 shows (1) that only part of the ground which might contain ore above the Español No. 2 level has been explored laterally and (2) that ore might be found below the Español No. 2 level to the east of the present mine workings. The latter possibility is suggested by the relative positions at which ore seemingly terminates westward in the Español No. 1 and San Roque adits, which in turn suggest that the ore body may have a northeastward rake.

Ore bodies comparable to those already found may be concealed beneath the alluvium. Indeed, cinnabar was found in the clay-rock eluvium by panning at 13 places among 22 pits that penetrate below the base of the alluvium. The configuration of the land surface is such that, if the foliation maintains a nearly constant attitude, the outcrop of an ore body conformable with the foliation would trend nearly parallel with the surface contours between the two forks of the Quebrada Cristales—that is, northeast of the alluvium-free area—but would trend diagonally uphill southwest of the alluvium-free area. The dip would be slightly steeper than the slope of the land surface.

In summary, there remains a possibility—though by no means an assurance—of finding limited quantities of ore within the alluvium-free area and larger quantities within the adjoining alluvium-covered areas. The grade of the possible ore cannot be predicted, although a few samples of the best cinnabar showings now visible assayed only a few percent mercury. Additional prospecting alone can determine whether the ore shoots are adequate in size, richness, and distribution to permit profitable mining.

MICA

Commercial mica of excellent quality, both phlogopite (amber) and muscovite (white), may be procured in Colombia in size 6 and in larger sizes, but neither variety could be profitably mined under the conditions and prices prevailing in 1943–44. Phlogopite has been

found only in southeastern Huila and in the Ocaña region of Magdalena and Norte de Santander (pl. 12), each of which regions was prospected. Muscovite in large books is a constituent of many pegmatites in the Cordilleras Oriental and Central. Systematic scouting and preliminary soil stripping were carried out in all the more promising areas, and two areas of Norte de Santander were prospected intensively. Furthermore, two pilot trimming shops were established, one for phlogopite in Garzón (lat. 2°12′ N., long. 72°38′ W.), Huila, and one for muscovite in Pamplona (lat. 7°23′ N., long. 72°38′ W.), Norte de Santander.

Nearly all FEA personnel participated to some extent in mica investigations and so contributed to the ensuing data. The most active participants were Gilberto Botero Restrepo, Louis Gence, W. E. Hammond, C. E. Dixon, and the author.

PHLOGOPITE

HUILA

Twenty-five prospects in the Garzón district (lat. 2°12′ N., long. 75°38′ W.) and one in the Suaza district (lat. 1°58′ N., long. 75°48′ W.) were explored sufficiently during 1944 to demonstrate either that the mica is not usable or that the percentage of usable mica procured per ton of rock mined is far too small to permit exploitation at a profit.

The deposits of the Garzón district (pl. 12) are scattered along the western slope of the Cordillera Oriental between latitudes 2°09′ N. and 2°30′ N. but are most numerous between latitudes 2°09′ N. and 2°14′ N. The deeply dissected, steeply sloping terrain is heavily wooded and almost uninhabited near the crest of the range but mostly cleared and rather thickly populated along the middle and lower slopes. The bedrock, which is fairly well exposed along creeks and along some trails, is medium-grained gneiss abundantly intruded by igneous material ranging in size from mere films to small stocks. The one prospect (Las Cruces) of the Suaza district (pl. 12) is located near the crest of of the range, 14 kilometers by air line south-southeast of the town of Suaza.

Phlogopite occurs as narrow lenses of nearly pure mica within zones of diopside rock; most of these zones are roughly conformable with gneiss foliation. Individual phlogopite bodies contain from a few pounds to more than a ton of mine-run mica in sheets up to 2 feet in maximum diameter. Excellent block mica up to size 3, suitable for spark-plug use, came from several prospects, yet surface trenching failed to disclose enough lenses to proceed with mining. Prepared mica recovered from 1¾ tons of mine-run mica amounted to about 6 percent of the total; a somewhat higher percentage could be recovered as workers in the trimming shop gained experience.

OCAÑA DISTRICT

A few phlogopite prospects are located in Magdalena and Norte de Santander, north, west, and south of Ocaña (lat. 8°15′ N., long. 73°22′ W.), on both slopes of the Cordillera Oriental (pl. 12). The range is deeply dissected by narrow gorges, is forested only along the crest, and is rather sparsely populated and cultivated. The bedrock includes gneisses, schists, and acid plutonic rocks.

Exploration was restricted to four places within Girón farm, located 20 kilometers by air line west of Ocaña. Phlogopite occurs as veinlets and small lenses of nearly pure mica within local zones of diopside rock. The largest lens was 1.4 meters by 0.4 meter by 0.4 meter in size. The work demonstrated that the mica pockets are small and scarce and also that very few of them yield mine-run mica from which usable material even of size 6 can be trimmed out. The other localities are still less promising.

MUSCOVITE

LAS ISABELES, SAN JOSÉ DE LA MONTAÑA, AND DURANIA DISTRICTS

Most of the known muscovite-bearing pegmatites in Norte de Santander (pl. 12) are found along both slopes of the rugged divide between the Río Zulia and the Río Pamplonita, between latitudes 7°26′ N. and 7°47′ N. and longitudes 72°36′ W. and 72°47′ W. The bedrock ranges from fine-grained, almost sericitic schist to medium-grained gneiss, but igneous bodies ranging in composition from granite to diorite and in size from mere blobs to small stocks are erratically scattered through the metamorphic rocks. Outcrops are scarce. Pegmatites are known, with few exceptions, only where active search has been made for them by means of float. Such prospecting has largely been restricted to three local districts: Las Isabeles, San José de la Montaña, and Durania.[124]

The Las Isabeles district (pl. 12), about 16 kilometers by air line north-northwest of Pamplona (lat. 7°22′ N., long. 72°38′ W.), comprises 15 square kilometers and includes (1) a large area—originally a single farm, named Las Isabeles, but now divided into many small tracts—and (2) surrounding farms. More than 50 pegmatites were discovered, 34 of which were explored during 1943–44. Nearly all are irregular, lenticular bodies of relatively small size; the largest is about 20 meters long and 4 meters wide. The essential minerals are milky quartz, pink feldspar, white feldspar, and muscovite; the minor minerals, found only in a few pegmatites, are black tourmaline, garnet, beryl, apatite, and uranium-bearing minerals. The pegmatites are

[124] Botero Restrepo, Gilberto, Estudio preliminar sobre las pegmatitas que contienen mica, en el Departamento de Norte de Santander: Compilación de los estudios geológicos oficiales en Colombia, pls. 36, 38, 44, and 45, 1945.

in gneiss, yet nearly all have an envelope of moderately coarse-grained igneous rock that probably is a border facies of the pegmatite itself.

Because of the very small size of most of the pegmatites, the spotty distribution of the mica, and the low percentage of the better qualities recovered from mine-run mica, successful exploitation under the conditions and prices of 1944 was utterly impossible. Muscovite generally occurs inside the pegmatite rather than along the border zones and so is relatively scarce and spotty. Some of the smaller pegmatites yielded no mine-run mica. In the remainder, the ratio of rock moved to mine-run mica recovered ranged from about 2,000:1 to slightly better than 100:1. The mine-run mica yielded slightly less than 1.5 percent "good stained" and better qualities in sizes up to 4 and about 12 percent "heavy-stained" qualities in sizes up to 2.

Near the small town of San José de la Montaña (lat. 7°36′ N., long. 72°43′ W.), along the western slope of the Pamplonita-Zulia divide (pl. 12), pegmatites probably are as abundant as in the Las Isabeles district, yet due to a less intensive search fewer now are known. In general, the pegmatites seem to be fairly small, irregularly shaped bodies, although none is sufficiently exposed to determine its true shape and size. Indeed, none is exposed over a linear distance of as much as 50 meters. The essential minerals are white feldspar, quartz, and muscovite; the accessory minerals, found in few pegmatites, are garnet, tourmaline, and pink feldspar. The muscovite may range in size from small flakes to books more than a foot in maximum diameter.

In the absence of more precise data from prospecting, it may be surmised that the pegmatites are slightly larger in the San José de la Montaña district and have a higher content of mine-run mica but that the percentage of "good stained" and better qualities recovered would be somewhat less in the San José de la Montaña district than at Las Isabeles.

Less than a dozen pegmatites containing sizable quantities of muscovite are now known in the Durania region (lat. 7°43′ N., 72°40′ W.), and nearly all are very small, irregularly shaped bodies. (See pl. 12.) The essential minerals are white feldspar, quartz, and muscovite; the accessory minerals in some pegmatites are garnet and tourmaline. The largest mica books at different prospects range from about 1 inch to 6 inches in maximum diameter, and the sheets are considerably fractured either by cross graining or by random cracks; however, a substantial amount of mica is free of mineral stain.

RIO TALCO DISTRICT

The Río Talco district (pl. 12) of Norte de Santander includes prospects on both sides of the Río Talco, about 45 to 50 kilometers by air line S. 75° E. of Pamplona (lat. 7°22′ N., long. 72°38′ W.).

All the known localities are within a single large farm, named Santa Isabel, owned by Roberto Hernández M. The region has very steep mountain slopes, is covered by a dense growth of brush and timber, has very few inhabitants, and is difficult of access. The pegmatites are in metamorphic rocks, mainly mica-rich gneisses, but sedimentary strata crop out along the uppermost parts of at least the west side of the Río Talco canyon.

Potentialities at eight pegmatites were determined during 1943–44. The four best are dikes that dip at steep to nearly vertical angles and maintain nearly constant widths throughout their exposed lengths. The thickest is 5 meters wide, the thinnest 2 meters. None is uncovered over its entire outcrop length; exposed lengths range from 12 meters to 60 meters. Thus the pegmatites are decidedly larger and more regular in shape than those of the Las Isabeles, San José de la Montaña, and Durania districts. The Río Talco pegmatites exhibit distinct zoning, with white feldspar and mica concentrated near the borders and pink feldspar and quartz concentrated near the center. Accessory minerals, in some pegmatites, include garnet, biotite, and chlorite.

Due to inexperience during the early stages of exploration, much more rock was moved than necessary. If the mica-bearing border zones alone are to be included, the ratio of rock moved to mine-run mica recovered would range from 90:1 to more than 200:1. From mine-run mica the percentage yield of "good-stained" and better qualities, in sizes up to 4, ranged from 0.5 percent to 3.5 percent. However, with systematic mining one could anticipate an ultimate yield of not more than 0.3 pound of prepared mica of the better qualities per ton of rock mined. Most of the "heavy-stained" and "black-stained" mica was discarded; the amount that could be trimmed out, in sizes up to 3 or 2, would be about 10 to 15 percent.

Because of the remote location, which results in relatively high transportation and labor costs, and of the low yield of the better qualities of mica per ton of rock moved, exploitation would cost more than five times the value of mica procured under the conditions and prices prevailing in 1944.

OCAÑA DISTRICT

Mica-bearing pegmatites are scattered along the crest and upper slopes of the Cordillera Oriental in Norte de Santander and Magdalena between latitudes 7°50′ N. and 8°30′ N. (pl. 12), both to the north and to the south of Ocaña (lat. 8°15′ N., long. 73°22′ W.). The terrain is rugged, sparsely covered by timber, and rather sparsely inhabited outside the towns. Micaceous gneisses and schists are intruded by quartz-poor monzonite(?) in bodies ranging from small

blobs to large stocks and batholiths. All the mica prospects are within areas of metamorphic rocks. The bedrock is fairly well exposed.

The known muscovite localities, with few exceptions, have been discovered by chance, for there has been little search for float and almost no excavating has been done in the region. These localities are most numerous in the municipio of Abrego, 20 to 25 kilometers southeast of Ocaña. At none of them have more than a few square meters of pegmatite been uncovered. The essential minerals are white feldspar, quartz, and mica. The muscovite contains little mineral stain, except at a few prospects where it is almost as heavily stained as in the Pamplona region. The books are small, and rifted sheets exhibit many irregular fractures and considerable cross graining.

The chances for locating sizable pegmatites containing a percentage of usable mica high enough to permit commercial exploitation seem slight.

ANTIOQUIA

Muscovite prospects in Antioquia are most numerous in the Briceño district (pl. 12), a triangular-shaped region between the Río Cauca and the Río Espiritu Santo north of the town of Briceño (lat. 7°07′ N., long. 75°32′ W.). Access is by a long, costly mule haul from the Medellín-Puerto Valdivia highway. The terrain is covered to a considerable extent by brush and timber and is fairly well populated. Landslides are not infrequent. The prevailing bedrock is mica schist; outcrops are scarce. The pegmatites are composed of white feldspar (in places kaolinized), quartz, and muscovite. Some are small lenses or dikes less than a foot wide; others are larger. None of the larger pegmatites is sufficiently uncovered to determine its true size and shape.

Although about 50 pegmatites are known in the Briceño district, less than a dozen hold any promise whatsoever of yielding usable mica. Most of the muscovite is free of mineral stain, but is reeved, cross-grained, and transected by irregular cracks. The bulk of the mica free of waviness and fractures is found in the center of sheets exhibiting "A" structure. Moreover, the mica books tend to be small. Hence usable material of even size 6 is scarce. During 1942, minor prospecting was done at five localities, from one of which about 2 tons of mine-run mica was extracted; all but insignificant amounts were too wavy to be utilized.

North of the Río Cauca, muscovite-bearing pegmatites are known at scattered localities extending all the way from Ituango (lat. 7°05′ N., long. 75°45′ W.) to Cáceres (lat. 7°35′ N., long. 75°21′ W.). Five in the headwaters (approximately lat. 7°23′ N., long. 75°29′ W.) of the Ríos Puqui and Rayo (pl. 12) and one in the Quebrada La Colina

(Irisi drainage?) were examined by Gilberto Botero Restrepo. He regards them as decidedly unpromising, because the mica is in scarce, small books whose sheets usually are free of mineral stain yet considerably cracked, cross-grained and reeved and so devoid of usable material even of size 6. Other pegmatites scouted yielded even poorer material.

Additional localities have been reported (1) between Toldas (lat. 7° N., long. 75°42′ W.) and San Andrés (lat. 6°55′ N., long. 75°41′ W.), as well as (2) east of Yarumal (lat. 6°58′ N., long. 75°24′ W.) and (3) in the general vicinity of Santa Rosa de Osos (lat. 6°39′ N., long. 75°28′ W.). None has yielded specimens, however, of such size and quality as to arouse particular interest.

Intensive scouting for new prospects, together with soil stripping at the more promising localities, would be necessary to evaluate with assurance the mica potentialities of Antioquia. Some localities doubtless could supply "good stained" and better qualities, at least of size 6. Nevertheless, data at hand suggest that exploitation would result in heavy financial loss.

HUILA AND CAQUETA

In the Cordillera Oriental, along both the western slope in Huila and the eastern slope in Caquetá, muscovite localities are scattered through three general regions: (1) in general proximity to the trail from Algeciras (lat. 2°35′ N., long. 75°18′ W.) to San Vicente (lat. 2°07′ N., long. 74°47′ W.) and in general proximity to (2) the town of Florencia (lat. 1°37′ N., long. 75°37′ W.) and (3) the Garzón-Florencia highway. (See pl. 12.) The terrain along the crest and upper slopes of the range is very rugged, heavily wooded, very sparsely inhabited, and difficult of access; the eastern flank, in the Florencia region, is less rugged and more thickly populated but likewise heavily wooded except where cleared for crops or pasture. The bedrock consists of medium-grained gneisses and schists into which is intruded fairly abundant igneous material ranging from mere films to small stocks. The widely scattered distribution of known muscovite localities in the three regions suggests that intensive search in these and other regions might result in many more discoveries. Nevertheless, the generally small size of the mica books, as well as the abundance of irregular cracks and, less commonly, reeves and cross graining in the mica, indicate that few pegmatites can be expected to yield usable material of size 6. Moreover, even where usable sheets can be procured, the percentage of prepared mica recoverable per ton of rock mined is likely to be very small. Hence the chances for exploitation at a profit, particularly in view of remote locations with consequent high transportation costs, seem decidedly unpromising.

Perhaps a dozen muscovite-bearing pegmatites are known within a radius of 15 kilometers from the town of Algeciras (pl. 12), Huila, and an equal number along the upper eastern slope of the range in Caquetá. Some of the latter are near the Algeciras-San Vicente trail and the remainder near Santa Ana settlement, 10 to 15 kilometers south of the trail. A mica scout visited and procured samples from five localities near Algeciras and five on the eastern slope. The mica is small, irregularly fractured, and to some extent cross-grained, reeved, or mineral-stained. From only one locality could good-quality sheets of size 6 be trimmed out.

A considerable number of reported muscovite localities are widely distributed around the town of Florencia (pl.12). A mica scout visited nine localities, at one of which minor exploration was done. Samples from one yielded "good stained" and better mica up to size 4; those from another, size 6 only. Samples of mica from the remaining localities are small and exhibit numerous irregular fractures, as well as some cross graining and waviness, yet are prevailingly free of mineral stain.

At scattered localities (pl. 12) near the Garzón-Florencia highway, but particularly near Guadalupe (lat. 2°01′ N., long. 75°45′ W.) and near San Antonio settlement (17 kilometers northeast of Guadalupe), there are muscovite-bearing pegmatites. In general, the small size of the books and the numerous reeves and fractures preclude the trimming out of usable material even approaching size 6. At one locality, Caguan (8 kilometers east-southeast of Garzón), "good stained" and better qualities of green muscovite up to size 5 have been obtained yet are too scarce to permit exploitation.

OTHER LOCALITIES

Muscovite is known to exist or has been reported in numerous localities other than the ones described above, but none has yielded samples to arouse particular interest. Two regions, the southwest border of the Sierra Nevada de Santa Marta in Magdalena and the central part of Nariño, would warrant scouting if a comprehensive program of mica exploration throughout Colombia were continued.

In Santander "black-stained" mica, similar to that of the Pamplona region, has come from a locality northeast of California (lat. 7°21′ N., long. 72°58′ W.), and mica relatively free from mineral stain but small in size, reeved, and irregularly fractured has come from the vicinity of Los Santos (lat. 6°46′ N., 73°07′ W.). In Norte de Santander, four pegmatites located half a kilometer east of Chitagá (lat. 7°09′ N., long. 72°40′ W.) yielded no mine-run mica when prospected. In Caldas, samples containing a small percentage of usable material have come from a locality south of Pijao (lat. 4°22′ N., long.

75°44′ W.). In Tolima, heavily reeved "A" mica containing almost no usable material was procured 10 to 15 kilometers south of Murillo (lat. 4°53′ N., long. 75°10′ W.), in the municipio of Líbano, and worthless mica has come from a number of widely scattered localities between Ibagué (lat. 4°27′ N., long. 75°14′ W.) and Chaparral (lat. 3°43′ N., long. 75°28′ W.). In Cauca, worthless mica has come from the Corinto region (lat. 3°11′ N., long. 76°16′ W.).

MOLYBDENUM

Molybdenite has been reported in Antioquia, Caldas, Caquetá, Cauca, Nariño, and Tolima (pl. 9). The personnel of FEA made a rather intensive study of the Tolima occurrences, which greatly outnumber those in all the remainder of Colombia, and also visited a prospect in Caldas and an alleged prospect in Caquetá. The Nariño occurrences, according to Royo,[125] have no economic interest, and an alleged prospect in Antioquia and another in Cauca remain unverified.

The number and distribution of molybdenite showings in Tolima suggest a metallogenic province in which commercial ore bodies could be expected. However, the chances at any of the known prospects for readily discovering either a single large deposit or a cluster of small deposits that in aggregate might support even a medium-sized mining project are slight.

At present the greatest possibilities offered by the Tolima district are (1) that two of the known molybdenite showings, one at Venecia and one at Nevadas, might prove to be small ore bodies when uncovered by soil stripping and (2) that promising new leads might be disclosed by painstaking search of float, supplemented by extensive soil stripping in the general vicinity of the known showings at several prospects.

CALDAS

The Concherí prospect (lat. 5°14′ N., long. 75°46′ W.), in the municipio of Anserma, was examined in 1942 by W. D. Longan. (See pl. 9.) At that time a small open-cut exposed a vertical face of schist 8 to 9 meters long and 3 meters high. Malachite stain, scattered patches of molybdenite, and a 3-ounce pocket of chalcocite were confined to an area 1 meter by 4.5 meters in extent, which was bounded on three sides by barren schist; hence the "ore" could extend in only one direction, downward. Prior to Longan's visit, a sample weighing 2 or 3 tons derived from the cut had been sent to New York, where an alleged assay of 12 percent of molybdenum plus 13 percent copper was ob-

[125] Royo y Gomez, José, Datos para la geología económica de Nariño y Alto Putumayo: Compilación de los estudios geológicos oficiales en Colombia, tomo 5, p. 160, 1942.

tained; a few specimens said to have been taken from the shipment tend to confirm the assay and to suggest that a very small, rich pocket was mined out. No encouraging float has been found in the immediate vicinity.

Alleged molybdenite showings near Risaralda (lat. 5°09′ N., long. 75°46 W.), Santa Rosa (lat. 4°52′ N., 75°38′ W.), and Calarcá (lat. 4°32′ N., long. 75°39′ W.) remain unconfirmed.

CAQUETA

Three pegmatites containing graphite instead of molybdenite were shown to G. R. Leland in 1943 when he examined alleged molybdenite prospects near the Algeciras-Guacamayo trail, approximately at latitude 2°23′ N., longitude 75°11′ W., and latitude 2°21′ N., longitude 75°07′ W. These pegmatites may or may not be the occurrences cited in an application for a molybdenum concession, "Expediente" 253, made by a person whose whereabouts could not be traced by FEA.

TOLIMA

GEOLOGIC SETTING

The molybdenite occurrences of Tolima are on the eastern slope of the Cordillera Central between latitudes 3°25′ N. and 4°35′ N. This is part of a single geologic province in which the bedrock is mainly (1) fine-grained chloritic and micaceous schist and (2) medium-grained igneous rock, of monzonitic and related composition; the latter forms stocks and long, narrow batholiths trending north-northeastward. The general form and distribution of igneous massifs in central Tolima are depicted by White Uribe's map.[126] Minor facies of the igneous massifs include numerous dikes and irregular bodies of felsite, which perhaps are aphanitic "aplites," numerous pegmatites, and here and there quartz-rich plutonic bodies. At very few places have rocks comparable in texture to the "porphyries" of Colorado been observed. Cretaceous and Tertiary sedimentary and volcanic rocks, none of which contains molybdenite, are in structural basins or grabens near the eastern margin of the Cordillera Central.

Fourteen prospects (pl. 9), each of which includes from 1 to 10 separate occurrences at which the presence of molybdenite has been verified, are listed below. Those south of latitude 4° N. were examined by G. R. Leland; those north of latitude 4° N. were examined by the author.

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[126] White Uribe, H. E., Departamento del Tolima, Estudio minera practicado en los Municipios de Ibagué, Anzoátegui, y Quesada: Bol. minas y petróleo, tomo 13, nos. 73–78, map opposite p. 280, 1934.

Name	Municipio	Approximate coordinates Latitude	Longitude
Santa Barbara	Anzoátegui	4°32′ N.	75°07′ W.
Paramillo	Ibagué	4°31′ N.	75°11′ W.
Nevadas	Cajamarca	4°28′ N.	75°29′ W.
La Guayaba	Ibagué	4°26′ N.	75°19′ W.
La Pradera	----do	4°23′ N.	75°19′ W.
Providencia	Rovira	4°17′ N.	75°21′ W.
Guerrero	----do	4°17′ N.	75°17′ W.
Venecia	San Luis	4°15′ N.	75°09′ W.
Santo Domingo	Rovira	4°08′ N.	75°14′ W.
Cucuana	----do	4°04′ N.	75°19′ W.
San Pedro	Chaparral	3°50′ N.	75°22′ W.
La Popa	----do	3°31′ N.	75°47′ W.
La Divisa	----do	3°27′ N.	75°47′ W.
El Genil	----do	3°26′ N.	75°46′ W.

Molybdenite that can readily be recognized, in small, medium, or large flakes, occurs as follows: (1) in hydrothermal quartz veins, as at Nevadas and La Guayaba; (2) in stringers, blobs, and small lenses of pegmatitic(?) quartz, as at Guerrero, La Popa, Providencia, Santo Domingo, and San Pedro; (3) in pegmatite, as at Santa Barbara, La Pradera, Providencia, Santo Domingo, and San Pedro; (4) in feldspathic segregations, probably of pegmatitic derivation, as at La Divisa; (5) in felsite, as at Santo Domingo and El Genil; and (6) in monzonite, adjacent to one of the above, as at Nevadas, Santo Domingo, and La Divisa.

Aphanitic molybdenite, very difficult to recognize, occurs as films coating fractures in fault zones at Guerrero and Santo Domingo and as films and disseminated aggregates in a massive sulfide vein at Venecia.

VENECIA PROSPECT

On the Venecia tract (pl. 9) in the municipio of San Luis, examined in 1943 by the author, molybdenite has been found at only one place, locally named El Afloramiento. There a 4.5-meter adit exposes a vein of mixed sulfides, slightly oxidized, that dips 75° to the west-southwest. The vein is 1.2 meters wide at the floor of the adit but fingers and pinches upward; hence it may possibly enlarge downward. Soil stripping on both sides of the adit is needed to determine lateral continuations. The wall rock is nonmineralized porphyry. Chips taken on El Afloramiento dump at random from about 50 pieces of the vein assayed 1.44 percent molybdenum, 2.86 percent copper, 1.61 percent lead, 3.93 percent zinc, 0.30 ounce per ton of gold, and 7.0 ounces per ton of silver.

NEVADAS PROSPECT

The Nevadas prospect (pl. 9), located a few hundred meters northeast of the Bolívar gold mine in the municipio of Cajamarca, was examined in 1942 by the author and Gilberto Botero Restrepo. A small

excavation in the bottom of a narrow ravine exposes two molybdenite-rich quartz veins, 50 centimeters and 10 centimeters wide, respectively, and lean molybdenite dissemination in the immediate vein walls. The MoS_2 content of these veins is at least 5 percent. The 50-centimeter vein terminates southeastward within the prospect but may continue beneath the creek and up the west bank of the ravine where soil and vegetation have not been removed. Quartz stringers and heavily disseminated pyrite extend into the walls beyond the limit of molybdenum deposition. Quartz monzonite(?) forms the immediate walls of both veins, but schist crops out a few meters distant.

SANTO DOMINGO PROSPECT

Santo Domingo prospect (pl. 9), in the municipio of Rovira, was examined in 1943 by the author. The Cerro Santo Domingo is a northward-trending mountain, several kilometers long, composed of medium-grained syenitic and dioritic rocks, which are cut by fairly numerous small felsite bodies and a few small pegmatites. A major fault probably separates this igneous complex from Gualanday (Oligocene?) strata immediately west of the base of the cerro.

Molybdenite in megascopic flakes was seen on the western slope of the cerro in seven different outcrops along two ravines and also in a few stream boulders. Some additional, less promising showings are alleged to exist in nearby ravines and on the eastern slope of the cerro. The molybdenite occurs within stringers and veinlets of pegmatitic quartz, in pegmatite, in felsite, and in syenite. Minute-grained molybdenite intimately associated with pyrite or limonite was found as films along fractures in two different faults. None of the outcrops comes even close to being a showing of commercially valuable ore. Painstaking search of float may possibly lead to one or more fault zones, now concealed by soil, that would be wide and rich enough to be exploited, but the general outlook must be regarded as unpromising.

LA DIVISA PROSPECT

La Divisa prospect (pl. 9) is in a very sparsely settled region 80 kilometers southwest of the nearest highway at Chaparral. The prospect is an outcrop in La Divisa ravine. Molybdenite is disseminated both in a pink syenite and in feldspathic segregations that form small pockets unevenly distributed within the syenite. Pyrite and chalcopyrite occur only in the syenite. The MoS_2 content of the segregations is nearly 1 percent, but that of the syenite is much less. Only five segregations were found in an exposed syenite area of about 165 square meters. All the surrounding ground, which is very steep, is covered by soil and brush.

In Esmeralda ravine, several hundred meters northeast of La Divisa prospect, according to White Uribe,[127] is another molybdenite-bearing outcrop, and on the slope to the east, quartz boulders containing molybdenite may be found.

OTHER PROSPECTS

The remainder of the known prospects in Tolima are less promising than Venecia, Nevadas, Santo Domingo, and La Divisa and so are not described here. Intensive scouting of occurrences reported but unverified doubtless would disclose additional localities.

OPTICAL CALCITE

One hundred and twenty pounds of commercial calcite of suboptical grade purchased at $7.50 per pound, American currency, was shipped during 1944 from a deposit on Izacas farm (lat. 5°20′ N., long. 74°26′ W.), Cundinamarca (pl. 12). In addition, nearly usable material was found at the Chapetón prospect (lat. 2°27′ N., long. 75°54′ W.) in Huila and the Vallecitos prospect (approximately lat. 4°14′ N., long. 75°11′ W.) in Tolima; both were explored sufficiently to eliminate any reasonable chance of procuring commercial material. Despite intensive scouting, no other locality was found to merit even exploration.

The Izacas deposit is high above the Quebrada Potosí on a hillside having a 60° slope, 5 kilometers southwest of the town of La Palma. Careful search for float in the immediate vicinity, where all bedrock is concealed by soil and thick brush, failed to disclose clues to other deposits. The country rock at the mine workings is dark shale of the Villeta formation (middle and late Cretaceous), which has a nearly horizontal dip. The author first examined the locality, and J. K. Cathcart supervised the ensuing exploratory work.

The entire deposit, some 70 cubic meters in volume, was mined out. It was a heterogeneous mixture of clay, decomposed shale, and calcite, penetrated by a few barite stringers. Laterally and vertically the deposit graded rather abruptly into solid shale transected by calcite and barite veinlets. The calcite includes white, purple, and pale-green varieties. It occurs (1) as coarsely crystalline varieties in nests and blocks less than a cubic meter in volume, crystals up to 60 centimeters in length, and veinlets up to 20 centimeters in width or (2) as aphanitic interstitial material. Commercial pieces were cobbed only from purple calcite and, except for a very few pieces derived from crystals, came either from nests and blocks or from veinlets. The ore body was localized along a fault that dips 67° to 82° SE. This fault strikes N. 50° E. outside the ore body but curves to strike N. 85° E.

[127] White Uribe, H. E., Yacimientos de molibdenita (in general section entitled "Departamento del Tolima") : Bol. minas y petróleo, tomo 13, nos. 73–78, p. 339, 1934.

within the ore body. Lateral movement of the hanging wall southwestward with respect to the footwall probably parted the walls where the strike is N. 85° E.; this in turn permitted shattered rock to break off the walls, thereby forming a chambered area only partly filled by jumbled shale fragments. Later, calcite was deposited in the chambered area.

PLATINUM

More than 99 percent of the platinum metals, along with about 10 percent of the gold output of Colombia, comes from placer deposits in the Intendencia del Chocó. Approximately 50 to 70 percent of the total is derived from dredging operations of the Cía. Minera Chocó-Pacífico, S. A., nearly all the remainder from primitive native mines, and only insignificant amounts from hydraulic workings. Gravel worked by Chocó-Pacífico during 1940–44, according to company officials, averaged about 15 cents, American currency, in combined gold and platinum metals per cubic yard. The records of the Ministerio de Minas y Petróleos give the following production figures, which obviously take no account of smuggling:

	Platinum metals, troy ounces
1941	37,349
1942	43,103
1943	34,564
1944	34,304
1945	34,757

Gold veins have been found at scattered localities along the little explored middle and upper slopes of the Cordillera Occidental. Few of these veins have ever been worked, although in 1944 a lode mine said to employ more than 100 persons was operating near the head of the Río Andágueda. No platinum-bearing lodes have been found.

Essentially all the data given herewith on gold and platinum distribution are derived from the Cía. Minera Chocó-Pacífico, S. A. The courtesy of that company in furnishing all desired information, in providing facilities for visits to dredges and to native mines in the Río San Juan area, and in according generous hospitality to the author during a 5-day visit in January 1945 is most gratefully acknowledged.

GEOGRAPHY OF THE CHOCO

Figure 3 shows the generalized drainage pattern of the Intendencia del Chocó between the latitudes within which are found all the productive gold and platinum deposits. The topographic provinces of the region are (1) the rugged western slope of the Cordillera Occidental which, east of the Ríos Atrato and San Juan, rises to altitudes of 2,500 to 4,000 meters and is dissected by deep gorges having steep gradients and precipitous valley walls; (2) the Serranía de Baudó,

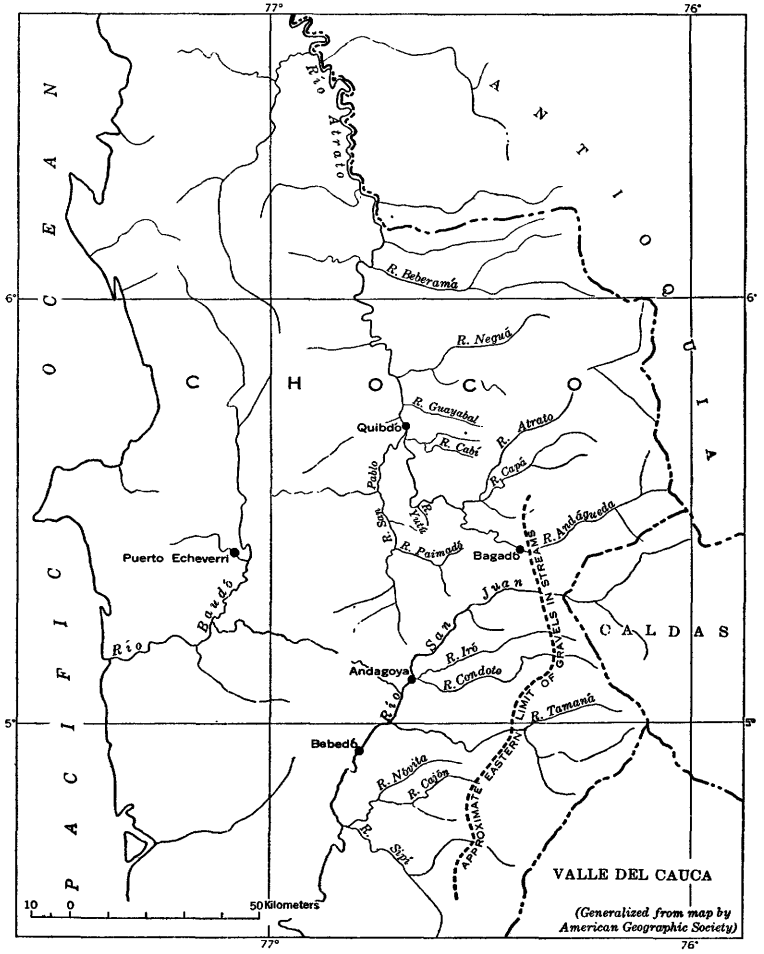

FIGURE 3.—Sketch map of part of the Intendencia del Chocó, Colombia.

a range of mountains 500 to 1,000 meters in altitude, located between the Río Atrato and the Pacific Ocean; and (3) the tropical lowlands, from which relatively low hills rise in places. The climate in the lowlands is hot, humid, and unhealthy, with a rainfall of more than 250 inches per year. According to the 1939 census, the total population of the Chocó is 111,216, which represents an average of 2.4 persons per square kilometer. Coal-black Negroes predominate, but there also are mulattos, whites, and indigenous Indians. Most of the inhabitants live along the banks of the principal rivers. The main camp of the Chocó-Pacifico company is at Andagoya. Malaria is common among the natives, the other most prevalent diseases being tropical anemia, venereal diseases, recurrent fever, and amoebic dysentery.

Transportation in the Chocó is almost wholly by water. Dugout canoes, 10 to 40 feet long, serve most of the inhabitants. However, marine craft ply the Río San Juan to Bebedó, the Río Atrato to Quibdó, and the Río Baudó to Puerto Echeverri; and open launches operate within both the San Juan and Atrato drainages, upstream nearly to the line designated "approximate eastern limit of gravels" on figure 3. Trails are scarce, and nearly all are foot trails in the mountains above the limits of navigation by canoe.

Electric power is generated in a hydroelectric plant at La Vuelta (lat. 5°28′ N., long. 76°32′ W.), owned by a company affiliated with Chocó-Pacífico; in 1945 there were two 1200-KVA generators. Electricity is supplied to several small towns between La Vuelta and Andagoya.

BEDROCK

Data concerning bedrock are extremely meager. Marine sedimentary rocks of Tertiary age are believed to underlie the lowlands of the Ríos San Juan and Atrato. Their eastern boundary probably lies a little west of the line designated "approximate eastern limit of gravels in streams" on figure 3. East of the Tertiary strata in places are sedimentary rocks supposedly of Cretaceous age. East of the Cretaceous (?) strata, in turn, are rocks grouped as undifferentiated Mesozoic on the 1944 geologic map of Colombia. Actually this belt, which comprises the crest and most of the western slope of the Cordillera Occidental, probably includes sedimentary, igneous, and metamorphic rocks of different kinds and ages. Various persons have reported green schists, greenstones derived from diabase, melaphyres, and other basic igneous rocks, and even serpentine, yet no extensive area of peridotite or serpentine that may be regarded as the source of platinum has yet been found.

GRAVELS

Gravels of Recent age throughout the San Juan drainage have many features in common. Along the main river south of latitude 5°10′ N. and in the lower reaches of tributary valleys, a heterogeneous assortment of well-rounded materials ranges in size from very fine grained to about a foot in maximum diameter. Upstream, there is a progressive increase both in the maximum size of the boulders and in the ratio of coarse to fine material. The prevailing rock types represented as pebbles and boulders are dark, indurated shale; fine-grained, basic igneous rocks that probably are diabase or gabbro; very fine grained feldspathic rock that probably is graywacke; and medium-grained igneous rock that probably is diorite. The relative proportions of these rocks vary somewhat from place to place, and so detailed study might delineate systematic geographic variations in the composition of

the gravels. The rock types represented in minor quantities include andesite and basalt, conglomerate with rather angular pebbles, gneiss, granite, cherty shale, and others. Conspicuous by its almost complete absence, even in the smaller sizes, is quartz. The gravels of the Atrato drainage were not seen by the writer.

Ancient gravels are represented by materials locally called "red caliche" and "gray caliche." The former is found in widely scattered erosional remnants. The largest such remnant is south of the Río Condoto at longitude 76°37′ W.; others are known approximately at latitude 5°36′ N., longitude 76°38′ W.; latitude 5°22′ N., longitude 76°36′ W.; latitude 5°18′ N., longitude 76°34′ W.; and latitude 4°54′ N., longitude 76°47′ W. The "red caliche" is a gravelly clay, about half of which is fine material and the remainder pebbles and boulders up to 1 foot in maximum diameter. The pebbles and boulders are well rounded; they tend to have flattened shapes but in general are slightly less flat than the pebbles and boulders of Recent gravels. The clay matrix and nearly all pebbles and boulders are permeated by red iron stain. The rock types represented are essentially the same as in Recent gravels. Nearly all the pebbles are so decomposed that they may be broken apart by hand. The "red caliche" contains platinum in sufficient quantities to permit native mining, but it is too lean for dredging.

"Gray caliche" in places underlies "red caliche" and so is older. It is a gravelly clay devoid of red stain but otherwise very similar to the "red caliche." The "gray caliche," which is essentially barren of platinum and gold, forms the bottom of the dredging ground in "flats" in the vicinity of latitude 5°05′ N., longitude 76°38′ W., and latitude 4°50′ N., longitude 76°37′ W.

HISTORY OF MINING

Placer mining in the Chocó dates back to early colonial times, when the most extensive work was in the same areas as now. For a long time platinum was thrown away.

Modern mining may be regarded as dating from November 1889, when Henry G. Granger appeared in Colombia with a group of mining engineers. Starting at Quibdó, this group explored and prospected gold-bearing rivers of the Atrato and San Juan drainages, then solicited and obtained title to ground that they regarded as exploitable by dredging. Granger went back to the United States but in 1906 returned and installed a small dredge a short distance above Quibdó. This dredge was wrecked by a sudden rise in the river. The South American Gold & Platinum Co., of which the Cía Minera del Chocó-Pacífico is a subsidiary, was formed in 1916 as an amalgamation of several interests, including some of the properties

owned by Henry G. Granger and the Anglo-Colombian Development Co., Ltd. The latter company had begun dredging the Río Condoto at Andagoya (lat. 5°06′ N., long. 76°40′ W.) in 1915. A company that was liquidated years ago, the British Platinum & Gold Corp., Ltd., from 1921 until 1927 operated one dredge at the town of Opogodó (lat. 5°05′ N., long. 76°37′ W.) and, for a short time, another on the Río Condoto.

In 1934 a company named Los Hermanos Lloreda, with aggregate funds amounting to about 100,000 pesos derived from Colombian and English sources, set up two monitors in the vicinity of San Marino settlement (15 kilometers upstream from Bagadó) on the Río Andágueda. Half the funds were expended in constructing an aqueduct; 2 years later the enterprise failed.

About 1935 a small company was organized to operate on the Río Neguá. Soon thereafter, an American named Lewis bought out his other associates in this company. In 1945 he was operating two very small suction dredges in the southern tributary of the Río Neguá about 15 kilometers upstream from its confluence with the Río Atrato.

Native mining by groups of two or more persons, mostly women, has continued with little change in mining method since the colonial period.

GENERAL DISTRIBUTION OF GOLD AND PLATINUM

The streams flowing down the western slope of the Cordillera Occidental are raging torrents; the valley floors contain large boulders but no true gravel until they reach the lower foothills. Figure 3 indicates the upstream boundary of true stream gravels and therefore of ground that may be worked by placer methods. The position of this boundary was given by F. D. Bradbury, assistant manager of the Chocó-Pacífico company.

Between latitudes 4°30′ N. and 6°35′ N., gold and platinum may be found by panning in the Ríos San Juan and Atrato and in nearly all tributaries entering from the east (fig. 3). On the other hand, the metals are wanting in nearly all tributaries entering from the west; there, however, they are found in scattered native mines located in the upper reaches of the Río San Pablo, the Río Paimadó, and the Río Yutú. Gold and platinum also are found in numerous flat areas adjacent to, and even between, rivers.

Although at least tiny amounts of detrital platinum accompany detrital gold in all the placers of the Chocó, a platinum-gold ratio in excess of 1:20 is found only along the Río San Juan drainage north of latitude 4°50′. The highest platinum-gold ratios, as well as virtually all the platinum nuggets ever found in Colombia, were along the Ríos Iró and Condoto.

Gravels bottom on true bedrock in all areas already dredged or delineated for future dredging, except in the large area of "flats" southwest of Condoto and in the lower part of the "flats" southwest of Cajón, where they bottom on "gray caliche." Depth to bedrock ranges from a few feet to more than 40 feet and shows much variation within short distances. In the rivers the pay channel may comprise the entire river bed or, more commonly, only part of it. In the "flats," workable ground may be a narrow channel comparable in width to a river channel or a broad, irregularly shaped area.

The vertical distribution of gold and platinum within the gravel, according to F. M. Estes, manager of the Chocó-Pacífico company, is extremely irregular. Usually the highest values are found in the lowermost foot or so. Nevertheless, drilling has demonstrated that gold and platinum may be distributed through a considerable part of any given vertical section and that a curve in which values are plotted against depths normally will show several peaks and troughs. The lateral distribution of gold and platinum likewise is very irregular in detail.

PLACER-MINING LOCALITIES AND METHODS

Dredges of the Chocó-Pacífico have operated, or now are operating, (1) along the Río Andágueda, from its confluence with the Río Atrato to above Bagadó; (2) along the Río San Juan, from a few kilometers downstream from Andagoya to longitude 76°25′ W.; (3) along the Río Condoto, from its confluence with the Río San Juan to longitude 76°15′ W.; (4) along the Río Tamaná, upstream from longitude 76°39′ W.; and (5) in "flats" adjoining the above rivers and also along the upper reaches of the Río Cajón. All five dredges are of the California type; they are electrically operated, have a double bank of transverse tables, are geared for operating to maximum depths of 36 to 44 feet, and have 72 to 84 buckets ranging from 5 cubic feet to 12 cubic feet in capacity.

Small-scale hydraulicking has been carried on from time to time at different localities.

Colombian law permits natives of the lower economic class, which includes most Chocó residents, to work placer ground along navigable rivers on their own behalf regardless of ownership. As a result, a great many natives are engaged, at least part of the time, in mining. The actual number is not known but may be roughly estimated at 10,000 to 15,000.

According to Colombian Government sources, native workings are scattered along the valleys of the Río San Juan and all its eastern tributaries from the Río Sipí northward; in the valleys of the Río

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San Pablo, between latitudes 5°10′ N. and 5°20′ N., and the Río Paimadó; and in the valleys of the Río Atrato and many of its eastern tributaries, particularly the Río Andágueda, the Río Capa, the Río Cabí, the Río Guayabal, and the Río Neguá, and also in the Río Yutú, a western tributary. They are most abundant in the minor tributaries of the Ríos San Juan, Iró, Condoto, and Tamaná.

Several different systems of mining, all primitive, are employed. By far the greatest number of native mines are located where a steep bank of gravel bearing gold or platinum, or both, is in proximity to a small stream. The material in the bank is scraped into a wooden pan and carried—or else scraped all the way—down the slope to a shallow ditch at the base, where it is washed by water diverted from the stream. A series of miniature dams controls the water supply and thus permits washing, frequently during the night, after an adequate supply of material from the bank has accumulated in the ditch. The gold and platinum metals are recovered in crude riffles located in the ditch immediately below the spot being worked. Less frequently, crude tunnels extend into the base of a bank of semiconsolidated gravel.

At places, natives work river playas by simple panning or the river bed itself by diving. The native divers train themselves to remain under water 2 minutes or more while collecting a panful of gravel. Sometimes divers work immediately in front of a dredge in order to obtain gravel closer to bedrock than could otherwise be procured.

SIZE AND FINENESS OF PLATINUM METALS AND GOLD

The size and fineness of the platinum metals vary from place to place. Most of those now recovered by dredging can be caught between the 80-mesh and 100-mesh screens, but some are small enough to pass a 200-mesh screen. The chief metals alloyed with platinum are iron, rhodium, iridium, palladium, osmium, and copper; gold occurs only in traces. The composition of platinum recovered from the Río San Juan is different from that of the Río Condoto and of the "flats" to the south, suggesting different sources, as is shown by the following data taken from analyses by Ledoux & Co.

	3,500 ounces from Río San Juan		4,000 ounces from "flats," south side of Río Condoto	
	Range (percent)	Average (percent)	Range (percent)	Average (percent)
Platinum	84.10–84.52	84.37	84.60–87.40	86.72
Osmium plus iridium	1.26–2.81	2.39	.69–1.96	.96
Palladium	0.43–0.56	.52	.51–.56	.54

The gold recovered by dredging normally is pinhead size or smaller. Much of it is very fine grained, and a small percentage is lost in the tailings. The average fineness during 1944 was about 795, and the normal variation was from 740 to 840. The dross ranges from 30 to 120.

According to officials of the Chocó-Pacífico company, there is little difference in the composition of gold from different places except that the fineness in the Cajón area and in the Río Tamaná normally is slightly higher than the general average and, in the "flats" south of the lower Río Condoto, slightly lower than the average.

SOURCES OF PLATINUM

F. D. Bradbury, assistant manager of the Chocó-Pacífico company, believes that platinum in Recent gravels may be derived mainly from eroded "red caliche." However, the original bedrock source in the Cordillera Occidental remains to be discovered, despite speculative assertions to the contrary scattered through the literature. Slight differences in composition suggest that the platinum in the Río San Juan above Andagoya may be derived from a different source from platinum in the Río Condoto.

QUARTZ CRYSTALS

The output of acceptable quartz crystals in Colombia has aggregated 1,503 pounds valued at $7,870, American currency. Approximately 67 percent by value came from the Alumbral mine in Boyacá, 19 percent from the Santa María deposit in Antioquia, 10 percent from the Cuincha deposit in Boyacá, and 4 percent from miscellaneous localities. (See pl. 12.) All the crystals were produced during 1942–44 as a result of widespread search and considerable prospecting fostered by FEA.

Regions to be regarded as possible sources of quartz crystals are (1) western Boyacá, northwestern Cundinamarca, and southwestern Santander, (2) northern Tolima, (3) west-central Huila, (4) east-central Cundinamarca, (5) eastern Antioquia, and (6) western Valle del Cauca. In each region are one or more prospects at which commercial crystals or near-usable crystals have been found. The near-usable crystals are very clear but either are less than 2 inches thick or weigh only 50 to 100 grams or else weigh more than 100 grams but are below grade due to twinning, veils, or fractures. Also in each region are many localities, not regarded as prospects, at which crystals no heavier than 50 grams have been found. In fact, the abundant and widespread distribution of very small crystals promotes undue optimism among local inhabitants and causes many reports and rumors of prospects that prove to be worthless.

The crystals are derived from small lodes which in general must be exploited by underground mining in solid rock. Few lodes can be expected to yield more than 100 kilograms of commercial crystals, and none as much as a metric ton, for even within crystal-bearing ground only a small fraction of 1 percent of the total quartz consists of usable material. Moreover, the deposits generally are in rugged, soil-covered terrain having 30° to 60° slopes and at distances of several hours by animal trail from a highway. The country rock is dark shale at most prospects in Boyacá, Cundinamarca, Santander, and Valle del Cauca, but it is either fine-grained schist or medium-grained igneous rock at those in Antioquia, Huila, and Tolima.

Mining and prospecting costs are excessive in Colombia as compared with a country where crystals are widespread in decomposed material that can be mined in open-cuts in relatively flat terrain accessible to motor transport. During 1942–44, the over-all cost of production greatly exceeded the value of the crystals procured. In case of an acute demand in the future, an output not exceeding 1,000 pounds of crystals per year doubtless could be achieved at a cost of 5 to 10 times their value according to 1944 prices.

ANTIOQUIA

In Antioquia, commercial crystals were mined at the Santa María prospect (lat. 6°34′ N., long. 74°44′ W.), and several clear but excessively twinned crystals weighing more than 200 grams were recovered in the Frontino gold mine near Segovia (lat. 7°07′ N., long. 74°41′ W.). However, at Santa María (pl. 12) the deposit proved to be too small, and at Segovia (pl. 12) large clear crystals were much too scarce, for either locality to be regarded as a potential source in the future. Less tangible leads include two clear but veiled crystals weighing 100 grams and 200 grams, respectively, allegedly found near Amalfi (lat. 6°55′ N., long. 75°03′ W.); two cloudy crystals weighing 300 grams and 500 grams, respectively, allegedly found near Remedios (lat. 7°02′ N., long. 74°41′ W.); a reported occurrence of many small crystals in topsoil at the abandoned Mina Cristales, 3 kilometers from Sonsón (lat. 5°42′ N., long. 75°18′ W.); and a report that crystals have been found in gold-quartz veins near Cañasgordas (lat. 6°45′ N., long. 76°01′ W.).

The Santa María prospect (pl. 12), located about 6 kilometers east-northeast of the town of Maceo, produced 267 pounds of usable crystals, sold for 2,646 pesos ($1,517, American currency), which is about 19 percent of Colombia's total output. This deposit is in a region of moderate relief where topsoil is thick, and outcrops are exceedingly scarce. The locality was examined by both G. R. Leland and J. R. Balsley soon after exploratory work began in 1943 and again by Leland soon after work terminated in 1944; their data follow.

The productive quartz body, apparently mined out, had a maximum area of 2.4 by 3.4 meters and extended to a depth of 7.3 meters beneath red clay and topsoil. It consisted of highly fractured quartz in which many well-faced, terminated, clear-ended crystals were heterogeneously distributed. Extending to a distance of 6 or 7 meters laterally northwestward from the main quartz body and also directly beneath it are scattered crystal aggregates within the schist wall rock. Conceivably, these crystals could lead into another productive body. Figure 4 shows a plan of the workings, a cross section of the main trench, the form and relations of the productive quartz body, and the places at which additional prospecting is justified by crystals in schist.

BOYACA

GEOGRAPHIC AND GEOLOGIC SETTING

Western Boyacá between longitudes 74° W. and 74°20′ W. contains deposits that contributed about 80 percent of Colombia's total output of crystals and also an abundance of prospects at which crystals below commercial grade have been found. During 1942–44, all possible leads were investigated. In the future, an acute demand for small quantities of crystals at very high prices would justify further exploration at seven localities: Alumbral (lat. 5°32′ N., long. 74°07′ W.), Cuincha (lat. 5°30′ N., long. 74°08′ W.), Peña Blanca (lat. 5°44′ N., long. 75°05′ W.), Amarilla (lat. 5°29′ N., long. 74°14′ W.), Ramal (lat. 5°32′ N., long. 74°12′ W.), Cuacua (lat. 5°30′ N., long. 74°05′ W.), and Isabí (lat. 5°28′ N., long. 74°08′ W.).

Quartz crystals also have been found at the Chivor emerald mines in Boyacá but constitute part of a geologic areal unit that lies mainly in east-central Cundinamarca.

Data for western Boyacá are derived mainly from FEA reports by G. R. Leland, who in turn utilized earlier reports by William Burns, W. T. Pecora, and J. R. Balsley. Leland personally examined the 11 most promising localities, supervised the activities of an FEA mineral scout who visited all the other reported occurrences of near-usable crystals, and gave technical advice to operators and prospectors. Soil stripping was resorted to wherever needed for a preliminary appraisal of a prospect.

The region is dissected by deep gorges between precipitous, soil-covered slopes at altitudes ranging from 700 meters to 1,800 meters; it is traversed by steep and muddy trails and is populated mostly by families living in one-room, doorless bamboo huts with thatched roofs. The 1944 geological map of Colombia shows both Cretaceous and lower Eocene rocks in the region, but the country rock at nearly all quartz crystal localities is dark shale, presumably of the Villeta formation (middle and late Cretaceous). Dips prevailingly are steep.

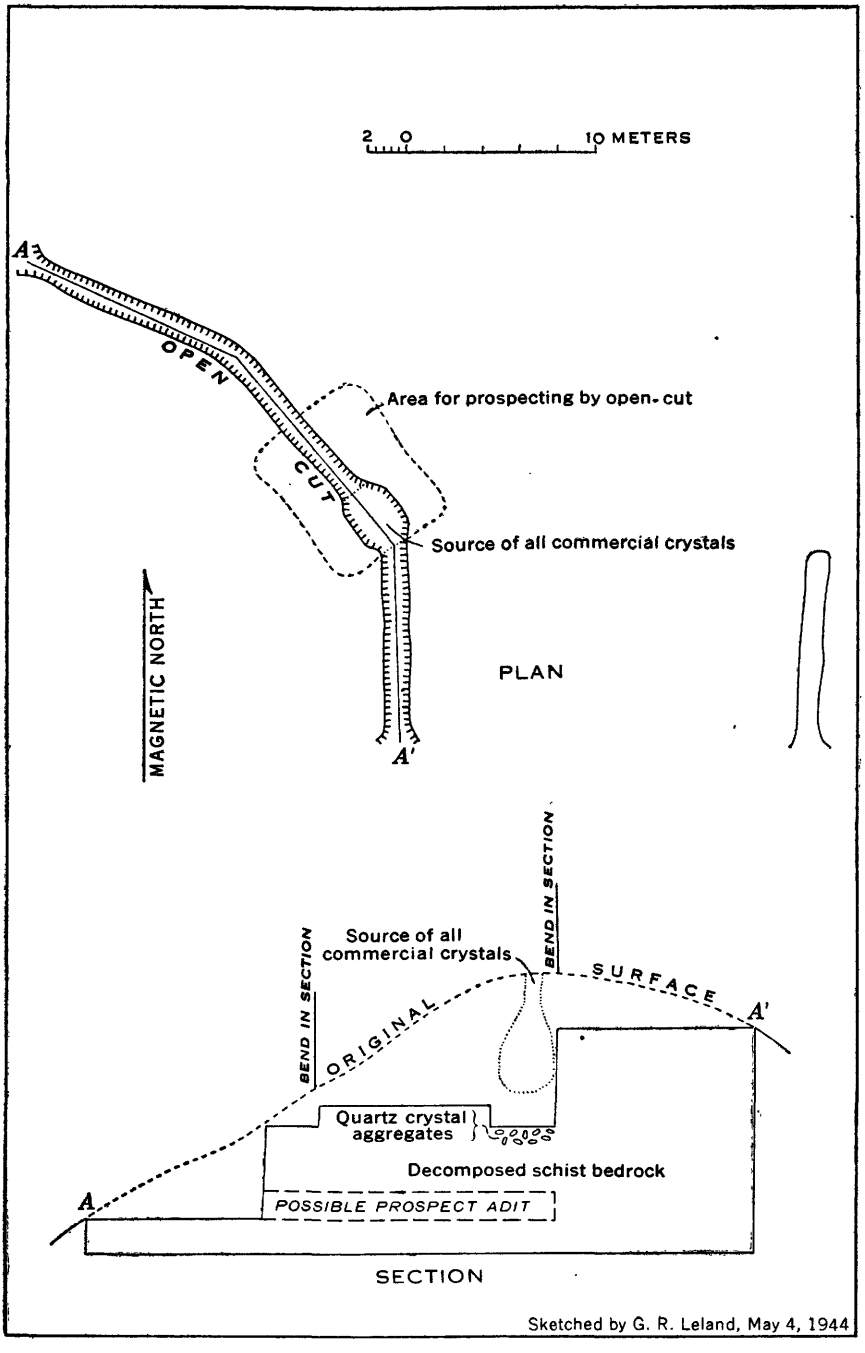

FIGURE 4.—Sketch map and section of the Santa María quartz crystal prospect, municipio of Maceo, Antioquia, Colombia.

Throughout the region, quartz veins are common, calcite veins moderately common, and pyritic-chloritic mineralized zones scarce and spotty.

The quartz veins range from mere stringers to bodies several meters thick and several tens of meters long. Although most of the quartz consists of anhedral grains, nearly all the occurrences exhibit local areas of coarse comb structure, manifested by prism faces on the outcrop surface. Many of the veins contain vugs lined with small crystals, and some veins contain vuggy "pockets" where large crystals are associated with limonite. The crystal "pockets" range from less than a meter to as much as 20 meters in outcrop length, and they are the site of all commercial crystals except a very few taken from a solid part of the Alumbral vein. In prospecting, if soil stripping did not reveal a "pocket" containing large crystals along a considerable outcrop length of vein, the locality was rejected.

ALUMBRAL MINE

The Alumbral mine (pl. 12) is a kilometer west of the town of Muzo (lat. 5°32′ N., long. 74°06′ W.) and about 3 kilometers east of the famous Muzo emerald mines. The workings are located near the base of a cliff that slopes 60° to 70° north-northeastward to form the left bank of the Quebrada Alumbral. Except for a cleared area of 2,500 square meters, the cliff is covered by soil and dense brush. The climate is hot and humid.

The deposit was discovered about 1940 by prospectors seeking emeralds, was worked intermittently by open-cut until the end of 1942, and then was explored and exploited by underground mining until shut down at the end of 1944. The excessively steep slope and the slabby character of the bedrock precluded anything except the cutting of a narrow bench along the outcrop. The plan for underground work was formulated and supervised by Burns during 1943. Thereafter, Leland visited the mine periodically and served as engineering adviser. Most of the data which follow are derived from Leland's final report to FEA, which in turn made use of data recorded by Burns, Pecora, and Balsley.

The main vein has an irregular form due to bulges, branches, and ramifications, as shown by plate 13. It strikes approximately N. 65° W. and dips 30° SW. into the cliff. The strike length is 44 meters at the surface but only 27 meters on the 750-foot level; and on the 737-foot level, the vein apparently is represented only by a few small lenses devoid of large crystals. Besides quartz, the vein contains irregularly distributed limonite, which is most abundant in vuggy portions, and blobs of calcite. A number of accessory veins, scarcely more than stringers, do not exhibit even near-usable crystals.

The wall rock is dark shale of the Villeta formation (middle and late Cretaceous) that strikes N. 15° to 30°E. and dips 70° to 80° SE., except in a local drag fold located west of the main fork of the vein at the surface, where the dip flattens to 50° SE. The shale readily cleaves parallel to the bedding and is transected by joints trending N. 60° E.; 30° SW.; the result is a tendency to break into large slabs which made mining dangerous.

The aggregate output of crystals was valued at approximately $5,300, American currency, or 67 percent of Colombia's total. Nearly 300 metric tons of "ore" extracted along the surface yielded 0.1 percent commercial material, and about 800 metric tons stoped above the 750-foot level yielded nearly 0.02 percent commercial material. There remain about 100 metric tons of "ore" unmined above the 750-foot level and perhaps 500 metric tons below it, from all of which a yield of about 100 kilograms of commercial crystals worth approximately $1,200 at 1944 prices could reasonably be anticipated.

CUINCHA DEPOSIT

The Cuincha deposit (pl. 12), located 5 kilometers south-southwest of Muzo, contributed approximately 10 percent of Colombia's output of quartz crystals. Exploratory work was done by driving an open-cut 15 meters wide into the steep mountainside for a distance of 11 meters. Work terminated in crystal-bearing ground when the cut face attained a height of 10 meters in material that was sloughing badly.

A single quartz vein whose generalized form in cross section is shown by figure 5 irregularly pinches and swells from half a meter to 2 meters in thickness. At places in one or both walls are several closely spaced stringers that parallel the vein. All, or nearly all, the commercial crystals came from the vein's steeply dipping western arm, which strikes about N. 20° E. and abruptly terminates in the cut face 4 meters above the floor. The relatively flat part of the vein, to a distance of 8 or 9 meters east of the productive arm, was followed by the floor of the open-cut, but still farther east the vein remains unprospected. Unconsolidated material resembling topsoil encloses the vein except along the east side of the cut, where decomposed dark shale dips 40° SE.

If additional work ever is done, a drift adit along the base of the productive arm of the vein, with stopes above the adit, would be preferable to further advance by open-cut, inasmuch as the height of the face of the cut increases as mining proceeds into the mountain.

PEÑA BLANCA PROSPECT

Peña Blanca prospect (pl. 12), located 3 kilometers north-northwest of Chancares (lat. 5°43′ N., long. 74°04′ W.), yielded 10 pounds of

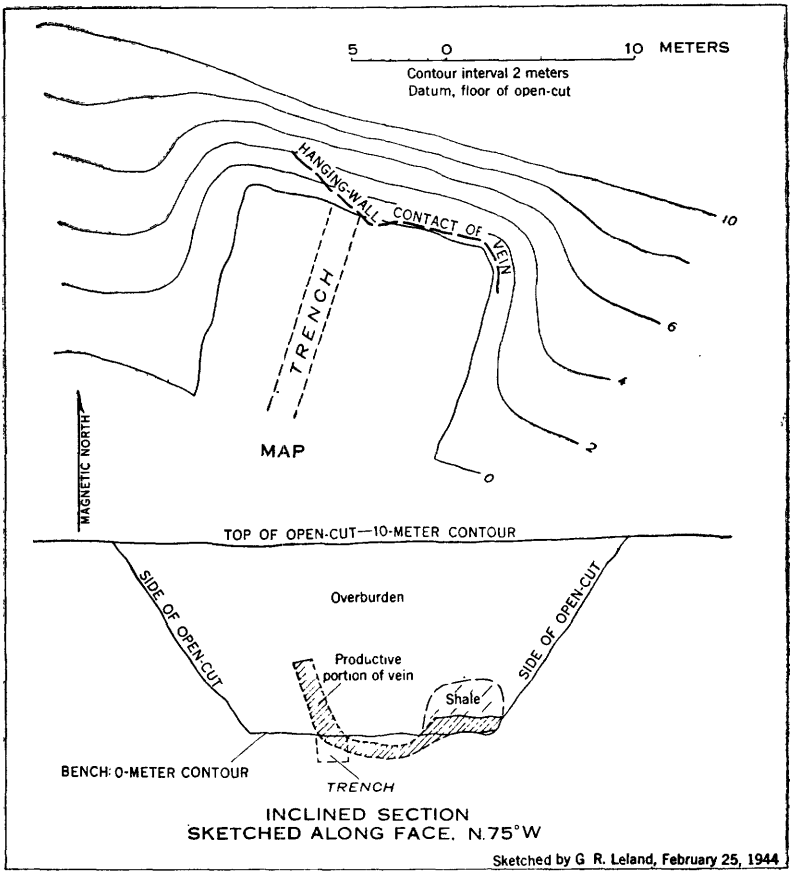

FIGURE 5.—Sketch of Cuincha quartz crystal prospect, municipio of Muzo, Boyacá, Colombia.

commercial crystals. The bedrock is shale and limestone, which dip 20° to 30° NNE. Two quartz veins, five calcite-quartz veins, and two calcite veins are exposed; others probably are concealed by soil. Fluorite and siderite(?) appear as accessory vein minerals. The average width of the veins ranges from 0.5 meter to 2.5 meters.

A few commercial crystals came from the float. The remainder were procured from a nearly vertical quartz vein 0.4 to 0.5 meter wide, which has been exposed for a length of only 4 meters along the surface and 3 meters along a prospect adit. Eighty meters south of the Hueco vein, within an area of 6 square meters, a quartz vein 1.2 meters wide that splits southward into two stringers is exposed. This vein, which trends N. 65° W., 20° SW., exhibits near-usable crystals up to 300 grams in weight. In addition, small clear crystals may be seen in the calcite-quartz veins. If the locality is prospected in the future, soil stripping may be carried out along both the Hueco vein and the vein 80 meters farther south.

AMARILLA PROSPECT

At the Amarilla prospect (pl. 12), located approximately 13 kilometers west-southwest of Muzo, nine crystals weighing in aggregate 3½ pounds were procured from a single "pocket" along the footwall of the Amarilla No. 1 vein. Uncovered by soil stripping along its entire outcrop, this vein is 60 meters long, averages about a meter in width, pinches out at both ends, and trends N. 65° E., 55° SE. The bedrock is dark shale that dips a few degrees to the southwest. The crystal "pocket," nearly filled by soft limonite and loose crystals, occurs in a bulge where the vein thickens to 2.4 meters. The "pocket" is 1.2 by 2.3 meters in area and has been mined to a depth of 5 meters along the strike into the hillside, where it had not yet terminated. No crystals and very little comb structure were observed in the vein outside the "pocket."

Three other veins are located at distances of 35 meters, 75 meters, and 97 meters, respectively, along the ravine upstream from the Amarilla No. 1 vein. They range from 0.7 meter to 2.5 meters in width and from 48° to 80° SE. in dip, and they have been uncovered for outcrop lengths ranging from 1.5 meters to 10 meters. The two most distant from the No. 1 vein exhibit patches of comb structure and a few milky crystals.

Additional soil stripping along the veins containing milky crystals and further exploration of the crystal "pocket" into the hillside may possibly disclose more commercial crystals.

EL RAMAL PROSPECT

Two veins have been discovered at El Ramal prospect (pl. 12), located approximately 11 kilometers west of Muzo. Each has been prospected only for a length of about 3 meters along the surface. One yielded 28 crystals that nearly met minimum commercial requirements, the other nothing but a few small and milky crystals. The first vein is 1 meter wide, dips 54° to the east, conformable with the shale bedding, and exhibits considerable comb structure. The second, which is 30 meters to the southeast, is 1.7 meters wide, dips 24° to the southeast, and exhibits almost no comb structure. Quartz float occurs in the vicinity of these veins. Additional soil stripping may possibly disclose commercial crystals, particularly in the vein that already has yielded near-usable crystals.

CUACUA PROSPECT

The Cuacua prospect (pl. 12) is located 5 kilometers south-southeast of Muzo. The main vein, which dips 31° to 36° SE., nearly coincident with the general slope of the mountainside, has been uncovered for a total linear distance of 78 meters in five different places. It

ranges from 1.1 meters to 2 meters in thickness, is composed of milky quartz exhibiting considerable comb structure, encloses fragments of the shale wall rock, and locally contains traces of pyrite and muscovite. Although small milky crystals line a number of vugs, sizable crystals were found along with limonite in only one small "pocket." Numerous veils appear in all the larger crystals, except one that was removed prior to Leland's examination. Two vertical veins, each about 0.5 meter thick, crop out immediately to the southwest of the main vein, but they have not been prospected.

Soil stripping along the outcrop of the vertical veins and the removal of the overburden from a larger area of the main vein conceivably may disclose one or more pockets containing commercial crystals.

ISABI PROSPECT

At the Isabí prospect (pl. 12), located approximately 9 kilometers south-southwest of Muzo, angular blocks of quartz that contain large milky crystals occur in topsoil along a linear distance of 50 meters. A vein in bedrock, although not found in three small pits already excavated, probably could be found by systematic trenching. Conceivably the vein may contain usable crystals.

CUNDINAMARCA

Despite an abundance of quartz crystal localities, the potentialities of Cundinamarca are not good.

Northwestern Cundinamarca, between latitude 5°10′–30′ N. and longitude 74°10′–20′ W., constitutes the southern extension of the quartz crystal belt of western Boyacá. This region was investigated by J. K. Cathcart, assisted by an FEA mineral scout. The terrain is very rugged, and outcrops are scarce. Crystals weighing more than 200 grams but not usable because of milkiness or other internal defects have been found in topsoil at six localities. At four of the localities, picayune quartz stringers or veins up to 25 centimeters in width reveal only small crystals in place. At the other two, no bedrock is exposed. All other localities were rejected either because their crystals were much too small or because they could not be located with reasonable precision. The country rock at all the prospects is dark shale of Cretaceous age.

In east-central Cundinamarca and adjoining parts of Boyacá, within the drainage area of the Río Guavio, quartz crystals have been found at several localities, four of which were examined by J. R. Balsley. At the Chivor emerald mine (approximately lat. 4°52′ N., long. 73°22′ W.), which is actually in Boyacá but is part of the east-central Cundinamarca region, exceptionally clear quartz crystals occur in certain

veins that are rich in pyrite and lean in albite. However, as these veins are scarce and narrow and as nearly all the crystals in them are thinner than the commercial minimum of 2 inches, profitable exploitation for crystals seems impossible. At Cerro Cristal (pl. 12), 1 kilometer southwest of Ubalá (lat. 4°44′ N., long. 73°32′ W.) is a partly exposed quartz vein that is not less than 10 meters wide nor less than 30 meters long. The enclosing rock—interbedded conglomerate, sandstone, and shale—has been silicified, pyritized, and transected by minor quartz veins up to 0.3 meter in width. The main vein exhibits considerable anhedral comb structure and contains many cavities half a meter or less in diameter which are lined by milky crystals up to 5 centimeters in thickness and by clear-ended crystals up to 1 centimeter in thickness. A similar vein, somewhat narrower and containing fewer cavities, occurs at Ynez farm 8 kilometers northeast of Ubalá. Both these veins were prospected by minor amounts of soil stripping. The fourth locality visited by Balsley is decidedly unpromising.

Three commercial crystals weighing in aggregate 870 grams were said to have been found in the Sumapaz region south-southwest of Bogotá, but were too vaguely located to be regarded as a prospect.

HUILA

Nearly all the quartz crystals found in Huila came from the upper slopes of Cerros Pelado and Blanquecino (pl. 12), which between latitude 2°09′ N., longitude 76°15′ W., and latitude 2°08′ N., longitude 76°05′ W., form the divide between the Ríos La Plata and Granates, two western tributaries of the Río Magdalena. The terrain is rugged, very sparsely inhabited, and difficult of access. A total of several hundred kilograms of crystals from this region was received for inspection in Bogotá; due to a profusion of veils, none of the material was usable. Afterwards J. K. Cathcart examined one prospect, and an FEA mineral scout visited another. At the first, crystals occur in place in a quartz-feldspar dike exposed over an area of a square meter; the country rock is quartz-poor monzonite(?). At both prospects crystals are fairly numerous along the beds of small streams, where one commercial crystal, weighing 540 grams, and several near-usable crystals were found. The region would merit systematic scouting in case of any further search for crystals in Colombia.

TOLIMA

During 1943 every clue that seemed to offer any possibility of leading to a crystal locality in central and northern Tolima and adjoining parts of Caldas was investigated by the author. Commercial or near-usable crystals have been found at the following prospects (pl. 12):

Name	Municipio	Approximate coordinates Latitude	Longitude
Anzoátegui	Anzoátegui	4°38′N.	75°05′W.
La Pava and Palmita mines	Santa Isabel	4°43′N.	75°05′W.
Santa Barbara	----do	4°47′N.	75°02′W.
Carrizales	Líbano	4°54′N.	75°06′W.
Paraiso	Villahermosa	4°59′N.	75°07′W.
Campeón	Fresno	5°08′N.	75°02′W.
Roblal	----do	5°12′N.	75°03′W.
Crucero	Caldes, near Tolima border.	5°11′N.	75°07′W.

The chances of profitably exploiting any of the above prospects for crystals alone seem slight, but small quantities of crystals perhaps could be procured as a byproduct of gold mining at La Pava and Palmita.

The quartz crystal localities of Tolima are along the central eastern slope of the Cordillera Central. The bedrock includes (1) fine-grained chloritic and micaceous schists, with intercalated graywacke, and (2) quartz-poor monzonite (?) and related facies, including quartz-rich bodies. The plutonic igneous rocks form stocks and long, narrow batholiths, mainly in the easternmost ranges. The volcanic rocks along the crest of the Cordillera lie outside the area of known crystal localities.

Veins of semitransparent to milky quartz are scattered throughout the region. They range from mere stringers to bodies several meters thick and several hundred meters long. Sulfide minerals are absent or scarce. Some veins carry gold or silver, or both; others are barren. Almost every vein, whether represented by outcrop or float, has at some time been investigated for gold and silver, and local knowledge of quartz crystals is largely a byproduct of the intensive search for these metals.

Crystals have been found (1) in local vuggy "pockets" of quartz veins and (2) unaccompanied by vein quartz, within narrow minor fault zones transecting schist. Innumerable veins in the region contain crystal "pockets"; nevertheless, available data strongly suggest that "pockets" are so sparsely and irregularly distributed as to comprise only a very small percentage of a vein, that most "pockets" contain only small crystals, and that even "pockets" containing near-usable crystals may prove to be devoid of any commercial crystals. Thus, the chances of finding enough crystals to pay for exploration at any prospect are very slight. Crystals not accompanied by vein quartz are found at a few localities near Líbano. All such deposits are picayune in size, and only one, Carrizales (pl. 12), has yielded commercial crystals.

Twelve pounds of commercial crystals valued at $29.41, American currency, were procured as specimens from Palmita and La Pava, two of six mines that comprise the Santa Isabel gold district. These two mines, according to the owners, exploit the same vein, which is 1 meter to 2 meters thick, has a strike length of not less than half a kilometer,

and dips 20° to the south. In 1943, a total of several hundred meters of stope length was developed in La Pava mine, less in the Palmita. Crystal "pockets" range from a meter to several tens of meters in longest diameter and are separated by massive, milky quartz. Although data are wanting to estimate reliably the ratios either of usable to nonusable crystals or of total crystals to massive quartz, it seems certain that commercial crystals comprise well under 0.01 percent of the entire vein. Parts of the vein contain grains and streaks of pyrite, but other parts are devoid of sulfide minerals. The wall rock is "granite," except for small areas of chloritic schist in the Palmita mine.

Quartz veins at other prospects are structurally similar to, but smaller than, the Palmita-La Pava vein. All of them remain only slightly prospected, and none exhibits a particularly promising crystal "pocket." They can be explored at least cost by soil stripping in order to search for possible crystal "pockets" along concealed outcrops.

At the Carrizales prospect crystals of varying sizes occur isolated and in aggregates along a minor fault that transects decomposed schist. The fault, which dips 5° to 30° to the south, is a zone of discontinuous fractures. The total outcrop length of the deposit was found to be only 10 meters. On the basis of recovery along the outcrop, not more than 35 kilograms of commercial crystals can reasonably be expected from the entire deposit.

VALLE DEL CAUCA

Clear crystals, several of which may have been of commercial grade, were uncovered during the excavation of road cuts 68 and 79 kilometers, respectively, from Cali along the Cali-Buenaventura highway. These localities were examined by W. T. Pecora. At kilometer 79 (very approximately lat. 3°36′ N., long. 76°47′ W.), nine quartz gash veins transect well-fractured, somewhat silicified shale along a fissure zone (pl. 12). The largest vein is 3 meters long and 1 meter wide. Vein cavities up to a meter in maximum diameter contain crystals from which clear portions weighing 300 grams or less could be cobbed. At kilometer 68, six quartz veinlets transect fine-grained sandstone. The veinlets are less than 15 centimeters thick and contain few crystals.

One commercial crystal weighing 340 grams is alleged to have come from the Río Yuramangí, which flows into the Pacific Ocean at latitude 3°23′ N., longitude 77°22′ W. A rapid reconnaissance of this river was made by J. K. Cathcart, who concluded that its stream boulders are a most unpromising source of quartz crystals.

SALT

SOURCES

In Colombia salt is derived from rock salt mines, saline springs, and marine salinas. All these sources of supply, except springs whose

concentration does not exceed 6° Baumé, are the property of the National Government and are exploited by the Banco de la República through its Sección de Salinas. The ensuing data are derived in part from visits made in 1945 by Gilberto Botero Restrepo and the author to all the operating salt mines and in part from both published and unpublished data kindly furnished by the Sección de Salinas.

Deposits of rock salt (pl. 7) are known at the following localities, but because of inaccessibility with respect to highway or railroad, the last listed is not exploited.

Name	*Departamento or intendencia*	*Approximate coordinates* *Latitude*	*Longitude*
Zipaquirá	Cundinamarca	5°02′ N.	74° W.
Nemocón	do	5°04′ N.	73°53′ W.
Sesquilé	do	5°02′ N.	73°49′ W.
Cumaral y Upín	Meta	4°16′ N.	73°35′ W.
San Miguel y Barital	do	4°26′ N.	73°26′ W.

Saline springs (pl. 7) are being exploited at:

Name	*Departamento*	*Approximate coordinates* *Latitude*	*Longitude*
Tausa	Cundinamarca	5°12′ N.	73°54′ W.
Gachetá	do	4°54′ N.	73°38′ W.
Chita y Muneque	Boyacá	6°06′ N.	72°20′ W.
Chámeza y Recetor:			
Recetor spring	do	5°21′ N.	72°44′ W.
Chámeza spring	do	5°16′ N.	72°54′ W.
Mongua spring	do	5°46′ N.	72°48′ W.
Gameza spring	do	5°49′ N.	72°49′ W.

The principal marine salinas are at Manare (lat. 11°45′ N., long. 72°33′ W.) and Bahia Honda (lat. 12°19′ N., long. 71°47′ W.), in Guajira (pl. 7). Other salinas, having a small output, are located in Guajira, near Santa Marta, and between Barranquilla and Cartagena.

Trivial amounts of salt are produced by private individuals, with whom the Government has not bothered to interfere, at saline springs in Antioquia, in Caldas, and elsewhere.

The magnitude of the salt industry and the relative importance of the different sources of supply are apparent from the following summarized statistics:

Output and net profit of salt mines, springs, and salinas in Colombia for 1943

[Statistics from Memoria de Minas y Petróleos, 1944, pp. 302-336]

	Brine sold		Rock salt sold		Refined salt sold		Net profit (pesos)
	Decaliters	Value (pesos)	Metric tons	Value (pesos)	Metric tons	Value (pesos)	
Zipaquirá	17,835,500	2,498,789	3,610	138,273	6,018	507,499	1,941,988
Nemocón	5,454,600	763,755					646,969
Sesquilé	1,865,000	261,223					176,898
Cumaral y Upín	50,300	4,985	1,647	52,575			5,277
Tausa	363,900	29,112					12,445
Gachetá	176,970	15,927					2,551
Chita y Muneque					270	21,600?	−1,863
Chámeza y Recetor					327	26,100?	−584
All salinas					18,971	1,419,161	171,024
Total	25,746,270	3,573,791	5,257	190,848	25,586	1,974,360	2,954,705

Estimated salt content of 25,746,270 decaliters of brine (23.5 Baumé)	metric tons	77,060
Rock salt	do	5,257
Refined salt	do	25,586
Estimated total	do	108,060
Aggregate value of brine, rock salt, and refined salt sold	pesos	5,738,999
	(approximately $3,279,430, American currency)	
Net profit	pesos	2,954,705
	(approximately $1,688,400, American currency)	

DEPOSITS OF ROCK SALT

MODE OF OCCURRENCE

The rock salt occurs as "stocks." The form, dimensions, and structural relations of these "stocks" remain imperfectly known. The Nemocón "stock" has been mapped by Scheibe [128] as having an area of about 800,000 square meters (198 acres) in horizontal cross section near the surface. The Zipaquirá "stock" is decidedly larger than the one at Nemocón, whereas the Sesquilé and Restrepo "stocks" are decidedly smaller. Mine workings have laterally explored an aggregate area of about 150,000 square meters (37 acres) at Zipaquirá, 30,000 square meters (7½ acres) at Nemocón, 15,000 square meters (3¾ acres) at Sesquilé, and 7,000 square meters (1¾ acres) at Restrepo. However, the maximum vertical distance explored by mine workings in any "stock" is only about 50 meters.

Except for minor impurities, the rock salt is an intimate mixture of halite and black shale. Halite is crystallized as grains of small to medium size; black shale occurs as specks, pellets, slivers, nodules, films, and bands of different sizes. At Zipaquirá, Sesquilé, and Restrepo, most of the shale has combined physically with halite to produce a "hybrid" rock exhibiting flow structure. The foliation ranges from vague where shale is scarce to strongly laminated where shale is abundant. Sparsely scattered throughout the halite-shale "hybrid" are rounded shale "xenoliths" ranging from a fraction of a meter to several meters in longest diameter and transected by seams and veinlets of halite. Bedding in the "xenoliths" may or may not conform with the foliation of the halite-shale "hybrid." Besides the shale "xenoliths," several sandstone boulders from the Guadalupe formation were found in rock salt at one locality in the Zipaquirá mine. At Nemocón, the mine workings reveal all gradations from halite-shale "hybrid" rock containing few "xenoliths" to shale penetrated by only minor amounts of halite; the distribution of the different facies seems erratic. Considered as a whole, the mass gives an impression of black shale "intruded" by halite in such a manner as to leave, in some places, septa or large bodies of shale penetrated only by apophyses, dikes, dikelets, and seams of halite; in other places, a profusion of "xenoliths"; and in still other places, typical halite-shale "hybrid" rock.

Cropping out above the bodies of rock salt is "rute," a rather jumbled mass of black shale transected by seams and veinlets of aragonite, pyrite or marcasite, and other minerals and locally exhibiting the white efflorescences characteristic of saline minerals. At several places masses of limestone crop out within the "rute," but

[128] Scheibe, Roberto, Informe sobre el yacimiento de sal de Nemocón: Compilación de los estudios geológicos oficiales en Colombia, tomo 1, fig. 10, 1933.

whether they are exotic or stratigraphically intercalated in the shale is not known. Clearly a product from which halite has been leached, the "rute" is here interpreted as a product of weathering rather than a product derived from leaching at depth during the intrusion of the rock salt, as believed by Scheibe.[129] The term "rute" also is used by local miners for a soft mixture of black shale and black gouge cut in fault zones at several places in different mines.

STRATIGRAPHIC AND STRUCTURAL FEATURES

The stratigraphic sequence, as set forth by the Servicio Geológico Nacional, of strata to be considered in connection with the geology of salt deposits is:

	Meters
Guaduas formation (uppermost Cretaceous?, Eocene, and Oligocene): Gray, mottled, and maroon shale; subordinate sandstone and conglomerate; coal seams, restricted to lower member	1,400–2,000
Guadalupe formation (late Cretaceous): Upper member composed of thick, somewhat friable sandstone, chert, and cherty shale all relatively resistant to erosion; lower member composed of dark shale with intercalated sandstone and limestone	1,000–1,500
Villeta formation (middle and late Cretaceous): Dark shale with intercalated beds of limestone and sandstone; middle part locally contains zone of thick sandstone	1,500+
Cáqueza formation (early Cretaceous): Mainly black shale with intercalated sandy beds; upper part rich in pyrite and secondary salts	2,000+

No beds of rock salt have been discovered in the sedimentary column of Colombia. The black shale intimately associated with halite may be derived from the Villeta formation, as stated by Scheibe,[130] but on the other hand it may be derived from the Cáqueza or the lower part of the Guadalupe. In fact, because of its color and its content of secondary salts, the Cáqueza now seems the most probable source of both the halite and the associated shale.

The prevailing bedrock in the general vicinity of Zipaquirá, Nemocón, and Sesquilé consists of strata of the Guaduas and Guadalupe formations. The prevailing bedrock near Restrepo cannot be stated because no areal geologic map is available, but the Guaduas, Guadalupe, and older formations crop out in the area.

Hasty observations by the author suggest that the salt bodies and their associated black shale at Zipaquirá, Sesquilé, and Restrepo occur

[129] Scheibe, Roberto, Informe sobre el yacimiento de sal de Nemocón: Compilación de los estudios geológicos oficiales en Colombia, tomo 1, p. 55, 1933.
[130] Idem.

within the hanging walls of major reverse faults, but no major reverse fault is known at Nemocón, where Scheibe [131] mapped the areal geology in some detail.

Evidence of a reverse fault is most apparent at Sesquilé. There a section along the surface from west to east reveals (1) a normal sequence of the Guaduas formation, underlain by sandstones and cherts of the Guadalupe formation, dipping westward; (2) a zone of steeply inclined and overturned strata in which the sandstones and cherts of the Guadalupe are missing; and (3) another normal sequence of Guaduas underlain by Guadalupe, dipping westward. Moreover, within the mine workings from west to east are found: (1) rock salt with the prevailing foliation dipping to the west; (2) a wide zone of gouge; (3) unaltered dark shale of either the lower Guadalupe or the Villeta formation, apparently with an overturned dip to the west; and (4) strata dentified by the Servicio Geológico Nacional as lowermost Guaduas, apparently with an overturned dip to the west. At Restrepo, the sequence from west to east is: (1) rock salt with the prevailing foliation dipping to the southwest, seen within the mine workings; (2) black shales dipping 60° to 80° W., at the surface; and (3) thinly bedded sandstones and sandy shales with films of coal, probably Guaduas, dipping southwestward, at the surface. At Zipaquirá, according to an unpublished geologic map by Benjamín Alvarado, an area of black shale and rock salt is surrounded on all sides by the Guadalupe formation; chaotic dips within the black shale and the anomalous steep dips of the Guadalupe along the eastern border of the shale and salt stock suggest the possibility of a reverse fault. Obviously, at all three localities, detailed areal mapping in the vicinity of the mines is needed to confirm, or to reject, the presence of a major reverse fault and to determine whether the body of salt occurs in the hanging wall of the main fault or of a branch.

As has already been implied, strikes and dips within the halite and shale "hybrid" rock indicate flow structure, not stratification. Reconnaissance observations within each mine reveal places where the foliation is uniform in attitude over areas of tens or hundreds of square meters and other places where local variations in strike and dip are numerous and abrupt within areas of only a few tens of square meters. Platy shale fragments commonly are oriented conformably with the foliation, yet at a few places they are at an oblique angle, producing a structure analogous to fracture cleavage which transects flow cleavage in a metamorphic rock. Detailed mapping of structure within the salt bodies, interpreted according to the methods of Hans Cloos, doubtless would give clues to their dimensions and shapes.

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[131] Scheibe, Roberto, Informe sobre el yacimiento de sal de Nemocón: Compilación de los estudios geológicos officiales en Colombia, tomo 1, fig. 10, 1933.

EXPLOITATION METHODS

The rock salt is mined at one or more levels underground. At Zipaquirá and Nemocón, the mining is done by the room-and-pillar system. The rooms are 9 to 11 meters wide along the floor but taper upward to an arch 12 or 14 meters high. The square pillars are 10 or 12 meters on a side at the base. Below the roof at each working face is a bench, 2 to 2.5 meters high and about 50 meters long, in advance of a 30° to 40° incline from the bench to the floor of the level. Drilling is done by jack hammers; blasting by either dynamite or black powder, according to whether the material is wet or dry, respectively; and loading and tramming by hand. At Sesquilé and Restrepo, no systematic room-and-pillar plan is followed as yet, and drilling is done by hand.

At all four mines, part or all of the salt is dissolved in underground sumps and pumped to the surface as brine; the brine so procured is supplemented by a natural brine derived from small springs within the mine. However, at Zipaquirá most of the rock salt is trammed to the surface, where brine is made in open vats. The solution in sumps and vats is regulated to produce a brine of 23° to 24° Baumé. Most of the brine is sold to private individuals and companies, who in turn produce refined salt; but at two mines, limited quantities of refined salt are made by the Sección de Salinas itself. At two mines only, Zipaquirá and Restrepo, part of the rock salt (material containing less than 50 percent shale) is sold directly.

At the two principal salt springs—that is, those in Cundinamarca—brine is sold to private individuals for refining, whereas at the smaller springs in Boyacá the Sección de Salinas itself produces refined salt.

The Colombian Government has planned the construction, near Zipaquirá, of a plant to manufacture chlorine and soda products from rock salt of the Zipaquirá mine.

SILICA

Brief data concerning silica for glass manufacture in Colombia were supplied by Gilberto Botero Restrepo.

There are four glass factories, located as follows:

Town	*Departamento*	*Coordinates*	
		Latitude	*Longitude*
Envigado	Antioquia	6°10′ N.	75°36′ W.
Caldas	----do	6°06′ N.	75°38′ W.
Pereira	Caldas	4°48′ N.	75°43′ W.
Bogotá	Cundinamarca	4°36′ N.	75°05′ W.

The Envigado factory, partly owned by the Corning Glass Co., is the newest; it was expected to start operating in 1948. The other three antedate the period of the FEA mission.

The two glass factories of Antioquia utilize, as a source of silica, sandstone derived from the coal measures near Angelópolis (lat. 6°07′ N., long. 75°43′ W.). The Pereira factory utilizes sandstone procured at Bogotá and milky quartz procured mainly from streams in the general vicinity of Santa Rosa de Cabal (lat. 4°52′ N., long. 75°38′ W.). The Bogotá factory utilizes sandstone from the upper member of the Guadalupe formation (late Cretaceous), which is quarried nearby, but at times also uses sandstone from the overlying Guaduas coal measures.

SILVER

Silver is recovered only as a byproduct of gold mining. Most of it is combined as an alloy in native gold, though in a few lode mines part of the silver may occur in other minerals. The assay data of Restrepo [132] indicate that in Colombia the placer gold contains about 30 to 360 parts of silver per thousand and the lode gold about 20 to 650 parts of silver per thousand. Silver-bearing sulfide minerals, ruby silver, and native silver have been found [133] in veins in various districts of Antioquia, Caldas, Huila, Nariño, Santander, and Tolima but are not recognized as ore constituents at any large or medium-sized mine currently operating. However, these minerals doubtless were important constituents of certain veins mined primarily for silver during past centuries, particularly during colonial times. Most famous were the silver veins of the districts of La Plata (lat. 2°23′ N., long. 75°53′ W.) and Mariquita (lat. 5°12′ N., long. 74°53′ W.).

The output of silver in Colombia during 1931–45 aggregated 2,757,473 ounces, worth about $1,100,000, American currency, whereas the output of gold aggregated 6,836,643 ounces, worth about $230,000,000. Thus silver constituted only 28.7 percent by weight and 0.48 percent by value of the combined totals for gold and silver. Production statistics, as published [134] by the Colombian Government, are:

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[132] Restrepo, Vicente, Estudio sobre las minas de oro y plata de Colombia, p. 41, Bogotá, Silvestre y Cía., 1888.

[133] Miller, B. L., and Singewald, J. T., Jr., Mineral deposits of South America, pp. 370–379, McGraw-Hill Co., New York, 1919.

[134] Memoría del Ministro de Minas y Petróleos al Honorable Congreso Nacional, 1946, p. 10, Bogotá, Imprenta Nacional, 1946.

Year	Gold (troy ounces)	Silver (troy ounces)
1931	184, 274	77, 709
1932	248, 249	194, 761
1933	298, 242	108, 005
1934	344, 140	127, 461
1935	328, 991	132, 965
1936	389, 495	151, 501
1937	442, 222	176, 971
1938	520, 715	192, 879
1939	570, 017	242, 628
1940	631, 927	260, 310
1941	656, 019	271, 115
1942	596, 618	246, 276
1943	565, 509	209, 957
1944	553, 530	197, 321
1945	506, 695	167, 614
	6, 836, 643	2, 757, 473

The principal gold mines, described in the section entitled "Gold," are also the principal silver mines of Colombia. However, the lode mines produce a higher percentage of the total silver than of the total gold.

STONE, SAND, AND GRAVEL

Stone, sand, and gravel are procured, as needed, from local sources throughout Colombia. No production statistics have been compiled.

The material most commonly used for concrete aggregate and road metal at each of the following towns and cities, according to Gilberto Botero Restrepo, is:

Barranquilla: Crushed white limestone, probably of upper Miocene age.

Bogotá: Crushed sandstone, derived mostly from the upper member of the Guadalupe formation (late Cretaceous) but also from the Cacho sandstone at the base of the upper member (Eocene) of the Guaduas formation; also gravel, from the Río Tunjuela.

Cali: Gravel, composed mainly of pebbles of andesite and metamorphic rocks.

Cartagena: Crushed white limestone, similar to that at Barranquilla; also sand, of Pleistocene age.

Cúcuta: Gravel, composed of igneous, metamorphic, and sedimentary rock fragments.

Ibagué: Gravel, composed of igneous and metamorphic rock fragments; also crushed stone, from large boulders in the gravel.

Manizales: Gravel, composed mainly of pebbles of igneous rock; chiefly from the Río Olivares.

Medellín: Gravel, composed mainly of igneous rock fragments; chiefly from the Quebrada Iguaná.

Neiva: Gravel, chiefly from small, dry ravines.

Pasto: Crushed andesite and volcanic breccia, of late Tertiary age.

Pereira: Gravel, composed of igneous and, subordinately, metamorphic rock pebbles; chiefly from the Río Otún.

Popayán: Gravel, composed of pyroclastic and metamorphic rock fragments.

Santa Marta: Crushed igneous and metamorphic rocks.

Tunja: Crushed sandstone, derived from the Cacho sandstone unit of the Guaduas formation.

SULFUR

Small deposits of sulfur in Nariño and along the Cauca-Tolima boundary have been formed by fumaroles and by springs near the craters of Recent volcanoes. During the early 1940's Indians of Nariño were exploiting one locality (Cumbal) in a small way to procure sulfur for the domestic market, primarily for use in making panama hats. In the past, other localities have been worked to a slight extent. None of the deposits seems likely to become a large producer.

NARIÑO

The sulfur deposits of Nariño are very briefly described by Royo,[135] whose data follow. Fumarole deposits occur on five volcanic peaks and spring deposits on one. However, only the fumarole deposits on Cumbal (lat. 0°58′ N., long. 77°52′ W.) and Azufral (lat. 1°04′ N., long. 77°42′ W.) have possible economic interest. (See pl. 6.) The sulfur occurs as crystals, as compact aggregates of partially formed crystals, and as friable fine-grained masses. The reserves have not been estimated, but the deposits at Cumbal are regarded as perhaps the largest in Colombia. The country rock is andesite tuff. At Cumbal, local Indians procure sulfur from a deposit that covers much of the floor and the walls of a secondary crater, 50 meters deep and 100 meters in diameter, located just below the snow line, at an altitude of 4,700 meters, northeast of the main peak. Other deposits doubtless exist on Cumbal, for fumaroles are known to continue northwestward from this secondary crater. At Azufral are two areas of fumaroles, each comprising some 20,000 to 30,000 square meters, located northwest of the main peak (see Royo's map opposite p. 258 of his report).

CALDAS AND TOLIMA

Reymond[136] has briefly described sulfur deposits at Otún lake (lat. 4°48′ N., long. 75°26′ W.), La Selva farm (approximately lat. 4°57′ N., long. 75°23′ W.), and the head of Azufrado Creek (approximately

[135] Royo y Gomez, José, Yacimientos de azufre del Departamento de Nariño: Compilación de los estudios geológicos oficiales en Colombia, tomo 5, 225–260, 1942.

[136] Reymond, Edouard, Informe sobre los yacimientos de azufre del macizo del Ruiz, en los Departamentos de Caldas y Tolima: Compilación de los estudios geológicos officiales en Colombia, tomo 5, pp. 401–416, 1942.

lat. 4°53′ N., long. 75°17′ W.). These three localities, according to information acquired by Reymond in Manizales, are the most promising of many scattered along the crest of the Cordillera Central near the snow-clad peaks named Ruiz, Santa Isabel, Quindío, and Tolima. Access is by animal trail from distant rail or highway points, either in Caldas or in Tolima. The bedrock is a sequence of andesitic and related pyroclastic rocks, of late Tertiary and Quaternary age, which in general cover the range above an altitude of 3,000 meters. The snow line is at an altitude of about 4,800 meters, although glaciers descend to 4,500 meters in some valleys.

At Otún there are approximately a hundred active and extinct fumaroles within an area of 40 by 160 meters (pl. 6). They are on a precipitous slope which constitutes the southeast outlet of the lake. Sulfur has been deposited as crystals in orifices of the fumaroles and as impregnations in tuff surrounding them. Nearly all the crystals were mined out some 50 years ago.

At La Selva there are two areas of 750 square meters and 2,500 square meters, respectively, in which springs have deposited very fine grained sulfur within detritus. The sulfur-bearing detritus is not a continuous layer, but a series of lenses tapering away from each spring.

At the Azufrado locality there are about 20 separate masses, ranging from a few square meters to several thousand square meters in surface area, of glacial debris cemented by sulfur. These deposits are derived from active and extinct fumaroles within a glacial cirque.

Reymond states that an estimate of the quantity and grade of the reserves at each of the localities will be published after his samples have been analyzed.

ZINC

Near Junín (lat. 4°47′ N., long. 73°38′ W.), Cundinamarca, is an unusually promising prospect (pl. 9), but not more than a few tens of thousands of metric tons of hand-sorted ore averaging about 60 percent zinc can reasonably be anticipated as the maximum ultimate recovery. Boulders similar to ore at Junín have been found at another Cundinamarca locality. In Caldas, at least one prospect (La Diamantina) merits soil stripping to determine the surface dimensions and grade of a quartz vein rich in mixed sulfide minerals.

Apart from deposits that might be worked primarily for zinc, there is a possibility of recovering sphalerite where it occurs as a minor constituent of gold veins. At the Segovia mine, Antioquia, the daily output during 1944 was some 300 metric tons of sorted ore, containing 1 metric ton to 2 metric tons of sphalerite; and at the Marmato and Ríosucio mines, Caldas, the aggregate daily output during 1944 was 75 to 85 metric tons of ore, probably containing about 0.3 metric ton of sphalerite.

CALDAS

La Diamantina, located 4 kilometers north of Marquetalia (lat. 5°17′ N., long. 75°04′ W.) is a copper-lead-zinc prospect described in the section entitled "Copper."

In the general vicinity of Samaná (lat. 5°32′ N., long. 74°57′ W.) are veins of different kinds (pl. 9). The two best showings of sphalerite are alleged to be about 4 kilometers and 6 kilometers, respectively, west and northwest of the town. Specimens exhibited in Bogotá were composed of dark sphalerite, with subordinate galena, pyrite, and carbonates.

CUNDINAMARCA

JUNIN PROSPECT

Zinc ore is found at two localities (pl. 9), 1.9 kilometers apart, which are approximately 4 kilometers southeast and south-southeast, respectively, of Junín (lat. 4°47′ N., long. 73°37′ W.). One of the deposits is a vein, the other an eluvial placer. The geography and geology of the area have been described by Alvarado.[137] In 1942, the deposits were examined by the author, who was the guest of Sres. Alvarado and Del Río, of the Servicio Geológico Nacional.

The Junín area has moderately rugged topography, but nearly all the land is cultivated. The bedrock in the vicinity of both zinc prospects is the Villeta formation (middle and late Cretaceous), composed of dark bluish-gray to nearly black shale in which at irregular stratigraphic intervals are intercalated beds of sandstone and, less commonly, limestone. The limestone beds are not more than 1 meter or 2 meters thick. On the basis of scattered dips, Alvarado (see his pl. 1) believes that the zinc prospects are about a kilometer west of the axis of a major anticline trending northeastward. However, minor folds and faults complicate the local structure. No igneous rocks have been reported in the region.

A vein, 50 to 80 centimeters wide, that trends N. 50° E., 65° NW., at á locality named El Rincón (see Alvarado's pl. 2) is exposed in two outcrops, 8 meters apart vertically, and also along a 50-meter adit driven into the lower outcrop. A geologic map of the adit has been published.[138] From the portal of the adit, the vein extends continuously southwestward along the floor, but discontinuously along the roof, for a distance of 33 meters to a place where it terminates in highly fractured ground. The vein at the upper outcrop terminates about a meter southwest of the portal of a prospect cut, almost directly above

[137] Alvarado, Benjamín, and Palau, Climaco, El yacimiento de zinc de "Playas," Municipio de Junín (Cundinamarca): Bol. minas y petróleos, nos. 121–144, pp. 7–36, 1939–40.

[138] Del Río M., Alejandro, Yacimiento de zinc del Municipio de Junín, Cundinamarca: Compilación de los estudios geológicos oficiales en Colombia, tomo 6, pl. 35, 1945.

its termination in the adit. The developed ore may be calculated as about 87.5 metric tons per vertical meter, which is equivalent to 28.3 metric tons per vertical foot. Possible vein extensions downward from the adit and laterally to the northeast permit a reasonable expectation of a total of not less than 1,500 metric tons and not more than 10,000 metric tons of ore. The average grade of two vein samples is 55.3 percent zinc, and that of a 200-ton stock pile is 58.7 percent zinc.

Ore boulders that are angular and up to 10 cubic meters in size occur in the soil mantle of a roughly triangular area comprising about 15,000 square meters (approximately 3 acres) at the confluence of the Quebrada Negra and the Río Rucia, 1.9 kilometers northeast of El Rincón. At least 500 metric tons of ore averaging about 61 percent zinc have been stock-piled. The ultimate recovery of this placer ore is likely to amount to approximately 1,500 metric tons, and one or more ore bodies comparable in size to the one at El Rincón may eventually be discovered in the bedrock.

The ore from both localities is coarse-grained. Hand-sorted pieces are composed of sphalerite alone or, more commonly, of sphalerite and minor siderite. The sphalerite has a moderately light brown color. Very little ore contains visible pyrite. Quartz and calcite are rare in the ore itself, but at the El Rincón locality these minerals form a myriad of films, gash veins, and nests, lacking any orientation in the wall rock.

SCATTERED ORE BOULDERS IN MUNICIPIO OF LA VEGA

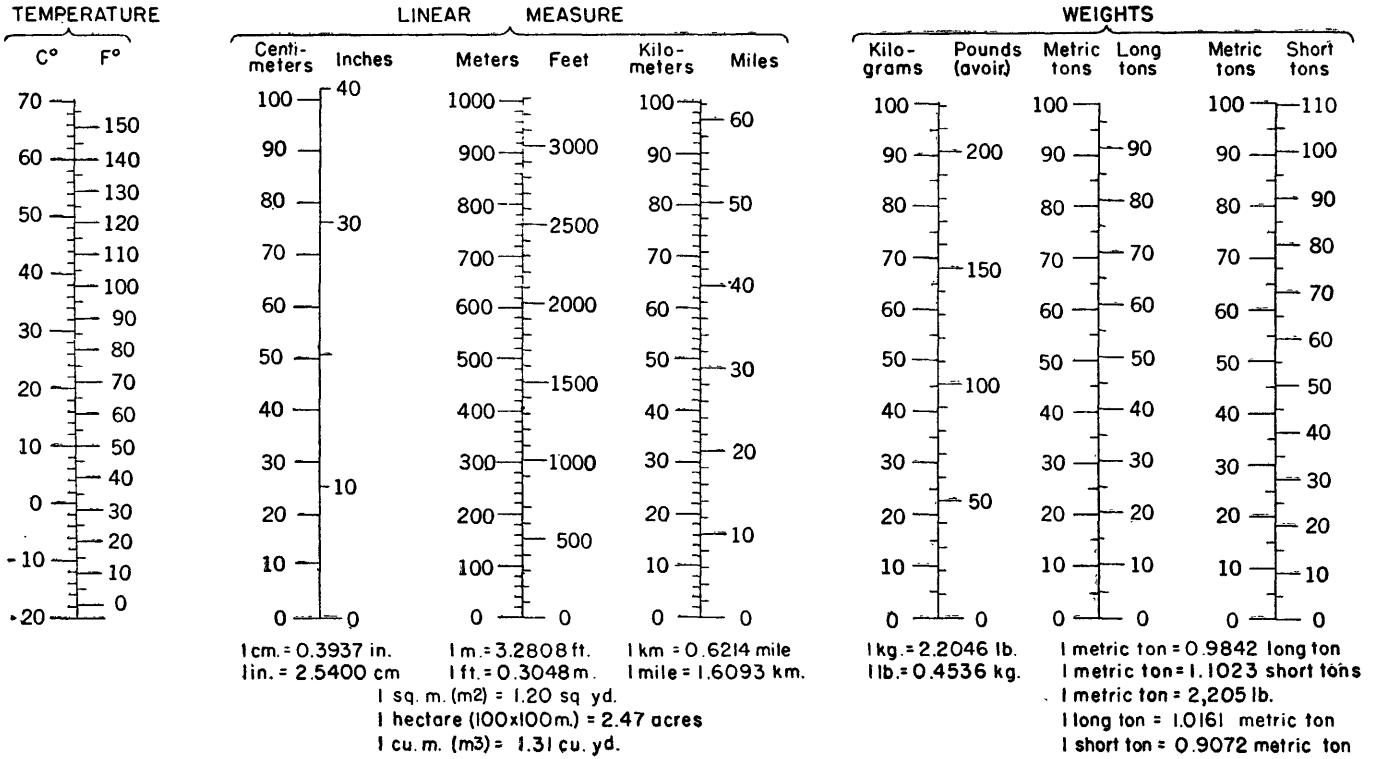
Scattered boulders of ore (pl. 9) very similar to those at Junín have been found in ravines north of La Vega (lat. 5° N., long. 74°20′ W.). The bedrock presumably is the Villeta formation. No prospecting has been done for veins in place.

TOLIMA

El Rubí prospect (pl. 9), located approximately at latitude 5°14′ N., longitude 75° W., about 23 kilometers by trail north of Fresno, probably is the best zinc showing to be seen in that general area. It was examined by C. E. Dixon in 1944. A vein, 20 to 60 centimeters wide, composed of pyrite, sphalerite, galena, and quartz is exposed at intervals for a vertical distance of 15 meters along a steep hillside. The walls are light-colored, coarse-grained igneous rock, but chlorite schist prevails in the region.

Mining promoters of Ibagué allege that sphalerite-bearing veins crop out (1) in the Cucuano region (approximately lat. 4°23′ N., long. 75°33′ W.) and (2) in an area 10 to 20 kilometers northeast of Ibagué.

METRIC EQUIVALENTS



1 cm. = 0.3937 in.
1 in. = 2.5400 cm

1 m. = 3.2808 ft.
1 ft. = 0.3048 m.

1 km = 0.6214 mile
1 mile = 1.6093 km.

1 sq. m. (m2) = 1.20 sq yd.
1 hectare (100x100 m.) = 2.47 acres
1 cu. m. (m3) = 1.31 cu. yd.

1 kg. = 2.2046 lb.
1 lb. = 0.4536 kg.

1 metric ton = 0.9842 long ton
1 metric ton = 1.1023 short tons
1 metric ton = 2,205 lb.
1 long ton = 1.0161 metric ton
1 short ton = 0.9072 metric ton

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