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SUMMARY OF MINERAL RESOURCES IN FOUR SELECTED AREAS OF COLOMBIA

by

C. M. Tschanz, R. B. Hall, Tomas Feininger, D. E. Ward
Richard Goldsmith, D. H. MacLaughlin, and E. K. Maughan
U. S. Geological Survey

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TABLE OF CONTENTS

TABLES

Page No.

ILLUSTRATIONS

SUMMARY OF MINERAL RESOURCES IN

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Introduction

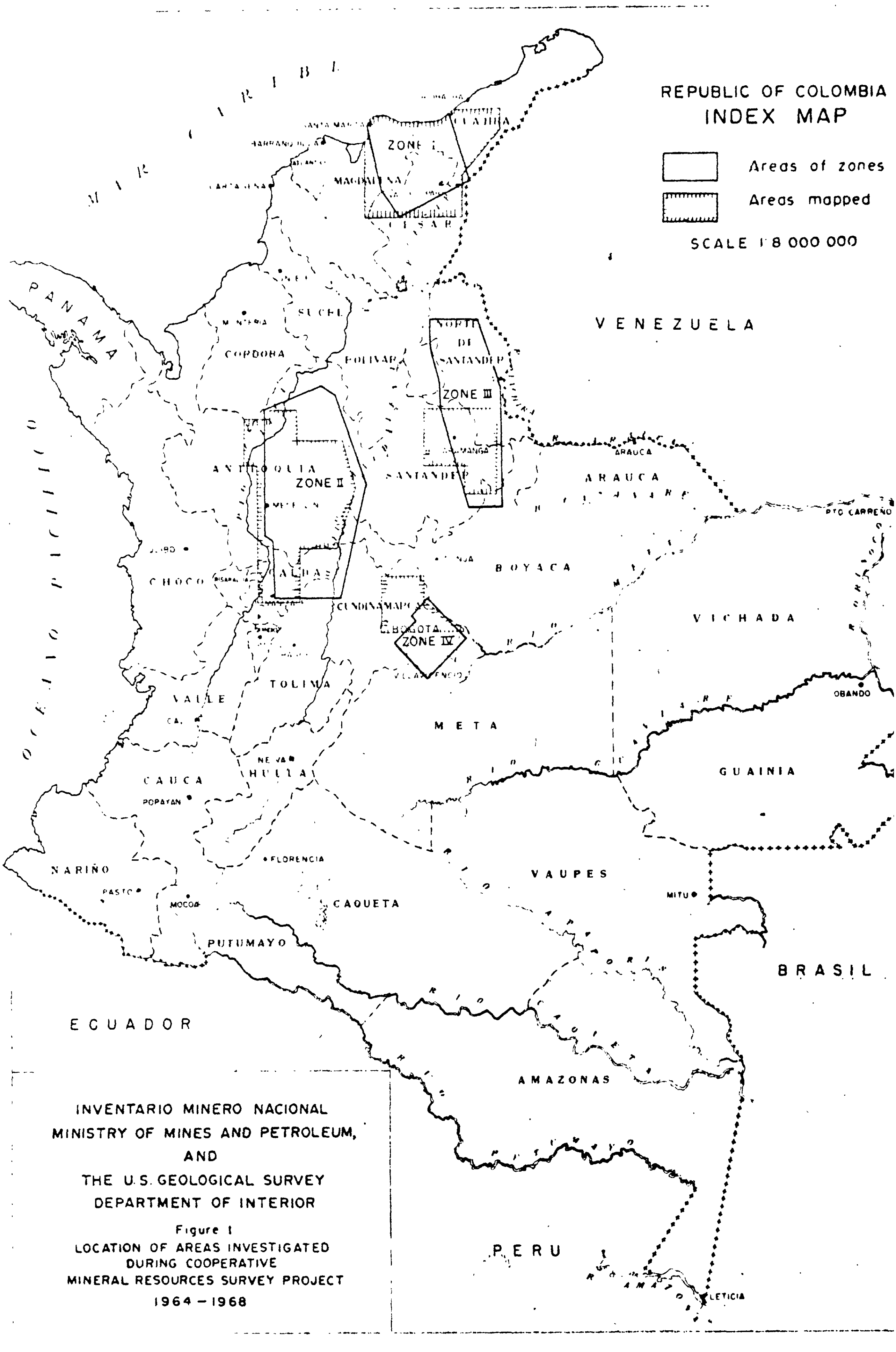
In September 1963, a development loan was consumated between the Agency for International Development of the United States Department of State and the Ministry of Mines and Petroleum of the Republic of Colombia as a project of the Alliance for Progress. The objective was a survey of mineral resources in four selected areas where several industrial complexes have developed that would provide a ready market for any economic mineral deposits encountered. The U. S. Geological Survey has provided technical assistance for the project which is staffed by about 50 Colombian and American geologists and technicians. Headquarters and laboratory support for the group, known as the Inventario Minero Nacional (National Minerals Inventory), are maintained in Bogota at the Colombian Geological Survey, an agency of the Ministry of Mines and Petroleum.

The present report summarizes the principal resources encountered in the four areas. During the course of the work in two of the areas (Zones III and IV), rock phosphate was encountered in Upper Cretaceous strata. Because fertilizer minerals deposits had not previously been known in the country, and because of their great importance to agriculture, investigations for phosphate were extended into surrounding areas with promising results. It is felt that this preliminary information may be useful for program and planning purposes, particularly to the Colombian Government.

The full and unhesitating support of Minister Enrique Pardo Parra, who consumated the agreement and initiated the project, and of Minister Carlos Gustavo Arrieta, upon whom fell the principal responsibility for sustaining the project, is most gratefully acknowledged. It is also a pleasure to express our appreciation for the fine collaboration of project directors Aurelio Lara Agudelo, Dario Suescún Gómez, and Andrés Jimeno Vega during the nearly five years of project operations. We also acknowledge

with gratitude the fine collaboration and excellent rapport of the many Colombian geologists, technicians, and friends who carried the burden that such a program necessarily requires during the arduous field work.

The following summaries of resources have been prepared by American technicians who worked in the four selected areas. The summaries are included as separate evaluations and do not supplant or modify any differing opinions of our Colombian colleagues who may have collaborated in the project.



INVENTARIO MINERO NACIONAL
MINISTRY OF MINES AND PETROLEUM,
AND
THE U.S. GEOLOGICAL SURVEY
DEPARTMENT OF INTERIOR

Figure 1
LOCATION OF AREAS INVESTIGATED
DURING COOPERATIVE
MINERAL RESOURCES SURVEY PROJECT
1964 – 1968

SUMMARY OF MINERAL RESOURCES OF THE SIERRA NEVADA DE SANTA MARTA, ZONE I

by Charles M. Tschanz, Geologist,
U.S. Geological Survey

Introduction

In Zone I no metal deposits of obvious economic importance and only one of doubtful value have been found. Its principal resources are non-metallic. The resources in order of decreasing importance are limestone marble, dolomite, and talc-tremolite. In addition many igneous and metamorphic rocks are suitable for use as polished slabs for decorative use. The identified resources of mica, graphite, lime, feldspar, garnet are not economically exploitable. With a large investment in a crushing and floation plant, potash feldspar could be produced from quartz-perthite granulites but the economics are questionable. Some white high lime clays might be usefull as fillers in paper, etc, but the required test work has not been done and no large reserves are known.

Summary of Reserves

The reserves of identifiable resources are presented in the table below.

Reserves Material	Location	Calculated Reserves (tons) Proved[1] (Measured)	Indicated[2]	Inferred[3]
Limestone	Durania	0	202,000.000	0
	Durania	0	5,474.000	0
	Chorrera	0	0	4,968.000.0
	Hato Nuevo	0	0	0
Marble	Ciénaga	0	0	0
Dolomite	Cerro Pedrera	0	0	0
Talc-tremolite	Q. Rodríguez	0	0	0

1). Measured ore is ore for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes and for which grade is computed from results of detailed sampling.

2). Indicated ore is ore for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geologic evidence.

3). Inferred ore is ore for which quantitative estimates are based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. in two dimensions.

Estimated Geological Reserves [1)]

Material	Location	Maximum Potential	Remarks
Limestone	Durania	800,000.000	Good for cement or agricultural
	Durania	0	Good for all uses
	Chorrera	0	Good for most uses
	Hato Nuevo	unlimited	Good for most uses.
Marble	Ciénaga	10,000.000	Good for pulverized limestone and limestone and possibly finished cut marble.
Dolomite	Cerro Pedrera	30,000.000	Good for agricultural dolomite
Talc-Tremolite	Q. Rodríguez	5-10,000.000	Fair quality, useable for ceramic if mixed with higher grade

1) Estimated on scattered samples and available geological data. Reliability of grade and tonnage poor. Requires systematic exploration.

Description of Principal Resources

Brief summaries of potential economic resources are given below.

Limestone. - Two large areas of low-magnesium Cretaceous limestone in the Sierra Nevada outcrop (1) near Durania at the southern tip south of the Fundación-Valledupar road and (2) along the west side of the Upper Ranchería Valley. Other limestones mapped in the Serranía de Perijá and Cerro Cerrejón are not included in the summary.

Durania

These deposits are near the railroad, roads, oil pipeline, natural gas field, and adequate water. Here probable reserves in 6 blocks covering about one-fourth of the total outcrop area are calculated at 202,000.000

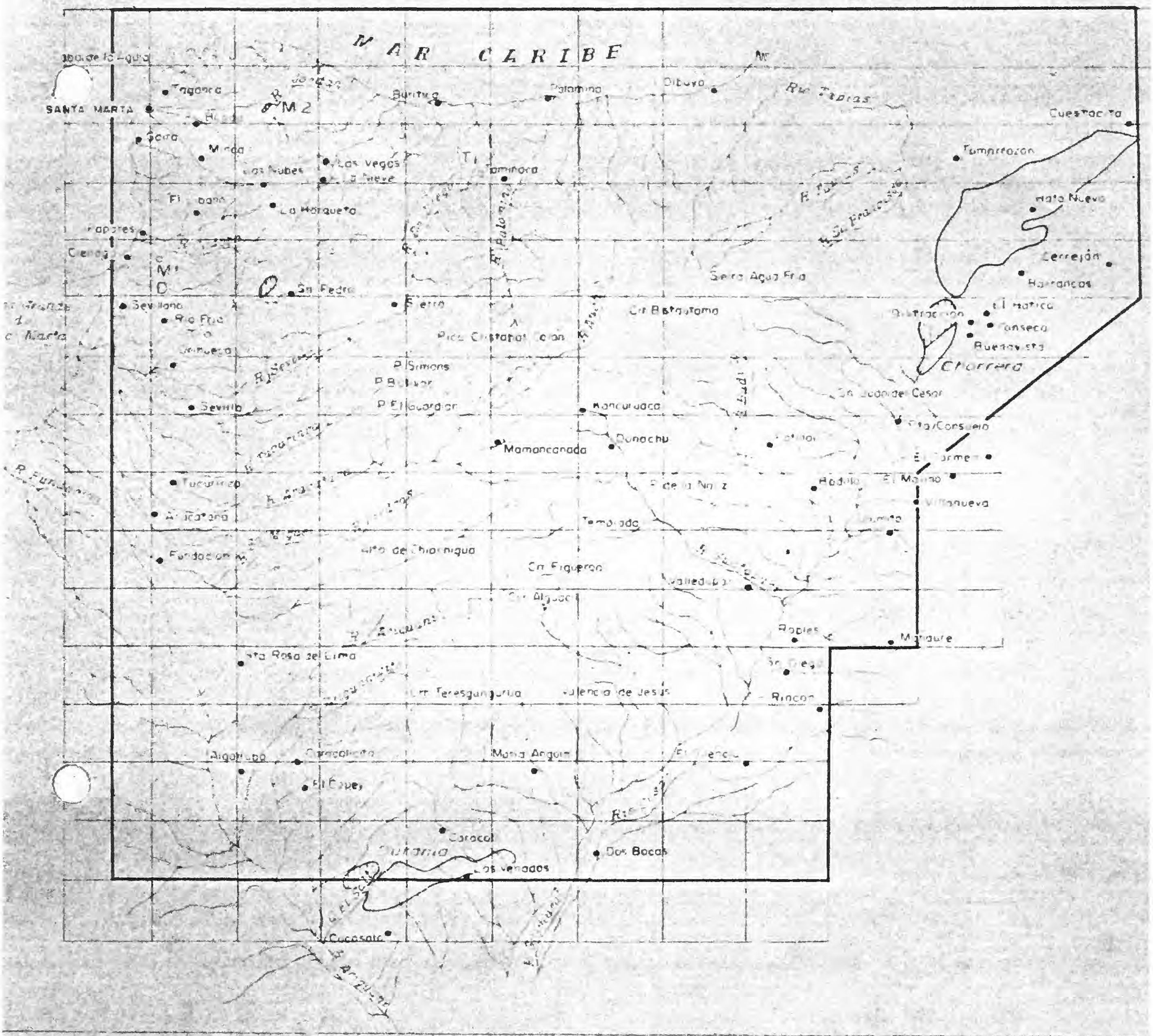


Fig. N° 2

LOCATION OF PRINCIPAL MINERAL RESOURCES
IN ZONE I, INVENTARIO MINERO NACIONAL,
COLOMBIA

EXPLANATION

M 1 – Marble, E. of Ciénaga

M 2 – Marble, near Piedras Blancas

D – Dolomite, Cerro Pedrera

T – Talc Tremolite, Q. Rodriguez

T₁ – Apatite Ilmenite, Q. del Hierro

Areas underlain by limestone

Areas of limestone of computed reserves

tons. This limestone averages 46.70% CaO, 36.88% (ignition loss, chiefly CO_2), 14.21% (insoluble, chiefly quartz and silicates?), 0.68% MgO, 0.39% Al_2O_3, 0.40% Fe_2O_3, and 0.19% P_2O_5. The thickness of the sample section varies between 5.45 and 15.9 meters and is much less than the total thickness. The deposit is suitable for open pit mining. The grade is perfectly suitable for cement, but clay from nearby deposits would have to be added. By selective mining of thickness of 3.5 meters from the top of block 1, which contains 5,474,000 tons, very good quality limestone fo almost all industrial and chemical use may be produced. The top 3.5 meters has an average analysis of 55.5% CaO, 42.7% ignition loss, 0.9% insoluble, 0.3% MgO, 0.11% Fe_2O_3, and 0.03% P_2O_5. This quality excee nearly all industrial or chemical specifications except SiO_2 if the insolubl material is entirely SiO_2. Even so, the lower 2.4 meters of this interval contains only 0.56% insolubles, well under the strictest specifications. This limestone could be used for calcium carbide, cyanamide, soda ash, or caustic soda manufactures.

Chorrera

Virtually limitless reserves of good quality, limestone occurs along the west side of the upper Ranchería Valley and large reserves are also present on the east side from Cerrejón southward. Some of these deposits were studied by Ronderos in 1956 (Informe 1183 of Servicio Geológico Nacional). Ronderos sampled the upper part of the Hato Nuevo forma tion of Paleocene (?) age near Hato Nuevo, the same interval on the anticline of Papayal, the Cogollo Group of Cerro Cerrejón, and the Carboniferous limestone on the west slope of Cerro Cerrejón. Ronderos does not give exact locations but all his analyses indicate that the limestone is suitable for cement although the P_2O_5 content (commonly 1 to 2%) may be high for many other uses.

Dr. Arias of Inminero collected 93 samples over 48.4 meters of uniform limestone exposed near Los Hornitos on the south bank of the Rio Ranchería near Chorrera, which we believe are representitive of this sequence throughout the 45-kilometer long belt to Cuestacita. The analyse are very uniform for the entire thickness sampled which is a very small part of the total thickness of the Cogollo Group indicated to be 1925 feet in the Papayal well. The average analyses of the sampled section was 53.34% CaO, 43.12% ignition loss, 1.05% MgO, 0.60% Al_2O_3, 0.10% Fe_2O_3, and 0.03% P_2O_5. These are excellent quality limestones, but they will require separate mining and mixing of clays or shale to make cement for the insoluble material and Al_2O_3 are very low. There is an abundance of argillaceous rock nearby and it is quite possible that a careful search will discover argillaceous limestones with nearly the right mixture of silica and Al_2O_3 in the Cretaceous and Paleocene sequences, judging from the logs of the Papayal and Cerrejón wells.

The indicated reserves in the block south of the Ranchería River, which has an area over 45 km^2 are over 4,968.000,000 tons using only the sampled interval. The potential reserves of similar quality material are very much greater. There are adequate reserves for any number of cement plants anywhere from San Juan de Cesar to as far north as Cuestecita. Since large coal reserves are developed at Cerrejón nearby, and adequate transportation and water are available, the limiting factor is the available market, either domestic or export. The very low magnesia content may permit export to areas where the local cement contains too much magnesia, either for mixing or for special uses for which the local cement is unsuitable. Limestones as low in magnesia as these are uncommon.

Marble - Ciénaga: East of Ciénaga on the drainage of Q. Macondo two separate areas of limestone, sandy limestone, and marble are present in addition to the dolomites to be discussed separately. The largest outcrop is 2 km long and 0.7 km wide. The other is 1.2 by 0.4 km. Good marble occurs at the south end of the smaller western outcrop where a grinding mill is being installed to produce pulverized marble for export. The marbles in the larger outcrop area are overlain by calcareous sandy rocks containing 66 to 96% insoluble material, chiefly silica (quartz) without economic value. The limestones in the lower part of the sequence contain 2.8 to 18.7 percent insolubles, 33-53 percent CaC, and 0.1-2.2 percent MgO. The total reserves of agricultural grade limestone are large, probably several million tons. Pure marble reserves are much smaller. They have been drilled by a private company and are apparently adequate for exploitation on a small scale.

A 30 meter thick sequence of comparable impure sandy limestone and marble can be followed for 1 kilometer of Cuchilla Piedras Blancas on the drainage of Rio Piedras. Nineteen samples of this sequence show impure sandy low-magnesian limestones roughly comparable with the Ciénaga rocks. The geologically inferable reserves are several million tons to a depth of 30 meters, but the economic potential is very small except for possible future local use as a soil additive, but this may be uneconomical because of difficult topography and lack of roads.

Dolomite: On Cerro Pedrera near the highway about a kilometer south of the marbles described above, two grab samples of dolomite were collected near the higher eastern summit. This dolomite bed averages 34.1% CaO, 17.15% MgO, 45.61% ignition loss, 2.2% insoluble, 0.08% Fe_2O_3, and 0.58% Al_2O_3. These analyses confirm analyses reported by Bueno and Wokittel (Bueno, Jesús A, 1957, Informe 1225 and Wokittel, R, Informe 1286). The dolomites appear to be confined to the central fault block, which averages 800 m long and 400 meters high. Assuming that the 6 analyses represent the block and that there are no interbedded limestones, there could be a maximum potential tonnage of 30,000.000 tons with an average analysis of 16.36% MgO and 8.16% insoluble, but the probable tonnage is likely to be a small part of this - say 8-12 million tons. The grade is erratic and many beds will have a high insoluble content of about 20%. Clearly this is an important resource of agricultural dolomite, but suitability for metallurgical or chemical uses is doubtful. Further exploration and systematic sampling in trenches or drill holes is required to evaluate this identified potential resource. Some metallurgical dolomite might be discovered even if the purer dolomite above is not suitable and the occurrence should be called to the attention of Paz del Rio considering the scarcity of metallurgical dolomite in Colombia.

Talc-Tremolite: Four lenses of tremolite-talc rocks are found in metamorphic rocks near Quebrada Rodríguez. No measured or indicated reservas can be calculated, but a large tonnage, perhaps 5,000.000 - 10,000.000, can be inferred on geological grounds of which 10-30% might be suitable for ceramics. We are unable to evaluate the commercial usefulness of these deposits but the fact that a foreign ceramic company has applied for a concession and plans to export indicates commercial value despite the negative results of a tested sample submitted to a firm in Medellín.

Clays and Feldspar: On the basis of 28 chemical analyses of anorthosite oligoclasite, and aplite and clays derived from them supplemented by thin section study, it is obvious that none of the white feldspars in the anorthosites or in the oligoclasite dikes have commercial value because of the high lime content. 16 samples of clays contained more than 28% Al_2O_3 with a maximum of 33%. Some contain quartz and most contain chlorite and sericite. No report was received on the clay samples shipped to Bogotá for laboratory evaluation. Clays derived from the anorthosite contain 10.5-15.1 percent CaO and that from oligoclasites contain between 7 and 11 percent. Probably all these clays contain residual feldspar and are not thought to have economic potential except for possible use as a filler where their white color is desirable.

Deposits of Iron, Titanium, and Apatite

A banded apatite-ilmenite rock associated with anorthosite was discovered in a heavily forested, inaccessible area on R. de Hierro, a tributary of R. Don Dieguito, on the north flank of the Sierra. Float was apparently derived from an area of 1 km^2 within a 3 km^2 area of anorthosite, which is cut by dikes of ilmenite-rich mafic rock and veins of pure ilmenite or magnetite. The banded ore contains nearly equal amounts of ilmenite and apatite and no other minerals are present. The rock was first reported to contain only 6.5% TiO_2, but a subsequent repeat analysis showed 19.7%. Both analyses showed about 33.90% Fe_2O_3 and 20.8% P_2O_5. We are awaiting a third analysis to confirm the TiO_2 content but it is probable that the higher value is more nearly correct, though still about 10% below the normal TiO_2 content of ilmenite, which was identified tentatively by X-ray diffraction. It is economically and technically feasible to produce both a saleable apatite and an ilmenite concentrate should exploration prove that reserves are large enough. The ilmenite concentrate would contain about 36.7% TiO_2 if pure. This is a saleable grade though less desireable than normal 48.6 to 54.2% TiO_2 content of ilmenite.

Reliable reserve estimates cannot be made without exploration, which will require cutting many kilometers of trail through dense montainous jungle. Any present indication of the size and shape of the body of banded ore requires geological assumptions that are highly uncertain. Nevertheless, the following tentative conclusions can be reached.

(1) The banded ore was apparently produced by floatation of early apatite crystals in an horizontal tabular mass of ilmenite liquid, which crystallized later than the apatite.

(2) The original size and shape of this banded ore body is unknown but the thicknesses of 2 to 4 meters were reached for float boulders with about 40 parallel bands totalling 2 meters were seen. The one doubtful outcrop had an apparent thickness of 4 meters and occurred next to a 2-meter vein of nearly pure ilmenite. Both were near the contact between gneissic anorthosite and intrusive (?) plagioclase rock with uniform granitic texture.

(3) A 2-meter thick stratiform mass of banded ore would contain 8,200.000 tons per square kilometer. This figure only indicates the size of the expectable target for future exploration.

(4) Several small gneissic anorthosite bodies up to 15 km^2 in area have been mapped in a belt extending 60 km northeast of Rio Sevilla and magnetite or ilmenite-rich rocks occur in or near several of them. Therefore, exploration might discover several ore bodies as the geological setting is favorable. However, the region is mountainous jungle of difficult access and any ore bodies found might be too small for exploitation in the immediate future.

SUMMARY OF MINERAL RESOURCES IN ZONE IIA
CENTRAL CORDILLERA

by Robert B. Hall, Geologist
U.S. Geological Survey

Introduction

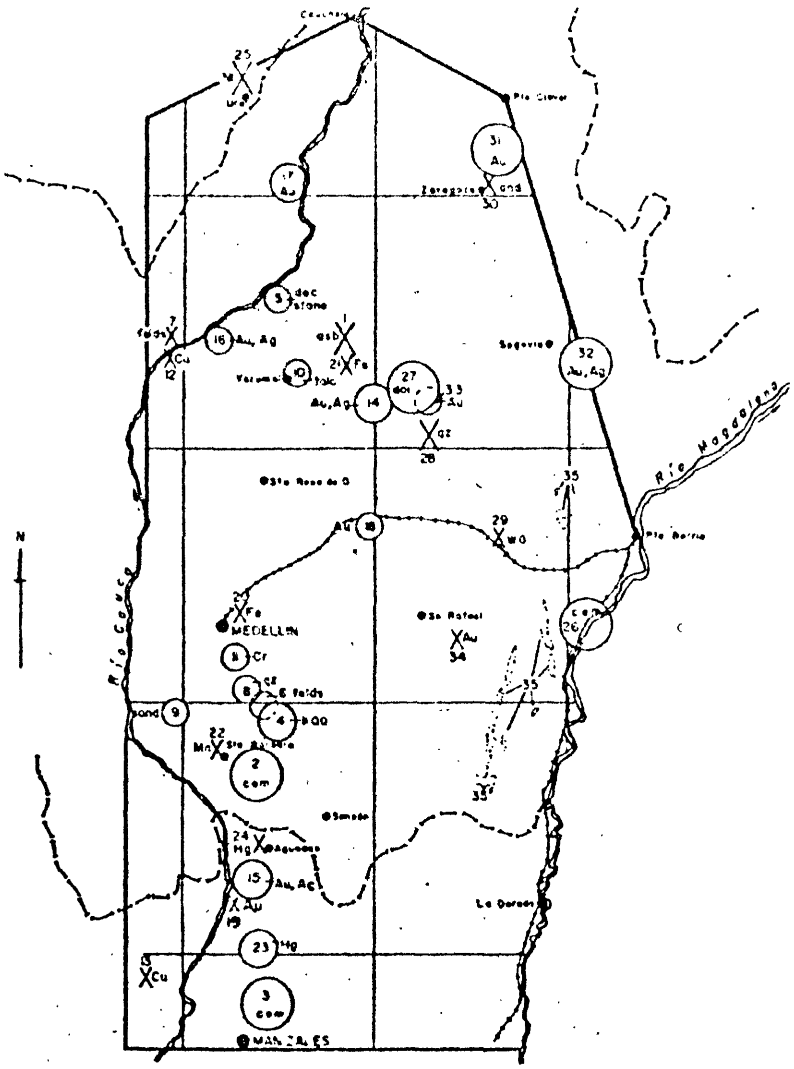
The accompanying table is an attempt to present in concise form the known facts about most of the mineral resources in Zone IIA. Included with the deposits that are being exploited now are less important occurrences which have been reported in the past, even though their potential for commercial exploitability may be poor or virtually nil, as for example the manganese prospects at Sta. Bárbara, the mercury prospect at Aguadas, or the ferruginous laterites east of Medellín. In most cases our information on reserves is at best of an order of magnitude. Figures are given for those deposits where a separate report has been made, e. g. of the Yarumal talc and the Uré laterite. In general, the listed mineral occurrences were known to exist, or had been exploited before inception of the present project. An appraisal of potential economic exploitability for each occurrence is given in the table. This necessarily is more opinion than fact, but is based on consideration of economics, technological and market factors as well as geology. Notably absent from the list are crushed stone, sand and gravel aggregate material for heavy construction, and coal. Only perfunctory attention has been given to aggregate sources, which are believed to be large and of satisfactory quality; coal is an important resource in the zone but is specifically excluded from the project.

Non-metallic Mineral Resources

Asbestos: The well-known deposit at La Solita 10 km airline distance north of Campamento, Antioquia has been the object of research by foreign companies. There are a number of reports by Canadian Johns-Manville Co. Ltd. dated from 1951 to 1953 in the archives of the Ministry of Mines and Petroleum. More recently in 1967, Nicolet Asbestos Co. of Canada with its Colombian partners, Asbestos de Colombia, Ltda., completed a drilling study, Inventario has only hearsay information from Nicolet's consulting geologist Mr. Herbert I. Harris. According to Harris, the reserve at La Solita is on the order of 4 to 6 million tons of rock containing roughly 4 to 5 percent fiber, predominantly short grades. This is too little to support an asbestos mill. Minimum reserve demanded is 20 million tons of 6 percent recoverable fiber. Neighboring occurrences such as Las Nieves and El Bufalo are much less promising than La Solita. In spite of the small reserves indicated at La Solita, the Nicolet Company was

Fig Nº 3

MAP SHOWING LOCATION OF MINERAL RESOURCES IN ZONE II EXCLUDING COAL AND PETROLEUM



Scale 1:1,500,000

MEDELLIN, JULIO/68

Drawn by Amparo Ruiz V

EXPLANATION

Producing mine or quarry: [illegible] per day; [illegible] per day; More than [illegible] per day

Prospect [illegible]

SYMBOLS

and	Andalusite
asb	Asbestos
Au	Gold placer
Au, Ag	Gold and silver lode mine, ore usually contains minor basemetal sulfides
cem	Cement raw materials, mainly marl sized limestone
	Limestone outcrops
Cr	Chromite
Cu	Copper
dec stone	Decorative stone
dol	Dolomite
Fe	Iron (ferruginous laterite)
felds	Ceramic feldspar (soda sp.)
Hg	Mercury
kao	Kaolin
Mn	Manganese
Ni	Nickel laterites
qz	Quartz
sand	Sand
talc	Talc
wo	Wollastonite

LIST OF MINERAL RESOURCES

ZONE - II - A

1 La Solita asbestos prospects
2 Cementos El Cairo plant and quarry
3 Cementos Caldas plant and quarry
4 La Unión kaolin pits
5 Valdivia greenschist decorative stone
6 La Ceja feldspar quarry.
7 Ituango feldspar prospect
8 El Retiro vein-quartz pits
9 Amaga glass sand (intermittent)
10 Yarumal talc pits
11 Las Palmas - Santa Elena chromite (intermittent)
12 Toledo copper prospect
13 Anserma copper prospect
14 La Bramadora lode gold mine, minor basemetal sulfides
15 Marmato lode gold mines, negligible basemetal sulfides.
16 Berlin lode gold mine
17 Puerto Antioquia placer gold mine
18 Porcecito placer gold mines
19 Supía placer gold prospects, once dredged, now abandoned, fair potencial exists for future placer operations in this vicinity
20 Medellín ferruginous laterite
21 Morro Pelón ferruginous laterite
22 Santa Barbara manganese prospects
23 Nueva Esperanza mercury mine
24 Aguadas mercury prospect
25 Uré nickeliferous laterites.

ZONE - II - B

26 Cementos Nare plant and quarry
27 Dolomite, Amalfi
28 Quartzitic conglomerate (ganister) at Amalfi
29 Wollastonite, Maceo
30 Alluvial andalusite, Nechi River
31 Pato gold dredges, Nechi River
32 Frontino lode gold mine, Segovia
33 La Viborita alluvial gold mine
34 Gold veins betwen San Rafael and Balseadero
35 Calcium carbonate rock, principally marble

encouraged to continue exploring Colombia and in May 1967 contracted with Aero Service Corp. to make a limited airborne magnetometer survey over selected serpentine targets in Antioquia. The maps and report of Aero Service Corp never have been made available to IMN. We understand that ground follow-up on the aeromagnetic data is in progress, but have no up-date information at this writing. If Nicolet's exploration proves additional reserves, the outlook for establishment of an asbestos mining industry in Colombia will be brighter. We understand that "Eternit" and other domestic asbestos-product manufacturers are operating on imported fiber.

Cement raw materials: The manufacture of portland cement is a major industry in Zone IIA, and was well-established before inception of the Inventario project. Cementos Caldas plant and quarry is at Neira, Caldas north of Manizales. Cementos El Cairo operates a quarry and kilns near Sta. Bárbara south of Medellín. We are told that Cementos Argos feeds its grinding mill in Medellín on El Cairo's clinker, marketing the ground and bagged product under its own brandname. IMN does not have at hand production statistics or data on raw materials reserves of these private companies, but presumably such data are available in the archives of the Ministry of Mines and Petroleum and the Ministry of Industry and Commerce ("Fomento").

Burned lime ("cal") for agriculture and the building trade is auxiliary to the cement industry.

It is necessary to point out that limestone resources in Zone IIA are quite limited in comparison with enormous reserves of Zone IIB.

Kaolin clays: Clay resources in Zone IIA are generally well-known, and investigations by IMN have been merely incidental. The better quality kaolin deposits like that at La Unión lie outside of IMN's mapping commission, although within Zone IIA. The Facultad Nacional de Minas in Medellín has done considerable research on this subject. Last year IMN assisted Locería Colombiana ceramic company in a preliminary investigation of La Unión kaolin as a potential source of high-grade paper-coater and filler clays. Results of tests by three large commercial kaolin companies in the U.S.A. were not very encouraging, although not wholly negative.

Future research may prove the feasibility of a plant for production of high-grade kaolin fillers and coaters as well as ceramic clays. These clays might be exportable if costs were kept competitive. Considerable capital would be needed, but private enterprise seems capable of taking this in hand if the economics should prove favorable.

Common brick and tile clays abound, especially on the Antioquian batholith, and small backyard brick-and-tile kilns are numerous. Although individually small, these plants in total make an important contribution to the economy.

Bentonite and fuller's earth clays are not known to exist in mineable deposits in Zone IIA, but we understand that geologic conditions are favorable for occurrences of these in Tolima and Valle del Cauca.

Decorative building stone: At least one company in Medellín, Piedra Esmeralda de Colombia, quarries greenschist at Valdivia, Antioquia and cuts, trims and polishes the slabs for architectural building trim. IMN does not have production statistics at hand. Reserves are large.

Feldspar: Ceramic feldspar used by Locería Colombiana and the Peldar glass plant is mined by open-pit at La Ceja, Antioquia. It is said to be of inferior quality but so far no better source has been exploited. Inventario Minero Nacional has reported potentially exploitable pegmatite soda spar occurrences 18 km by road southeast of Ituango, Antioquia (Oct. 67 and Feb. 68, monthly reports). Neither Locería Colombiana nor Peldar have shown interest in the Ituango occurrences on the grounds that higher haulage costs would offset any quality advantage that the Ituango spar might have. Nevertheless, the Ituango pegmatites clearly are a potential resource. Both La Ceja and Ituango feldspars are of the soda-rich-type. Potash spar in mineable bodies is not known to occur in Zone IIA.

Quartz and silica sand: Ground silica powder is prepared by Triturados Impalpables S. A. and other custom-milling plants in Medellín and sold to industries throughout Colombia. One source of raw quartz is reported to be at El Retiro 40 km south of Medellín. Milky vein quartz occurrences are fairly numerous in the Antioquian batholith and its enclosing rocks, but are individually small.

Peldar's glass plant in Medellín uses silica sand taken from Tertiary sandstone at Amagá, Antioquia. Peldar also washes and screens decomposed batholith regolith at Bello, north of Medellin; the clean quartz "sand" product makes a good glass sand. (Peldar's main source of glass sand is in Santander. This sand has an appreciably lower iron content than Amagá sand, thus justifying the longer haulage).

Talc: The talc deposits at Yarumal have been exploited on a small scale by primitive hand methods for at least the past 15 years. Present production is about 2000 tons per year of crude lump. The ceramic plants of Locería Colombiana in Medellín and Bogotá are the largest consumers, but it must be pointed out that the talc is used in sagger bodies or kiln furniture and not as an ingredient in the body mix of ceramic products sold to the public. Triturados Impalpables S. A. and several smaller custom grinding mills in Medellín, sell finely-ground bagged talc powder to domestic industries, especially paints, rubber, plastics, and cosmetics. The high iron content (over 5 percent Fe_2O_3 plus FeO) is a major obstacle to greater exploitation of Yarumal talc, which is not exportable. Based on diamond drillholes and geologic studies made by IMN in 1966-67, reserves are tentatively estimated at between 6,000.000 and 20,000.000 metric tons of material equal in quality to that now handmined and hand-cleaned by local campesinos. Lack of reserves is not the problem at Yarumal, but rather inferior quality coupled with high production costs and limited market. The present domestic market is not big enough to support a beneficiation plant, and costs would make beneficiated Yarumal talc non-competitive on the world market. Meanwhile, present small-scale hand operations are easily filling the domestic demand.

Miscellaneous: Bauxite has been reported at Llanos de Cuivá 80 km north of Medellin. Local patches of residual clay saprolite a few meters thick contain about 5 percent of gibbsite as nodules and veinlets. These occurrences are not commercially exploitable now or at any foreseeable future date.

Native sulfur deposits are unknown in Zone IIA, although reported to occur on the slopes of el Nevado del Ruiz in Caldas immediately south of the Zone II boundary. On the other hand, pyrite is widespread in our zone but in sparse disseminations and nowhere in exploitable concentrations. (Pyrite is a "nonmetallic" mineral when considered as a source of sulfur for acid). One prospect of massive pyrite has been reported by IMN located 1 km south of Ituango (Oct. 67 monthly report). It is doubtful that exploration would prove a deposit large enough to support a roasting plant for making sulfuric acid. Pyrite is common in gold- quartz ores but very rarely exceeds 5 percent of the vein-matter. We were told that Frontino Gold Mines in Zone II-B is forced to waste about 30 tons per day of pyrite in tailing. A few years ago they considered erecting a plant to roast pyrite for acid, but the study showed that the minimum plant of economic size would require 60 tpd of clean pyrite concentrate, double their output, and therefore the project was shelved.

Metallic Mineral Resources

Chromite : A north-south belt of serpentinized ultrabasic rock east of Medellin contains chromite in small highly localized seams and lenticles and in sparse, scattered eluvial float. These occurrences have been exploited intermittently on a small primitive scale, especially in the vicinity of Las Palmas and Sta. Helena about 10 km southeast of Medellín. Surface indications suggest reserves of no more than a few thousand tons. Tenor is highly variable, but small amounts of fairly high-grade material, possibly up to 50 percent Cr_2O_3 (34 percent Cr), may be obtained by selective mining and careful hand sorting. A few hundred tons per year of chromite are trucked to Bogotá and Medellín to be used in coloring beer bottles, making dyes and chemicals, and as a refractory lining in cupola furnaces. The known deposits appear adequate to meet this limited demand for some years to come, but obviously cannot support a large mining operation. Odds appear very high against discovery of a large-tonnage ore body, although the possibility of hidden or "blind" orebodies cannot be dismissed summarily. According to USGS geophysicist William Dempsey, of geophysical methods, only a gravity survey would have any chance of success.

Copper: During Inventario's mapping program, several small local occurrences of copper mineralization were noted, one 7 km west of Toledo, Antioquia, two others a few kilometers west of Anserma, Caldas. None of these are exploitable by any stretch of the imagination. Odds are prohibitively high that further exploration would prove fruitful at any of these locations.

Sparse chalcopyrite is disseminated in gold-quartz ores at La Bramadora and Marmato gold mines but is economically insignificant by itself.

Gold and Silver: The two largest lode gold mining operations in Zone IIA are at La Bramadora 18 km by road south of Anorí, Antioquia and at Marmato, Caldas. Both have been active for many years and details are available in governmental archives. Although "largest" in Zone IIA, they are very small compared to Frontino Gold Mines in Zone IIB. No meaningful reserve figure is available for either La Bramadora or Marmato. The present operators work on a day-to-day hand-to-mouth basis with little regard for reserves.

The old Berlin mine west of Yarumal, once the most important gold mine in Zone IIA, was shut down in 1946, and except for desultory small-scale "sniping", has been abandoned since then. During its heyday from 1935 to 1944 it was operated by Canadian interests. Reserves are believed to have been nearly exhausted.

Silver is an ubiquitous associate of gold in veins. Crude doré bullion from the mines is acid-treated at government-licensed "fundiciones" in Medellín to separate silver from the gold, bars of both metals are then shipped to Banco de la República in Bogotá.

Placer gold: Placer mining by old-fashioned hand-sluicing and panning with "bateas" is still going on in a number of creek and river valleys, but aggregate production is picayune. Señor Guillermo Mora of Medellin operates a small monitor near Puerto Antioquia, but data on yardage washed and recoveries are not available to IMN. There is a good potential for dredging in the broad alluvial flat lying within the Pto. Antioquia-Cáceres-Tarazá triangle(July'67 and Sept.'67 monthly Reports). Monitors and a small dredge worked at Porcecito 25 km southeast of Santa Rosa de Osos in the 1930's and 40's, but operations have been suspended since about 1947 except for small hand mining using sluices or bateas. The best ground has been exhausted. Dredging at Supia, Caldas has been suspended since about 1950, but other tributaries of the Rio Cauca in this district are potential placer ground and some of the wider alluvial flats might be workable with a small dredge. One may expect a sharp revival in gold mining, both lode and alluvial, if and when the official price of gold is raised above US$35 per troy ounce. Without such price-raise however, no improvement in methods or scale of operations is likely to occur.

Iron ore: Negative is perhaps the best word to summarize this item in Zone IIA, Much has been said and written about laterites, but the fact remains that the great bulk of this material is not economically exploitable now or in the foreseeable future, and must be classed under the euphemism "potential" resource. Julian Cock reported ferruginous laterites on top of serpentinite east of Medellín in 1938. Reserves according to Cock, are 800,000 tons of laterite containing 44 percent Fe, and 300 million tons of material containing 22 percent Fe. In the future this material might be considered as an economic source of iron, but that day seems very remote.

A lateritic cap over serpentinite at Morro Pelón 7 km northeast of Campamento, Antioquia was test-pitted and sampled by IMN in 1965-66. The laterite is enriched in iron (up to 50 percent) in the upper 2 or 3 meters; the lower 1 to 2 meters, just above fresh serpentinite, is poorer in iron but locally contains up to 1 percent nickel. In this respect the Morro Pelón laterite resembles that at Uré. Reserve is estimated at approximately 4 million tons of surficial material, variable in both Fe and Ni ténor depending on position within the laterite cap, but having an overall average tenor of very roughly 25 percent Fe and 0.6 percent Ni. At best this is a "potential" resource, not exploitable in today's economics.

Lead and Zinc: No deposit is known in Zone IIA in which lead or zinc are the metals of principal value. It is true that galena and marmatic sphalerite are disseminated in the quartz veins at lode gold mine like La Bramadora and Marmato.

About 12 tons per month of bulk sulfide concentrate is taken on homemade Wilfley tables at La Bramadora and shipped in burlap bags to the American Smelting and Refining Co. smelter at Selby, California, USA. The concentrate is mostly pyrite with base-metals tenor of roughly 2 percent Pb, 3 percent Zn and 0.3 percent Cu. This tenor does not even pay shipping costs. Obviously the concentrate is shipped to the smelter for contained gold and silver not extractable by panning or cyanidation at the mine. The base metals are only incidental and pay for but a part of the transport. They are not economically exploitable by themselves. No base metals are recovered at Minas Nacionales de Marmato, and tenor of Pb, Zn and Cu is much too low to pay for their recovery at the present scale of operations.

If the gold-quartz mines were to be operated on a much larger scale and equipped with modern flotation plants, the recovery of base-metal sulfide by-products might be economical. Frontino Gold Mines is an example. Any change in system or scale of operation at Marmato and La Bramadora seems very remote at this time. A rise in the price of gold would make these districts more interesting to large foreign-based mining companies with the capability to make improvements.

Manganese: The only significant manganese occurrences in Zone IIA are near Sta. Bárbara. These have been reported on by G. Botero Restrepo in 1942 and R. Wokittel in 1955. Inventario geologist Dario Velásquez re-checked these occurrences in 1967. Manganese oxides are intimately interbedded with marine cherts so that SiO_2 is high, from 20 to 50 percent, and average manganese tenor is less than 30 percent except for selected specimens. Moreover, the individual deposits are too small and discontinuous to be exploited profitably.

Mercury: The Nueva Esperanza mine at Aranzazu, Caldas is operated by Southern Union Production Co. with home offices in Dallas, Texas. In August 1967 they were producing about one flask (76 lbs ea) of native quicksilver per day. We are told unofficially that the production rate has increased somewhat since that time, but details are not available to IMN at this writing. The company has been beset by a number of problems including low tenor of the ore, poor recovery, contamination of underground air by mercury vapor, serious caving in underground workings and high royalty payments to concession holders. It appears doubtful that operations have been profitable. IMN does not have at hand information on the company's future plans or data on reserves.

The Aguadas mercury prospect in Caldas is held as a speculation by a syndicate of Colombian businessmen. Known showings of native mercury with cinnabar have been examined by IMN geologists and have no importance except to suggest a geological ambience favorable for mercury occurrence in the region. Only a systematic exploration program by a well-financed technically-staffed mining company has any chance of success. Cost would be high, and it is very hard to estimate whether or not the potential rewards are high enough to induce such an organization to mount a program of this kind.

Nickeliferous laterite: The laterites at Uré, Cordoba are being described in detail by Dario Velásquez; his report is still in preparation. He has estimated a total reserve of some 23 million tons, with average tenor of 0.8 percent Ni. Iron tenor ranges from 14 to 37 percent. Commercial exploitation seems remote.

SUMMARY OF MINERAL RESOURCES IN ZONE IIB, CENTRAL CORDILLERA

by Tomas Feininger, Geologist
U.S. Geological Survey

Introduction

The Antioquian mining tradition is founded wholly on the exploitation of gold, the overwhelming bulk of which came from Zone IIB, from both lode and placer mines. In fact, the area of Zone IIB ranks as one of the world's major gold districts, and to date has produced about two percent of the gold recovered by man since the beginning of his history, In stark contrast to the auriferous wealth of Zone IIB is its poverty in other metals. Production of base and ferrous metals has been virtually nil, and restricted entirely to a byproduct of gold mining. Nonmetallic mineral wealth is principally in carbonate rock. The known reserves of this rock in Zone IIB are among the largest in Colombia.

Metallic Mineral Resources

Gold: The two largest operating gold mines in the country are in Zone IIB. They are lode mine of Frontino Gold Mines, Ltda., at Segovia, and the alluvial mine of Pato Consolidated, Ltda., at Zaragoza. The gold production of these mines in 1967 was 70,500 and 88,800 oz respectively. Dozens of small gold mines, both lode and alluvial, dot the north half of Zone IIB. The total production of these mines, however, is less than four percent of the production of the above mines.

The lode mines are all in quartz veins. Many of these veins are in, or directly related to the quartz diorite Antioquian batholith. All the veins are poor in sulphides. Pyrite rarely exceeds five percent by weight. Galena, sphalerite, and arsenopyrite are the commonest base metal sulphides, but they are generally present only in trace amounts. Chalcopyrite is even rarer. The quartz of these mineralized veins is more resistant than the enclosing rock and thus, in the course of normal weathering and erosion, forms surface concentrations of loose boulders and cobbles at and near the vein outcrops. The only area where such concentrations suggest the presence of economic veins is on the Antioquian batholith in a zone along the Guatape River, between Balsadero and San Rafael. The deep weathering (generally more than 30 m of saprolite (weathered rock) overlies fresh rock of the batholith, based on scattered borehole date) would make evaluation of the veins difficult and costly.

Most alluvium in Zone IIB is auriferous. Some, such as that in the Nus and Porce Rivers, was especially rich and in some places had values in excess of a dollar per cubic yard. Smaller areas of rich alluvium were in the Ité, Pocuné, and San Bartolomé Rivers and some of their tributaries. Little if any of the alluvium (excluding that in the Magdalena Valley) in Zone IIB has not been exploited or at least tested. In general, the alluvium on the Antioquian batholith was the richest, although river gravels in the lower canyon of the Porce River and the vast alluvial flats of the Nechí River downstream from Zaragoza (currently being exploited by Pato), are notable exceptions.

Late Tertiary high-level alluvium between Amalfi and Anorí is also auriferous, but of markedly lower grade than modern auriferous alluvium. Nevertheless, these deposits have been worked intermittently, and one of them, at Amalfi, is currently being exploited.

The future of gold production in Zone IIB will be tied to the price of gold on the international market. At the current price of US $35 per ounce, the future may not be a long one. A substantial increase of this price would not only markedly prolong the lives of the mines currently being worked, but would see the exploitation of prospects previously considered of too low grade to be workable.

Other metals: No occurrences of base metals with even remote chances of exploitation have been found in Zone IIB. Furthermore, it is unlikely that Inventario geologists have missed hidden sulphide bodies. The prevailing humid tropical climate would favor the development of gossan on sulphides, an eye-catching and resistant material that is absent in Zone IIB.

Non-metallic Mineral Resources

Calcite, marble, dolomite marble, wollastonite, quartzose conglomerate, bloating shale, and andalusite are the principal non-metallic mineral resources of Zone IIB.

Marble: Calcite marble crops out over 89 km^2 of the zone. Assuming exploitation to an average depth of 50 m, reserves are 12 x 10^9 tons. The marble ranges from fine - to coarse-grained. Much has thin (1 to 5 cm) intercalated beds of quartzite or calcsilicate rock, though not in sufficient abundance to reduce the value of the marble for cement manufacture. Cementos Nare, one of the largest cement plants in Colombia, is located at the confluence of the Magdalena and Samaná Norte Rivers in Zone IIB. Aside from Portland cement, the plant also produces white cement and calcium carbide. Production of these commodities in 1967 was 106,302, 24,659, and 3,141 tons respectively. Marble for this production is quarried at Canteras, on the Samaná 15 km upstream from the Magdalena, and transported to the plant as a slurry by pipeline.

Calcite marble is quarried on a smaller scale at at least a dozen other places in the zone, from north of Segovia, south to San Miguel just north of La Dorada. Most of this production is burned and sold as lime for agriculture, building plaster, and whitewash. Some of the calcite marble of Zone IIB may be suitable for decorative and architectural stone. Evaluation for such use however, is highly specialized and was not attempted during the Inventario program.

Dolomite marble occurs in two places in Zone IIB. One, at Amalfi, has long been known and exploited. A detailed study by Inventario geologists showed that dolomite marble forms only 1.5 percent of the body being exploited, and that reserves are thus limited to only 600,000 tons. The other occurrence, perhaps previously unknown, is east of El Jordán (Mpio. of San Carlos). Here dolomitic marble forms a series of lenses, generally less than 50 m thick, in quartzite. Owing to their high grade of metamorphism, these dolomitic marbles contain considerably (commonly 40 percent or more) calc silicates, chiefly diopside, and thus are not suitable for high grade agricultural lime.

Wollastonite: Wollastonite occurs sporadically in calcareous rocks around the periphery of the Antioquian batholith. It is being exploited on a small scale hand-picking operation from a quarry at San José del Nus (Mpio. of Maceo) for use in the manufacture of floor tiles in Medellín. A similar occurrence 5 km to the north was investigated in some detail, including a diamond drill program, by Inventario geologists. Reserves were calculated at 16,000 tons (to a depth of 25 m.). As the wollastonite is in beds less than a meter thick intercalated with quartzite and marble, it would be difficult to exploit. Other occurrences of wollastonite in the zone have afforded museum specimens of the mineral, but none have economic potential.

Silica: White quartzose conglomerate at Amalfi, probably more than 95 percent SiO_2 may be useable as ganister. Chemical and firing tests are needed to evaluate the suitability of this material for silica brick. The conglomerate crops out close to a road.

Shales: Simple furnace tests at the Planta Metalúrgica de Medellín on samples of shale from Amalfi show that some of the shale bloats and would make suitable raw material for lightweight aggregate. The shale crops out along a road. Reserves of the shale are unknown, but are probably large.

Andalusite: Andalusite is common in Zone IIB. It has two occurrences. One is in gneiss of regional metamorphic origin. In this rock, which is widespread, the andalusite is fresh. Nevertheless, the economic potential of this andalusite is nil as individual grains are tightly locked in the gneiss and, in addition, generally contain inclusions of quartz, mica, and other minerals. The other occurrence of andalusite is as porphyroblasts (grains conspicuously larger than the grain size of the metamorphic rock in which they occur), probably of contact metamorphic origin, in sericite schist in the Amalfi-Anorí area. These porphyroblasts weather free of the enclosing schist and are concentrated in alluvium and colluvium. However, the overwhelming majority of these andalusites are sericitized; they have been replaced by fine-grained aggregates of white mica. Economically they are valueless. About one percent of the porphyroblastic andalusites are fresh. These crystals preferentially survive stream transport. As a consequence, the only andalusites found in alluvial gravels of the Nechí River (at Zaragoza) 50 km downstream from the source are fresh. There bright pink andalusite crystals, 1 to 3 cm long, rounded and polished, are conspicuous on spoil piles from gold dredging operations, and locally exceed one tenth of a percent of the gravel by volume. Reserves of fresh andalusite are probably on the order of thousand of tons. Nevertheless, owing to the low tenor of the gravels and the difficulty of separating the nonmagnetic, relatively light (s. G. 3.15) andalusite, it is unlikely that the andalusite will be an economic resource in the near future.

SUMMARY OF PRINCIPAL MINERAL RESOURCES IN SEDIMENTARY ROCKS IN AND NEAR THE SOUTHERN HALF OF ZONE III, EASTERN CORDILLERA

by Dwight E. Ward, Geologist
U.S. Geological Survey

Introduction

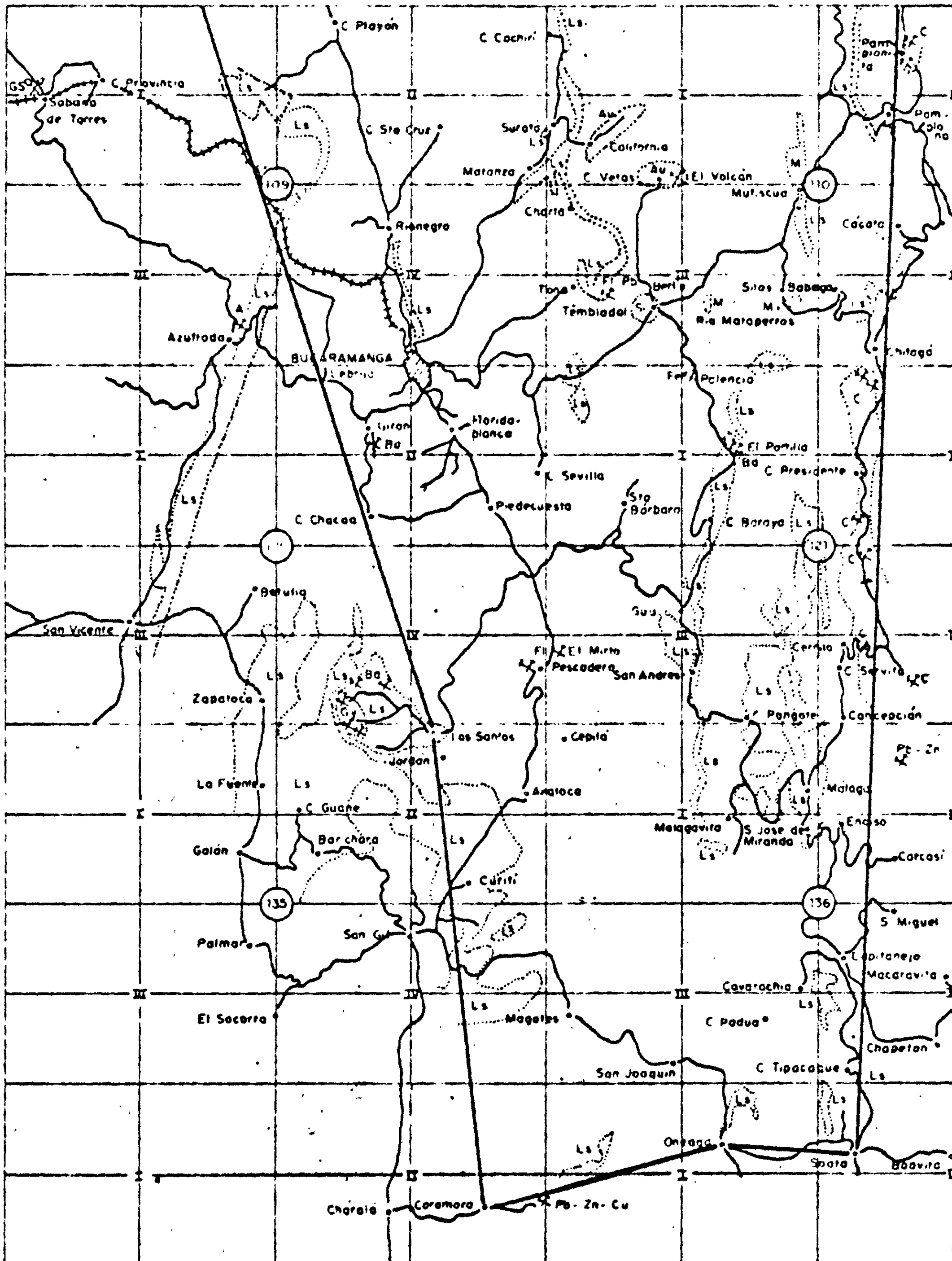
Principal mineral resources encountered in the areas of sedimentary rocks in the southern half of Zone III or in areas closely bordering are briefly summarized. This concerns the part of the zonethat has been mapped geologically thus far, and is therefore the part with which there is reasonably good familiarity.

In order to take a balanced view regarding the present status of the mineral resources, one that is neither too optimistic nor too pesimistic, it is believed appropriate to divide these deposits and resources into three categories, those now being exploited, those with definite potential but not yet developed, and those with prospective potential.

I - Mineral and rock resources actually being exploited and marketed, thereby demonstrating a definite need and demand, even though development may be on only a minor scale.

Gypsum is being quarried from surface outcrops at three concessions (Guayacán, Diviso, and Toro) on the steep southwestern slope of the Mesa de Los Santos, 10 kilometers west of Los Santos village.

Tonnage: As of now, the deposit is known only approximately in two dimensions, the outcrops at the three concessions and the thickness of four to six meters of useable gypsum. The third dimension, which is the extent of the gypsum beds eastward under the mesa will require drilling or tunneling to determine. The distance from Guayacán southward to Diviso is about three kilometers and from Diviso southeastward to Toro about one and a half kilometers. Although it is reasonable to expect that the gypsum beds are continuous between these places, a cover of slope wash prevents tracing between them. Furthermore, a study of the deposit now in progress indicates a poorer section of gypsum at Diviso than at the other locations. Until there is information about the extent of the gypsum from the outcrop eastward under the mesa, and/or of its presence on the opposite side of the canyon to the west, I would think it reasonable to predict a potential of more than 10,000,000 tons, which would be to assume that the gypsum extends 500 meters eastward under the mesa.



INVENTARIO MINERO NACIONAL

Fig. 4 – LOCATIONS OF PRINCIPAL MINERAL RESOURCES, ZONA III
(Petroleum and phosphate rock not included)

0 5 10 15
Km

Metallic Minerals		Non Metallic Minerals and Rocks	
Au	Gold	A	Asphaltite
Cu	Copper	Ba	Barite
Fe	Iron	C.	Coal
Pb	Lead	Fl	Fluorite
Zn	Zinc	GS	Glass Sand
		Gy	Gypsum
		Ls	Limestone
		M	Marble
		Si	Silica

Grade: The gypsum rock has a light to dark gray color due to the presence of considerable clay. Some beds are made up of alternating thin layers of gypsum and clay. Small amounts of carbonate are present. The rock is quite suitable for the cement industry, but its suitability for other uses in large volumes such as plaster and plasterboard remain to be seen.

Development possibilities : Underground mining will be necessary to recover nearly all the gypsum. The gentle slopes of the beds, 6°-10°, toward the outcrop appear favorable for such methods by tunneling up-dip from the outcrop. The demand for gypsum will probably continue to be determined mainly by the needs of the cement industry within economical transport distances, and a very large mining operation will therefore probably not be needed.

Coal resources have been studied and reported on previously by the Servicio Geológico Nacional and have therefore not been given much attention by the Inventario. In the part of Zone III covered thus far, coal beds are being mined in the Lower Tertiary rocks near Pamplonita, in a synclinal area four kilometers southeast of Mutiscua, and in a belt extending southward 40 kilometers from Chitagá to Cerrito. The coal is mined on a small scale from outcrops and shallow underground tunnels, and is used by small local industries, mostly in firing brick and lime kilns. Possibilities for larger scale development are limited by the thinness of the seams, low quality of much of the coal, and complicated structure involving much folding and faulting of the beds.

Sand for glass-making. About two kilometers northwest of Sabana del Torres, which is on the railroad from Bucaramanga to Puerto Wilches, white quartz sand at the surface of a low terrace is being dug from shallow pits, screened and dried for shipment to Medellin for glass manufacture. The sand layer seen in one active pit is from one to two meters thick and is a mixture of loose sand and pebbles of porous friable sandstone which is easily crushed. Below the white sand layer is more sand and pebbles with a light-yellowish brown color that is not suitable, probably because of the iron content. The sand is apparently derived from the Tertiary La Paz Formation which forms the first prominent ridge in the foothills to the east.

The glass sand deposit is outside of Zone III, and up to this date no study has been made of the surface extent or tonnage of recoverable sand that may be present. Without quantitative data other than the thickness observed in one pit, it appears that the deposit could cover an area of at least one square kilometer to a depth of one and a half meters, for which a potential tonnage of 3,000,000 could be predicted. The deposit could be explored rather easily with shallow pits or possibly by auguring if the pebbles are not too resistant. The convenience of rail transportation is a favorable factor to greater development.

Asphaltite: A small underground mine that produces two to three tons of asphaltite per day from a lenticular body in the Cretaceous La Luna Formation is located 20 kilometers west northwest of Bucaramanga, or two kilometers north of the junction of the highway to San Vicente with the road to Sabana del Torres. The lens has a northeast-southwest trend that is oblique to the nearly northsouth trend of the La Luna. The lens was first mined to the northeast of the Quebrada La Sorda for a distance of 50-60 meters and to a depth of 15-20 meters with maximum width of about eight meters. That part of the mine was apparently abandoned when it reached the level of the quebrada and water became too much of a problem. Mining is now going on to the southwest of the quebrada, but the extent of the lens is not known. The odor of gas is quite strong in the mine. At least one other lens has been mined and abandoned in this area.

The asphaltite is sold to brick makers for fuel for kilns. Asphaltite from a lens in the same formation about 65 kilometers north northwest of Bucaramanga was tested as to physical and chemical properties which apparently are not suitable for using the material in the manufacture of such items as cases for storage batteries.

In the investigations of the La Luna Formation for phosphate beds, no other asphaltite lenses of comparable size have been reported, and therefore they are apparently not numerous or extensive enough to constitute more than a minor resource. On the basis of present knowledge, continued small scale development for local use as fuel is all that can be expected.

Construction materials

Limestone: Resources are plentiful to meet all demands and are fairly well distributed throughout the southern half of Zone III. The most extensive limestone area includes the Cretaceous Rosablanca and Tablazo Formations where they crop out along the western foothills from north of Vanegas southward to San Vicente, Zapatoca, San Gil, and Coromoro. Other belts of these formations are in the general areas of Suratá-Charta-Tona-Picacho, Pamplona-Chitagá, and Guaca-San Andrés-Málaga . At Bucaramanga a short belt of Permian limestone just north of the city is used for cement manufacture. Another belt of Permian limestone extends intermittently from south of Cucutilla southward nearly to Baraya.

The principal uses of limestone are for cement manufacture, road metal, and for making calcined lime, which is a widespread local industry. Some is also ground for agricultural use. In the San Gil area where the beds are structurally undisturbed, large blocks of Rosa Blanca limestone are sawed into slices which are polished for interior facings or large buildings.

The limestone of the Rosablanca Formation is purer and more uniform, and is therefore more suitable for use where such impurities as silica and clay are not acceptable. The Tablazo Formation contains sandstone as well as limestone beds, and many of the limestone beds are sandy. Both formations contain varying amounts of interbedded black shale. The Rosablanca Formation reaches a maximum thickness of 300-400 meters, and series of beds of nearly uniform limestone up to 20 meters thick are not uncommon.

Sand and Gravel: These are gleaned from many local stream beds in small operations by individuals who have trucks and a few workmen with shovels and simple screens. Although gravel and sand are widespread in this mountainous area, large deposits of well sorted material are not common, particularly close to Bucaramanga where the demand is greatest. Such probably occur farther westward where the streams flow out of the foothills into the Magdalena Valley.

Clay for brick and tile: Clay is found in many places. In the Bucaramanga area, sources are mainly in the finer-grained beds of the Giron and Jordán Formations.

II - Underdeveloped resources, or those available in quantity but not yet being exploited even though there is a need and therefore a potential market.

Phosphate rock in large amounts has been found in the Upper Cretaceous sedimentary rocks only within the past two years. Investigation of this resource for the Inventario is under the direction of Mr. Edwin K. Maughan.

Utilizacion of phosphate resources is slow to get started even though is great need for it to improve the country's agricultural output. This situation will probably continue until it can be widely demonstrated that crop yields can be improved by direct application of the ground rock. If and when this occurs, much of the phosphate that is not suitable for large scale development will probably be developed successfully by small local industries for local use.

III- Prospective resources, or those mineral deposits for which there are small but favorable surface indications, but which require subsurface exploration to prove them large enough to make sustained development feasible.

Lead-zinc-copper mineralization: Narrow veins and replacements occur in dolomitized limestones at prospects eight kilometers southeast of Concepción and six kilometers east of Coromoro. Similar but less favorable prospects are near Tipacoque and Soatá. Beds of limestone up to more than two meters thick in the Lower Cretaceous Rosablanca and Tablazó Formations have been altered to dolomite and contain galena and sphalerite and less abundant chalcopyrite in scattered masses that tend to be concentrated near veinlets of siderite. The two main prospects are about 60 kilometers apart and the surface exposures are small, but the similar mineralizations are of a replacement type in limestone that may occur more commonly than in now known. Even if no large ore bodies occur, numerous smaller ones mined on a small scale could possibly yield enough to be the basis for an economic mining industry with central milling operations to recover concentrates for shipment to smelters.

Barite is being produced in quantity from a deposit in metamorphic rocks by shaft and tunnel operations near Ocaña, and attempts are being made to develop deposits in sedimentary rocks in the southern half of Zone III. Probably the most favorable of the latter is in the lower part of the Rosablanca Formation on the western slope of the Mesa de Los Santos about 10 kilometers northwest of the village of Los Santos. Development is also going on at another deposit about five kilometers to the east. I have not visited these prospects and will therefore leave comment as to development possibilities to Jaime Cruz who has visited the first deposit.

Two kilometers south of Giron a vein of barite about 40 centimeters thick is exposed in beds of the Giron Formation just to the east of the Rio de Oro, Some of the mineral has been excavated from this outcrop but the extent of the deposit is still unknown.

At El Portillo, 18 kilometers south southeast of Berlin on the road to Baraya, barite occurs in scattered irregular lenses in Permian limestone. Individual lenses attain thicknesses up to one meter, but maximum length is only three to four meters. Barite has been excavated from seven or eight of these lenses which are scattered over an area about 250x 100 meters. The limestones extend northward intermittently towards Cucutilla for a distance of about 50 kilometers and constitute a large prospective area for more and possibly better deposits.

SUMMARY OF MINERAL RESOURCES IN IGNEOUS AND METAMORPHIC ROCKS, ZONE III, EASTERN CORDILLERA

by Richard Goldsmith, Geologist

U.S. Geological Survey

Introduction

This report covers those deposits or prospects for which there is sufficient factual data available to make a reasonable estimate of potential. Many small shows of minerals have been encountered that are too small to warrant further investigation. These are not mentioned. Discussion of the distribution of the mines and prospects in the Zone with respect to the regional geology is deferred to the final report.

Metallic Minerals

Gold

El Volcán Mine, Vetas, Municipio de California, Santander

About 90,000 tons of tailings are present at the El Volcán mine. The material is sand size and smaller. The sand fraction carries 18.16 g/ton gold and 37.93 g/ton silver. The mud fraction carries 25.7 g/ton gold and 43.8 g/ton silver.

The tailings are readily accessible. Processing would have to include roasting because much of the gold is held in pyrite. Development possibilities are good.

Mines of the California-Vetas District, Municipio of California, Santander.

Precise data on the California-Vetas district are being processed and are not yet available. Raw data indicate that gold is the primary resource of this district. Silver, copper, lead, and zinc are minor by-products or are penalty products detrimental to easy processing of the gold. Copper, lead, and zinc are largely confined to the La Baja area near California. Contrary to expectations, economic quantities of uranium-bearing minerals have not been encountered.

Gold-bearing veins are spread over a principle area of 2 square kilometer area near Vetas. To effectively and economically develop those areas will require a large operation with a large capital investment. In this way a large volume of rock, even if at relatively low tenor as for example 2 to 3 g/ton of gold, could probably be mined successfully.

Iron

Cuchilla de Palencia, 14 kilometers south of Berlin on the Berlin-Baraya Road, Municipio de Silos.

A set of lenticles and seams of magnetite and hematite and silica fill east-west-trending fractures in metamorphic rocks near an intrusive mass of quartz-monzonite. The seams are scattered over an area about 200 meters long and 75 meters wide. The thickest lense averages about 0.5 m wide and 2.5 m long. Most lenses and seams average about 1 cm in width. A magnetometer traverse over one of the seams indicates that it is a thin, tabular mass and does not thicken at depth.

Tonnage is difficult to estimate because the seams are scattered. On the basis of 20 seams averaging 0.01 m in width, and totaling 200 m long (individual seams are less) and assuming a depth of 75 meters, a figure of 15,000 tons of magnetite and hematite plus silica is reached. No figures are available on the quality of the ore.

Tonnage available is small for an iron resource. In addition, large amounts of barren rock would have to be handled. This is not a good prospect.

Non Metallic Minerals

Fluorite

El Mirto, Río Manco, Municipio of Umpala, Santander, 1 kilometer west of Umpala.

Lenticular veins of fluorite, quartz, and galena in granite. Galena is subordinate. An estimated 1100 tons of fluorite are present. Quality of the fluorite appears to be high. Reserves are probably small.

Pescadero, Pescadero, Municipio of Umpala, 1 km southeast of Pescadero, Santander.

A vein of fluorite about 50 cm wide, 30 meters long in granite. Indicated tonnage is about 675 tons of fluorite.

Tembladal, 5 km WNW of Berlin, Municipio of Tona, Santander

Fluorite, quartz, galena, chalcopyrite, with a little sphalerite occur in a series of lenses along a fault in lower Cretaceous beds. The ulfides are quite localized. The fluorite can be traced for about 50 meters with an average thickness of 1 meter and maximum thickness of 3 meters. An estimated 4000 tons of fluorite are present; quality appears to be good. Grab samples from the dump representing the small sulfide-bearing area show 0.77% copper, 3.38% lead, 0.24% zinc, 6 g/ton gold, and 47.6 g/ton silver. Volume however of these is too small to be of interest.

Development possibilities are low as no water is available, and the mine is relatively inaccessible to transport.

Silica

Berlin, Municipio of Tona, Santander

A swarm of veins of almost pure quartz crop out around Berlin. Impurities appear to less than 1 percent. Widths range from less than 1 meter to several tens of meters. Lengths of some veins are nearly a kilometer.

A highly conservative estimate of tonnage is about 640,000 tons, based on eight veins averaging 250 meters long and 2 meters wide worked to a depth of 20 meters. The veins typically stand above the adjacent rock. Reserves are almost unlimited.

This material should be suitable for ganister or silica brick and for ceramics. Distance from any market, however, makes the quartz no more than a potential resource.

Marble

Marble for use in the building trade or for lime is available in the Silos and Mutiscua areas. Santander and Norte de Santander.

Mutiscua, Norte de Santander

White to gray, lightly metamorphosed marble currently being used in small local lime-making operations is present in large amounts along Río La Plata and Rio Sulasquilla. Area of exposure of the main belt is about 1/2 kilometer wide and 8 kilometers long. Recent mapping indicates that the beds may extend an additional 15 kilometers toward Cucutilla. Quality is not known, but crude test indicates that it is fairly pure $CaCO_3$.

Silos, Santander.

Gray to black marble exposed over an area 2 kilometers by 1/2 kilometer near Silos, Quality is not known.

Beds of white, gray, green and pink marble about 100 meter thick, exposed for about 1 kilometer are located in a canyon and are nct readily accessible. The marble contains many pegmatite dikes and lenses of silica. If used for swan or cut marble, quarrying would have to be highly selective. Quality not known, but crude test indicates it is fairly pure $CaCO_3$.

SUMMARY OF THE MINERAL RESOURCES
OF ZONE IV, CORDILLERA ORIENTAL

Donald H. McLaughlin, Jr. Geologist
U.S. Geological Survey

Introduction

The mineral deposits briefly described below were studied over a period of three and half years in conjunction with the regional mapping project of the Inventario Minero Nacional.

Coal, which is commonly present in late Cretaceous continental beds, has been specifically excluded from our investigations. Building stone, glass sand, concrete aggregate materials and emeralds have also been exempted from serious study.

Non-metallic Minerals

A. Salt

1. Sabana Area

a. Zipaquirá and Nemocón

Detailed geologic mapping both within the Zipaquirá and Nemocón mines and in the adjacent surface areas strongly suggests that these deposits are not salt diapirs but are actually interbedded within the sedimentary strata which contain them. Structurally these deposits lie within the axial regions of highly faulted anticlines. Because of the stratigraphic rather then the intrusive nature of these deposits, minimum thicknesses of the salt section in both mines have been determined. The simplest structural interpretation suggests a minimum thickness of 180 meters of salt section in the Zipaquirá mine and about 160 meters in the Nemocón mine.

At the present time, as no core holes have been drilled, it is impossible to calculate reserves with any degree of precision, However, from the area of salt exposed in the main level mine workings at Zipaquirá, indicated immediately mineable reserves are on the order of 30 million tons of NaCl over a working depth of 60 meters. Inferred reserves based on geologic interpretation indicate some 68 million tons of NaCl over an average working depth of 150 meters. The upper

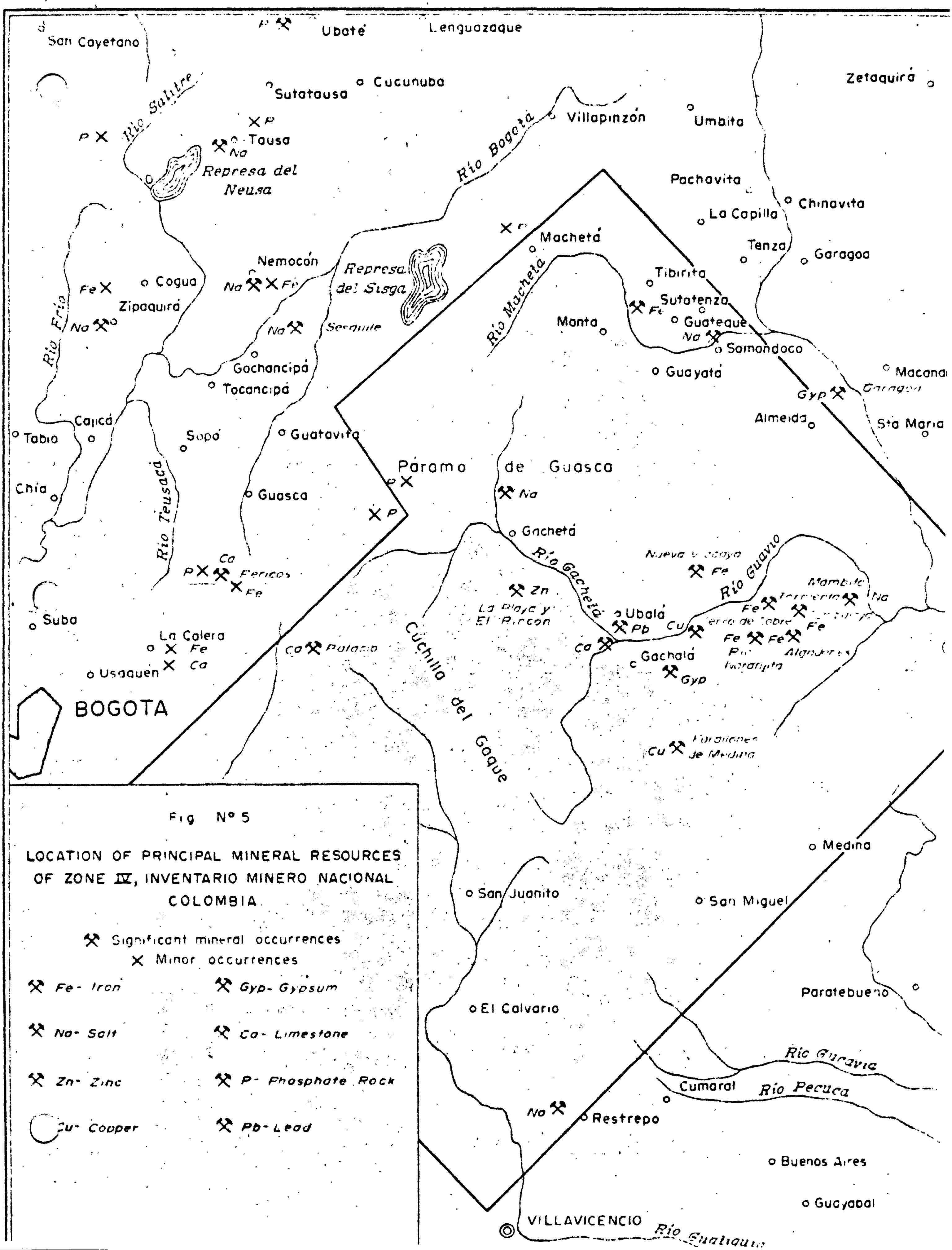


Fig N° 5

LOCATION OF PRINCIPAL MINERAL RESOURCES OF ZONE IV, INVENTARIO MINERO NACIONAL COLOMBIA or church level has not been included in these calculations. Future potential reserves, implying a strike continuation of the salt to the northwest, may be on the order of 130 million tons.

In the Nemocón mine immediately mineable reserves appear to be on the order of 3.74 million tons of halite based on a working depth of 30 meters. As the geology of both the mine and the immediately surrounding area is much more complicated than that of Zipaquirá, present knowledge is too scant to permit any meaningful calculations of inferred reserves. Suffice it to say that future potential reserves may be two or possibly three times the figure given for the more immediately mineable reserves.

Only minor and very sporadic traces of potassium were noted in these two mines. There would appear to be no chance for any economic potash production.

A thirty-day sample of the Zipaquirá tailin gs, taken in 1965, indicates that a little more than 13 tons of pyrite were being discarded each day. This would amount to an equivalent of somewhat more than 6 tons of elemental sulfur. The rute hood itself may contain considerable sulfur. (The term rute refers to the residual, insoluble materials concentrated over the top of the salt deposits as a result of surface water leaching.

Core-hole locations have been made both within these two mines and in the areas directly adjacent to them.

b. Tausa

Detailed surface mapping in this area shows that the Tausa salt deposit is located axially in the Tausa anticline and that stratigraphic salt may occur along the axis of this structure for as much as 1900 meters south of the Quebrada de Las Salinas. The salt deposit itself has never been seen but the abundant rute in the area indicates that it is not very far below the surface. No tunnels have ever been driven into the salt and the deposit was exploited by surface-water leaching.

Fossils recovered in the Quebrada de Las Salinas, deep within the rute, indicate a late early Conician age for the salt horizon. Mapping in the other saline regions, plus occasional fossil evidence, suggests a late early Coniacian age for all the Sabana salt occurrences.

Drilling sites have been selected for the Tausa area; core-hole information is vitally needed to establish the suspected strike extension of this deposit to the south. Until the occurrence of salt is definitely established in this area, no reserve figures can even be roughly determined.

c. Sesquilé

Detailed surface mapping in this area shows that essentially the same geologic conditions prevail here as at Tausa. Our mapping suggests that stratigraphic salt may be present in the shallow subsurface in the area between the old mine portal and the Quebrada La Lisonjera, some 1400 meters to the north, along a high valley several hundred meters wide.

Drill sites have been selected and nothing more may be said with confidence regarding the extent or lack of the salt until the subsurface information is available.

d. Other saline regions in the Sabana area.

Mapping done during the course of the Zone IV regional mapping has revealed several places where the surface geologic conditions suggest the presence of stratigraphic salt at relatively shallow depths. Foremost among these salt prospects is Pantano Redondo, a high valley along the axis of the Zipaquirá anticline which lies some 3 kms northwest of the Zipaquira mine. Core-hole information is needed and several drill sites have been selected. Another salt prospect may exist in the area immediately southeast of the Represa de Neusa where the western flank of the Tausa anticline has been completely faulted out, a phenomenon highly suggestive of salt. This area lies between 5 and 9 kms southwest along the structural strike from the Tausa Viejo area. Core-holes are vitally needed.

Enrique Hubach (1957, plancha I) has noted rute in the vicinity of El Salitre on his generalized map of the Sabana. Although our mapping of this area, just south of the road to Guasca, did not reveal any rute, the overall geologic picture is suggestive of salt at shallow depths. Drilling information would be exceedingly helpful.

2. Eastern Andes East of the Sabana

a. Restrepo

Mapping both within the mine and in the immediately adjacent regions suggest that this deposit is similar to those of the Sabana area. Lithologically the salt here is essentially identical to the Sabana salt, although of slightly smaller average grain size. The Restrepo salt is interbedded stratigraphically with black, locally marly claystone typical of the Caqueza Formation in this area. Little can be said regarding the overall structural nature of the Restrepo deposit as the region is exceedinly jungly, covered with thick terrace deposits, and, in general, lacking in outcrops except along the two rivers that flank the mine on the north and south. The saline sequence as mapped within the mine appears to be on the order of 80 meters thick. The age of the Restrepo salt has not been precisely determined; regional considerations suggest that it may be Valanginian.

Here, as in the Sabana mines, reserves can only be approximated as the total geometry of the Restrepo deposit is unknown. Drilling is essential. Our map shows rute cropping out about 200 meters downdip from the mine. The interveningvarea between the mine and the rute outcrop should certainly be drilled; the 80-meter thickness may prove to be a minimum figure. Core holes should also be drilled northwest of the mine in order to prove or disprove strike extension in this direction. A very tentative figure for immediately mineable reserves based on a 10-meter depth would be only on the order of 72,000 tons of NaCl, based on our present, highly limited information. With more work in the area, this figure would most certainly be expanded.

b. Gachetá

The salt at the Salinas de Gachetá is produced from a brine well some 18 meters deep. The deposit, which originally formed a brine spring, appears to be located just east of the faulted axis of the Tibirita anticline. The exact stratigraphic position of the salt is difficult to determine; it may be in situ as a lens within the lower horizons of the Fomeque Formation, or it may be structurally emplaced along the thrust fault that crops out just east of the Salinas. If in situ that salt is probably Aptian or Barremian in age. If emplaced structurally, it may be considerably older. As the area is densely forested, it would be very difficult to recommend drilling sites at the present time.

c. Mambita

This salinas, consisting only of a brine spring, is about 2.5 km. southeast of the village of Mambita. The spring appears to be flowing from the approximate base of a thick terrace deposit which presumably lies on the black, well-bedded limestone and black, carbonaceous claystone which form the Caqueza Formation in this area. It is probable that the brine is being formed by solution of a salt lens within the Cáqueza. Although no fossils were found, the strata in this area may be Valanginian, suggestive of a correlation between the Mambita and Restrepo salt deposits.

No development program appears feasible at the present time for the Mambita salinas. When the salinas was visited in May 1967, the brine was flowing unhindered into an adjacent stream; no efforts were being made to exploit it.

3. Conclusions

If core-hole drilling indicates the presence of salt in the prospects briefly described above, the possibility of resorting to solution-mining methods might be seriously considered. Salt brines produced by solution-mining could easily be transported by pipe line to the Soda Plant near Cajicá. As all the prospects are at higher altitudes than the Soda Plant, located on the Sabana floor, the brine could flow under gravity-feed entirely. Pumping would only be needed to lift the brines to the surface at the well-head. This method of producing salt would be far more economic than underground mining, such as is used at Zipaquirá.

It should be emphasized that rock salt is the cheapest source of sodium and chlorine, two elements without which modern chemical industry cannot function. Virtually every manufactured product which involves chemistry in its fabrication also involves sodium and/or chlorine. If Colombia is to advance into a modern industrial nation, it is vital that her chemical industry be developed to a maximum extent. Any such development would be based, in large part, on sodium and chlorine, both of which may occur in the Sabana area, in considerable amounts. It is essential that the possibilities of increasing salt production be considered with the utmost seriousness as soon as possible. It is worth noting that in the United States the per capita household use of salt is only 3 percent, the remaining 97 going to industry. At the present time the average per capita yearly production of salt in the United States is more than 10 times that of Colombia. This ratio can and should be reduced.

B. Phosphate Rock

Although no large phosphorite beds appear to be present in Zone IV, many small phosphate deposits crop out, mainly within the Lower Gudalupe and locally within the Upper Gudalupe Formations. These small phosphorite beds, generally less than a meter thick and of limited lateral extent, are too small for commercial exploitation. They should not, however, be completely ignored just because of their small size. Some of them may be suitable for very local use by the farmers who work and live in the immediate vicinities of these small deposits. The people, if convinced that this material will actually increase their agricultural yields, might be persuaded to dig out and grind these small phosphatic interbeds and apply them directly to their fields. Steps should be taken, however, to find out if this manner of phosphate utilization is feasible. If this should be the case, some kind of educational follow-up would be needed to convince the farmers of the value of these small deposits.

The largest of the minor phosphatic lenses lies with the Lower Guadalupe just above its faulted contact with the Guaduas Formation between the Machetá and Gachetá roads. The apparent northern and southern limits of this horizon crop out in quarries on these two roads. Whether or not the horizon is continuous is impossible to say, as the region is one of dense vegetation. Conceivably the horizon could extend about 32 km along strike. No analyses have yet been made of the phosphorite.

Another phosphorite lens is present in the Serranía de Pericos west of the iron bed. The phosphorite is disseminated through several meters of fine-grained sandstone. The lateral extent is a little less than 300 meters.

Three kilometers northeast of Tausa Viejo, at Alto de La Mesa, another very small phosphorite lens crops out in the Lower Guadalupe Formation in the eastern flank of the Tausa anticline. It is several centimeters thick and has a strike extent of only a few tens of meters.

A phosphatic limestone was found by Pedro Mojica in 1966 a few kilometers west of Ubate. This horizon, about 3 km in length and from 20 to 30 centimeters in thickness, locally contains 15 percent P_2O_5. Although probably not commercially attractive, it might serve local needs.

Another as yet untraced phosphorite lens is present along the road up to El Sanctuario west of Neusa. Its location along the road makes it very accessible.

C. Limestone

In the Bogotá area two limestone quarries are currently being exploited. At Palacio Cementos Samper is quarrying limestone from a large lens in the Upper Guadalupe. This deposit has been described by Ricardo de La Espriella (1959, p. 27-60). Another small quarrying operation is located in the axial region of the Sopó-Sesquilé anticlinal trend in the Serranía de Pericos, about midway between the iron bed and the phosphorite lens mentioned above.

The Ubalá limestone, yet to be mapped over its complete extent in Plancha K-12, would also appear to be a good cement source for this region. Utilization of this limestone would help greatly to reduce construction costs of this area which is some five hours from Bogotá by truck.

D. Minor Deposits

1. Gypsum

Two small gypsum deposits are currently being exploited in the lower horizons of the Caqueza Formation. On of these, at Lusitania, immediately north of the Rio Garagoa, some 3 km southwest along the road to Santa María from the junction of the Macanal road. The deposit is a brecciated mass of gypsum and black claystone. It is probably a relict salt deposit from which all the halite has been leached, judging from the associated mineral assemblage. The manager of this quarry states that gypsum forms only a small part of the material present in the quarry.

The other small gypsum quarry lies about 4 km east of Gachalá and appears to be fairly close stratigraphically to the Caqueza-Quetame contact. Although Inventario Minero geologists have yet to be permitted access to the quarry, from the distance it appears very similar to the deposit along the Rio Garagoa at Lusitania. The quarry east of Gachalá appears to produce about 10 tons of gypsum per day.

2. Barite

Inventario Minero geologists have not yet encountered and barite deposits in their mapping to date, but numerous small outcrops of this mineral are noted throughout the outcrop area of the Cáqueza Formation in Plancha K-12.

Metallic Minerals

A. Iron

1. Pericos and Other Sabana Occurrences

The Pericos iron deposit is located along the western flank of the Sopó-Sesquilé anticlinal trend several kilometers south of El Salitre, a small settlement on the road to Guasca. The iron-bearing bed is composed of fine-grained, silty sandstones and siltstones which have locally been highly impregnated with hematite. The bed also contains numerous, light-gray to gray claystone interbeds which separate the more porous, more highly ferruginous clastic beds. Detailed mapping in the area show the iron-bearing strata to have a strike extension of 6340 meters. The northern limit of the bed is formed by its intersection with the Pericos fault. The precise nature of the southern limit is not entirely clear; it appears to pinch out stratigraphically, but its southern termination may have also been caused by intersection with the Pericos fault.

Locally the iron-bearing horizon may reach a possible thickness of 100 meters on the outcrop. This thickness however, comprises the entire zone within which the iron-impregnated zones occur. No individual iron bed appears to be more than 10 meters thick. Fifty-three samples from the outcrop belt show an average content of 48 percent Fe. Insoluble residue, mainly silica in the form of quartz sand and silt, forms an average of 15.5 percent.

Eleven core holes have been drilled slightly down-dip from the outcrop face. Although chemical analyses of the cores have not yet been received, Dr. Marino Arce described the cores and is of the opinion that the iron content diminishes down dip from the outcrop face. A tenuous reserve figure for this deposit would be on the order of 600,000 tons of hematite.

Stratigraphically overlying the main iron-bearing horizon in the Pericos area are several other lenses of similarly iron enriched sedimentary rocks which are interbedded in the Coniacian Chipaque clay shales.

In other places in the Sabana region lithologically similar iron-bearing sandstones and siltstones are neither as thick nor as laterally extensive as the bed at Pericos. They are all Coniacian in age. The more prominent of these beds occur at La Siberia, La Caldera north of Zipaquirá, Cerro Volador near Nemocón, and another small hill immediately south of Nemocón. Most of these deposits have at one time or another been exploited. The silica associated with all these deposits, however, is a very serious detriment to their exploitation; at the present time other iron deposits in the Zone IV area appear to be more promising.

2. Tibirita

This small prospect, located above the junction of the Manta and Machetá-Guateque roads, is a ferruginously impregnated siltstone lens interbedded within the claystones and carbonaceous shales in the upper part of the Fomeque Formation. The ferruginous lens ranges from approximately 1 to 3 meters in thickness, and, although mainly hematitic, contains an appreciable amount of siderite, a mineral which is only rarely present in the iron beds of the Sabana.

Minor igneous activity that resulted in local copper mineralization has been noted in the Tibirita deposit. Some azurite and malachite coatings, and small quartz euhedra are present.

The Tibirita deposit occurs along the axial part of the Tibirita anticline. Lateral extent along this structure is yet to be proved, although similar mineralogical conditions may be present along the anticline as far south as the vicinity of Manta some 5 km south of the present mine.

More detailed work in the area, mainly geologic mapping, is indicated.

3. Nueva Vizcaya

This deposit is located some 9 km northeast of Ubalá along the road to Santa Rosa. The northern limit of the mineralized zone lies several hundred meters southeast of the road camp at Manizales.

This deposit is composed of manganiferous hematite which has impregnated Devonian siltstones and silty claystones. The thickness of the mineralized zone locally approaches 20 meters and appears to extend laterally some 200 meters south from the northern limit of the deposit near the Manizales camp.

Various chemical analyses have been made from the ore samples and show the following average composition; 60 percent Fe, 3.5 percent Mn, 0.06 percent P and less than 1.0 percent Si. The low silica and phosphorous contents greatly enhance the attractiveness of this deposit, and much more detailed work is certainly indicated. The mineralized zone should be mapped in detail and, following this, a core-hole program should be initiated.

The property is under concession to Minera Nueva Vizcaya Ltda. Initial geologic work was carried out under the direction of Dr. Roberto Wokittel and is being continued by Geocolombia.

Reserve figures may be as high as ten million tons of hematite based on limited present knowledge.

4. Cerro de Montecristo

South of the Rio Guavio, some 10 to15 kilometers northeast of Gachalá, are several outcrops of specular hematite in the general area of Cerro de Montecristo. Chemical analyses indicate that the Fe content alone may be as much as 68 percent Silica and phosphorous are neglible. These outcrops occur along the Rio Naranjito, in the area of Tumbalaya near Algodones and in the Rio Tormenta about 1 km southeast of Las Mesitas on the south bank of the Guavio. There may be many more such outcrops as yet unknown.

The largest and most spectacular outcrop lies along the Rio Tormenta. Recent landslides have exposed between 20 and 25 meters of Paleozoic quartz sandstones that contain lenses of specular hematite which range from a few centimeters to 30 centimeters in thickness. A rough estimate suggests that about 30 percent of the section exposed in the quebrada is composed of Hematite.

It is most important to establish the strike extension of the Rio Tormenta outcrop. Trails should be cut through the dense jungle into the outcrop and also along the possible strike extension for at least 50 meters. This done, the soil cover could be removed locally, probably by water-jetting, and if the hematite is found, drilling could be carried out.

It must be emphasized that this outcrop is located in an area of dense jungle and very precipitous slopes and can be only reached by animal from Las Mesitas and then by an hour's climb on foot through the heavy jungle cover. Las Mesitas lies some 3 to 4 hours by animal from the end of the main road from Gachalá.

Much of the region is under concession to Minera Hansa, Ltda. In spite of the obvious logistic problems mentioned above, the Cerro de Montecristo area may be of great economic importance to Colombia.

B. Copper

1. Farallones de Medina

Numerous outcrops of copper ore, mainly chalcopyrite, are known to occur in the Farallones region southeast of Gachalá. The area, very similar in topography and jungle to Cerro de Montecristo , has attracted geologists for many years. No systematic geologic study has yet been made, however. Inventario Minero geologists will be getting into this region as their mapping in Plancha K-12 progresses.

2. Other areas

Small outcrops of copper have been noted in many places within the mapped area of Plancha K-12. One such copper occurrence is at Cerro del Cobre, about 15 km east of Ubalá. The mineralized zone, composed of chalcopyrite, appears in the crest of an anticline probably formed in Devonian siltstone and claystone. The Cerro del Cobre deposit has been mined from time to time. Inventario Minero geologists will be in this area shortly and future plans can be evolved.

C. Zinc

1. La Playa

Located on the northern bank of the Río Sucio, about 5.5 km south of Gachetá, is a landslide of sphalerite, siderite, minor vein quartz and some chalcopyrite. The vein from which these minerals were derived does not crop out, but is probably located a short distance to the north of the landslide. A trench was dug through the landslide some years ago, presumably in an attempt to find the vein, but has since caved.

2. El Rincon

This deposit, about 1 kilometer south of La Playa, was mined a number of years ago, but the tunnel has caved and entry is impossible. The dump contains abundant siderite, minor marcasite, and minor sphalerite. A few years ago the sphalerite was hand-picked from the dump and shipped out.

Common stratigraphic and/or structural control may have influenced the ores at La Playa and El Rincon. The deposits appear to be in close proximity to the Fomeque-Cáqueza contact, which may locally be faulted. Mr. William J. Dempsey of the USGS has suggested that geophysical methods such as electromagnetic might help in this area to determine the location of the vein and to trace it between La Playa and El Rincon. If these methods should not prove feasible, however, shallow drilling could probably supply the needed information at a cost not much above that of geophysics.

D. Lead

Although small lead shows are reported from manu places with the confines of Plancha K-12, the most promising deposit is located directly along the road between Ubalá and Gachalá on the north side of the Río Gachetá. Galena is disseminated in several sandy horizons within the Ubalá limestones above the unconformity that separates the Paleozoic and Cretaceous systems. The Paleozoic sandstones below the unconformity are also locally mineralized. The mineralized zone withinthe limestone is on the order of 85 meters thick.

Much more detailed geologic mapping is needed here to delineate the mineralized zones and to find out whether they have any appreciable strike extension. Once this work has been done, geophysical methods may be helpful in further evaluating the prospect. If not, a drilling program should be contemplated.

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PHOSPHATE ROCK. RESOURCES IN COLOMBIA

by Edwin K. Maughan, Geologist

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Introduction

Studies in Colombia from 1967 to 1968 have resulted with the discernment of ext nsive phosphorite deposits that are probably exploitable (fig. 1). The potentially economic phosphorite strata occur as beds of pelletal apatite, probably calci-fluroapatite. The principal exploitable horizon is in the lower part of the Galembo Member of the La Luna Formation and equivalent strata of Upper Cretaceous age (Santonian?) that underlie wide areas in the Departments of Santander, Santander del Norte, and Boyacá.

The Cogollo and Simití Formations (Cenomanian?), lateral equivalents of one another lying below the La Luna Formation, also have favorable indications of containing phosphorite reserves. A small and potentially exploitable reserve has been discovered at this stratigraphic level near the village of San Andres, Santander.

A third potential economic phosphorite horizon is at the base of the Umir Formation and its equivalent, the Colón shale (Maestrichtian), that overlie the La Luna Formation. This phosphorite accumulation is composed mostly of detrital grains derived by erosion and reworking of pelletal phosphorite of the underlying La Luna Formation and which were re-deposited as a younger basal micro-conglomeratic stratum. The thickness and tenor of P_2O_5 of this unit varies markedly; but it could contain some of the richest and thickest phosphorite deposits in Colombia.

Other potential reserves at about the same stratigraphic levels extend southward into the Departments of Tolima and Huila and possibly as far as the Ecuadorian border.

The areas now known to have probably exploitable reserves are briefly described below and Table 1 summarizes in a tentative way the potential reserves for each of these areas based upon data collected to date.

▲ Phosphate locality with its name.

Fig Nº 6 LOCATION OF PRINCIPAL PHOSPHORITE LOCALITIES IN COLOMBIA

Table 1. Summary of potential phosphorite reserves

Area	Reserves in metric tons
Municipio de Lebrija, Santander	168, 300. 000
San Vicente de Chucurí, Santander	18, 750. 000
Sardinata, Norte de Santander	62, 100. 000
Orú, Norte de Santander	140, 000. 000
Gramalote, Norte de Santander	10, 000. 000
San Andres, Santander	7, 000. 000
Turmequé, Boyacá	4, 822. 000
Iza-Tota, Boyacá	43, 750. 000
Tesalia, Huila	9, 000. 000
Total	463, 722. 000

Criteria employed in Computation of Reserves

In conformity with mining practices in other parts of the world economic mining depth, for purposes of computation of reserves, is assumed at 1, 000 meters down dip in areas where the subsurface extension of the phosphorite horizon is not known to be limited by other factors such as faults, folds, or exceedingly weak walls. This 1, 000 meter depth is measured from the outcrop along the incline of the strata. Limitation of reserves to those above the water table is considered anachronistic, and against established principles of conservation of resources.

A specific gravity of 2.5 has been used in all cases to obtain the weight from the volume determined by measurements of thickness and areal extent.

Measured reserves are calculated for areas where all 3 dimensions and tenor are known. Except for a very small volume of rock in the immediate vicinity of the adits and raises of the mine at Turmequé, studies to date have not yielded sufficient data to calculate reserves to this exactitude. Reserve calculations presented in this report are classified as indicated or inferred.

Indicated reserves is used to identify those reserves for which thickness, tenor, and strike-length are reasonably well established and all known data point favorable to the existence of the quantity and quality of rock as specified. Generally the length is known from more or less continuous exposures, but thickness and tenor are known only at widely separated locations, and there are no data to know the extent nor the quality of the rock in the subsurface. However, the continuity and uniformity observed in the surface exposures suggest a similar continuity and uniformity in the subsurface that permit extrapolation for a short distance into the subsurface with reasonable sureness. Trenches are needed to expose the phosphorite stratum between presently established points of control to confirm the extension, thickness, and grade, and the absence of unexpected changes in these parameters. Drill holes of course are needed to establish the extension of the bed into the subsurface, to obtain thickness measurements, and unweathered samples for mineralogy and analysis of grade. It is not expected that additional data will alter these indicated reserves by more than 20 percent . Although part of the areas for which the reserves are classified in this category could be unexploitable because of unexpected local thinning, decrease in the tenor, unfavorable lithologic composition, or complicated structures

Inferred reserves is used to identify those reserves for which thereis not yet sufficient data to estimate accurately the quantity and/or the quality. These are possible economic phosphorite bodies for which additional data ought to be obtained, but which could prove to be unexploitable. In some cases, the thickness, and possibly the tenor of a phosph orite bed is known at least at one locality, and other data suggest an areal extension that may be large. On the other hand, factors such as variability in thickness or tenor, known to occur in the bed at other places do not permit extrapolation of known data into unknown areas and an otherwise favorably appearing possibility may be unexploitable.. In other cases, thickness and tenor of apparently continuous and uniform strata are extrapolated to extend some distance into the subsurface without additional corroborating evidence other than the observed continuity and uniformity at the surface. Numerous borings are needed to prove the extent, thickness, and tenor in these areas. Unknown and unexpected structural complications may also reduce the size of these inferred reserves.

Reserves in some areas where data have been obtained only by brief reconnaissance and limited observation are presented as potential reserves.

Description of Deposits

Azufrada-Vanegas, (Municipio of Lebrija), Santander

Phosphorite beds are found in the La Luna Formation where it crops out along the west flank of the Eastern Cordillera of the Andes from south of San Vicente de Chucurí, to north of Vanegas in the Department of Santander. South of Quebrada Los Altos, near the Caserio of Azufrada, the phosphorite strata are thin or of low grade and economic potential is not promising. At Quebrada Los Altos and northward to the area of Conchal and Vanegas, strata with potential for exploitation occur. These strata are in the lower part of the Galembo Member and are probably continuous over a distance of 21 kms between Azufrada and Conchal. They are also exposed along shorter fault block ridges of the La Luna Formation in the vicinity of Vanegas.

There are two beds of phosphorite in the lower part of the Galembo with combined thickness that varies between 1.3 and 2.2 meters separated by ½ to 1 meter of sterile rock. Preliminary analyses and visual estimates indicate the grade to be between 20and 25 percent P_2O_5 for both these beds.

Table 2. Phosphorite reserves in the Municipio of Lebrija in the area of Azufrada, Conchal, and Vanegas, Santander.

Part	Block[1]	Area in sq. m.	Average Thickness	Volume in cubic meters	Reserves in metric tons	
	A	443,000	1.6 m.	708,800	1,772.000	Indicated
	B	None	-	-	-	
	C	132,000	2.1	277,200	693,000	"
	D	148,000	1.3	192,400	481,000	"
I	E	518,000	1.6	828,800	2,072.000	"
	F	5,200	1.6	8,320	20,800	"
	G	686,000	2.2.	1,509.200	3,773.000	"
	H	289,500	1.4	405,300	1,013.250	"
	I	641,200	1.8	1,154.160	2,885.400	"
	J	1,375,600	2.2	3,026.320	7,565,800	"
	K	880,750	1.5	1,321,125	3,302,800	"
				Total	23,579,050	"

Table 2. (continued)

Part	Block[1]	Area in sq. m.	Average Thickness	Volume in cubic meters	Reserves in metric tons	
	A	305,000	1.6	488,000	1,220.000	Indicated
	B	120,000	1.8	216,000	540.000	"
	C	145,000	2.1	304,500	761,250	"
	D	170,000	1.3	221,000	562,500	"
II	E	414,000	1.6	662,400	1,656.000	"
	F	130,000	1.6	208,000	520,000	"
	G	427,000	2.2	939,400	2,348.500	"
	H	534,000	1.4	747,600	1,869.000	"
	I	716,000	1.8	1,288.800	3,222.000	"
	J	833,000	2.2	1,832,600	4,581,500	"
	K	400,000	1.5	600,000	1,500.000	"
				Total	18,780.750	
	A	2,700,000	1.6	4,320.000	10,800.000	Inferred
	B	1,080,000	1.8	1,944,000	4,860.000	"
	C	Probably none or small	-	--	---	
	D	680,000 [2]	1.3	884,000	2,210,000	"
III	E	3,690.000	1.6	5,904.000	14,760,000	"
	F	1,170,000	1.6	1,872,000	4,680,000	"
	G	1,708,000 [2]	2.2	3,757,600	9,394,000	"
	H	2,223,000	1.4	3,112,200	7,780,500	"
	I	5,373,000	1.8	9,671,400	24,178,500	"
	J	6,142,500	2.2	13,513,500	33,783,750	"
	K	3,600,000	1.5	5,400,000	13,500,000	"
				Total	125,946,750	"

1 Data for calculations in blocks A through G were supplied by Jacob Abozaglo M., blocks H, I, and J by Patricio Saenz, and block K by Raúl Durán of the Inventario Minero Nacional, July, 1968.

2 Calculated to a depth only of 500 meters below the local physiographic base level.

Part I is the reserves lying between local physiographic base level and exposures of the phosphorite beds. Part II is the reserves lying below the local physiographic base level to a depth of 100 meters, and Part III is the reserves between 100 and 1000 meters below.

The phosphorite reserves in this area are readily accessible on the south by the highway from Bucaramanga to Barrancabermeja and on the north by the railroad from Bucaramanga to Puerto Wilches. The highway is paved between Bucaramanga and Azufrada, but is unpaved from a short distance west of Azufrada to Barrancabermeja. Another unpaved road leads from the highway at Azufrada northwesterly to Sabana de Torres which is also on the railroad. Only short access roads would need to be constructed to place any of these reserves within direct reach by either the highway or the railroad.

San Vicente, Santander

A potentially large deposit of phosphorite may exist in the vicinity of Hacienda Palmira about 5 kms. west of the town of San Vicente. The principal exposure is adjacent to the road from San Vicente to Barrancabermeja. It is composed of 5 or 6 meters of nodules and broken pellets of apatite and some quartz and glauconite in a matrix of clay. It unconformably overlies the Galembo Member of the La Luna Formation and forms a basal micro-conglomerate stratum in the Umir Formation. The lateral extent of this grossly thick unit is not known. This basal Umir stratum is known at several other places in the Santander Departments and varies considerably in thickness and lithology from place to place. Locally, this variation is represented by exposures near Hacienda La Union, about 5 kms. south of Hacienda La Palmira where 12 meters of slightly phosphatic sandstone of less than 5 percent P_2O_5 (Gilberto Manjarres, written communication, 1968) is probably the equivalent of this unit. In opposite direction, two kms. north of Hda. La Palmira, the thickness is about 2 meters (Fernando Pachón, written communication, 1968) and the quality is similar to the thicker exposure near Hacienda La Palmira.

A reserve of 18,750,000 tons is inferred in this area based upon the presently available data. From the three exposures in this general area, a lenticular body 3 kms. long by 1 km. wide and an average of 2.5 meters thick is assumed. An extensive exploration program with trenches and drill holes will be needed to confirm this preliminary calculation and to establish if this inferred reserve is economically potential.

About one-third to one-half of this estimated reserve lies on or near the surface of a dip slope and may be accessible by open-pit mining methods. However, structural complications may interrupt the continuity of these strata and adversely affect the mineability of this deposit. Because of the steepness of this dip-slope, the uppermost strata of the Galembo and the adjacent overlying strata are commonly displaced and contorted owing to down-dip sliding. Subsurface mining may be difficult owing to incompetence of the overlying shale beds. On the other hand, proximity of the road leading to either Bucaramanga or Barrancabermeja and the possibility of a large reserve in a relatively small area are favorable and justify further investigation to measure and define this body of phosphorite.

Sardinata, Norte de Santander

The phosphorite reserve in this area is composed of a stratum of pelletal apatite in a sequence of beds in the La Luna Formation equivalent to the lower part of the Galembo Member. This stratum is exposed on the north flank of the Santiago Dome and is traversed by the road that leads east from Sardinata and connects with the road from Cúcuta to Tibú. Exposures of this phosphorite occur at many places along this road and in adjacent quebradas suggesting that the stratum extends continuously for a distance of 13 kms. In 4 kms. of this distance, the phosphorite bed is exposed at the surface or lies beneath less than 15 meters of overlying strata and soil in a roughly triangular that has a maximum width of 1.000 meters and an average width of about 500 meters. This phosphorite bed is also exposed at the surface or beneath thin cover in a narrow band about 50 meters wide that extends for an additional distance of 6 kms. The phosphorite can probably be strip-mined from most of this area of 2,300.000 square meters. The strata dip between 10 and 25° to the north.

Thickness ranges between 1.0 and 2.0 meters and probably averages 1.5 meters. The phosphorite bed is also exposed in similar dip-slopes a few kilometers south of Sardinata, and are probably exploitable in an area of approximately 1,200,000 square meters.

Reserves of 62,100,000 tons are calculated from the above data. These reserves are summarized in Table 3. Reserve Block A is the area that can probably be strip-mined east of Sardinata. Reserve Block B is contiguous on the north with Block A but represents the area where the phosphorite stratum is deeply buried and will require sub surface mining. It is assumed that the phosphorite bed continues in the subsurface 1,000 meters north of the surface exposures. Block C is the potentially exploitable area south of Sardinata, and this too can probably be exploited by surface mining, at least in part.

Quality of the rock is not yet well-known, but the tenor is high. Analyses from a few samples have yielded P_2O_5 as high as 31 percent (Cathcart and Zambrano, 1967) but channel samples have not yet been analyzed. Visual inspection indicates rock of very good quality with abundant apatite pellets throughout the potentially exploitable beds, and it is estimated that this rock should average 20 to 25 percent P_2O_5. It is high in calcium carbonate.

Table 3. Phosphorite reserves in the vicinity of Sardinata, Norte de Santander

Block	Area in square meters	Reserves in metric tons	
A	2,300,000	8,600,000	Indicated [1]
B	13,000,000	49,000,000	Inferred
C	1,200,000	2,250,000	Indicated [1]
		2,250,000	Inferred
	Total	62,100,000	

1 Probably mostly recoverable by open-pit mining.

There is an erosional unconformity at the base of the overlying Colón shale and in some areas the phosphorite stratum is absent because of this erosion. Therefore, the phosphorite stratum may be reduced in thickness of may be absent in some areas within the area of blocks A and C, and may be oonsiderably less extensive than inferred in the area of Block B. On the other hand, the basal stratum of the overlying Colón Shale may also contain exploitable reserves in this vicinity. At one place this basal stratum is one meter thick and contains abundant grains of detrital apatite pellets. Resolution of the extent and quality of these reserves and the possibility of an additional reserve represented by the latter possibility will require an extensive trenching and drilling program.

Orú, Norte de Santander

A large volume of phosphatic rock lies in the vicinity of Orú in the Department of Norte de Santander. As yet, the quality of this rock is not known and can be evaluated only by visual observation of the abundance of detrital apatite grains and a strong reaction with ammonium molybdate powder and nitric acid indicative of a high phosphorous content. The $P_2\theta_5$ content may average about 15 percent, a very tenuous estimate that will be resolved by samples now awaiting analyses.

This phosphatic deposit is a micro-conglomeratic stratum that forms the base of the Colon Shale. It is equivalent to similar rocks at the base of the Umir Formation and the potentially exploitable reserve at San Vicente de Chucurí in the Department of Santander. This bed is 2.5 meters thick at Crú. It is 4 meters thick 5 kms. south, and 7 meters thick 10 kms. south. Farther south, this bed thins and it is 2 meters thick 14 kms. south of Crú. Assuming a lenticularly shaped body with a length of 14 kms. exploitable for 1,000 meters in down-dip direction, and an average thickness of 4 meters, there are 140,000. 000 tons potential but probably low-grade phosphorite reserve in this area.

Gramalote, Norte de Santander

Phosphorite in the vicinity of Gramalote, Norte de Santander, is a southward continuation of the same horizon that occurs in the vicinity of Sardinata. Thickness varies between 1.3 and 3.0 meters and the stratum is exposed at several places extending from 1 km south of Gramalote to 3 kms. north. Exposures of the phosphorite bed are repeated in section by a series of step-faults. The dip of the strata varies from 30 to 50°. Until mapping and construction of cross-sections are completed (now underway), the lateral extent of the phosphorite in each fault block can only be approximated. A total possible dip length of 500 meters divided into several segments by the faults is assumed for calculation of reserves in this area, and a reserve of 10,000.000 tons inferred. Grade of the rock is visually estimated about 20 to 25 percent P_2O_5. and it is moderately to very calcareous.

The road from Gramalote leads to Zulia and Cúcuta via Lourdes and Sardinata to the north, or via Santiago to the south. Reasonably good access is provided by these roads to the agricultural areas of Santander del Norte, and the commercial center of Cúcuta. Mining will have to be subsurface, but there are several favorable entry locations providing access to the phosphorite stratum in several of the fault slivers.

San Andres, Santander

The existence of 7,000.000 tons of phosphorite is strongly indicated near the town of San Andres in the García Rovira district of the Department of Santander. This reserve is a bed 2.5 meters thick in the

Cogollo Shale (equivalent to the upper part of the Simití Shale of the middle Magdalena basin) of about the Coniacian or Turonian stage in the Upper Cretaceous. It is composed of abundant apatite pellets in a matrix of limestone. The grade analyzed in one channel sample is 25 percent P_2O_5 and very calcareous. The stratum has been traced by sporadic outcrops for 3 kilometers along two sides of a high bench about 750 meters above the town and is believed to cover an area of 1,125,000 square meters. Beds dip gently between 5 and 10° in most of this area, but locally steepen to 18°.

San Andrés is accessible only via poor road from Bucaramanga or Malaga making this reserve of very difficult access. Probably because of the difficult access and high $CaCO_3$ content, these reserves can be used only locally for grinding and direct application. Acción Comunal in San Andres is interested in the potential use and wants to develop this resource for local agricultural use. Some technical assistance to develop and use it properly is needed. Most of the reserve lies beneath thick strata of soft shale that will render subsurface mining difficult.

Turmequé, Boyacá

A phosphorite mine based upon discovery and preliminary studies by Pedro E. Mojica of the Inventario Minero (1967, Cathcart and Zambrano, 1967) was opened in March 1967 by the Instituto de Fomento Industrial at a favorably appearing exposure on the road between Turmequé and Ventaquemada in the Department of Boyacá. The mine is now being operated by Colminas, Ltda.

The phosphorite stratum is composed mostly of pelletal apatite, phosphatized foraminifera, and is non-calcareous to slightly calcareous. It is near the base of strata assigned to the Guadalupe Formation and forms part of a sequence that is very similar to the sequence of strata that compose the lower part of the Galembo Member of the La Luna Formation in Santander. This similarity permits a provisional correlation suggesting that the same phosphorite horizon extends from Santander into Boyacá.

Reserves and grade at this location are relatively low, but an accurate evaluation is yet dependent upon additional geological data. The initial mine opening was made into two adjacent phosphorite beds that total 3.6 meters thick. Samples from this location indicated content of P_2O_5 as high as 21 percent. Subsequent studies (Mojica, 1967, and unpublished data) indicate that the lower 1.4 meters is a probably continuous unit in this area and that the upper 2.2 meters which includes intercalations of claystone and porcelanite at the mine entrance, grades laterally into sterile beds. The lower bed, with an average P_2O_5 content of 22 percent, is exposed in several shallow trenches and natural exposures which indicate its probable continuity in most of the area. However, some of these exposures reveal considerable thinning which may be due to originally thin deposition or to later thinning by weathering and leaching that may only affect surface exposures of this bed. Brecciation, porous texture and concommitant scarcity of apatite pellets are suggestive that weathering chiefly accounts for this thinness. On the other hand, regional studies indicate the proximity of this area to areas apparently unfavorable to the deposition of phosphorite; and within a few kilometers strata equivalent to this horizon are only slightly phosphatic. The upper bed averages a low-grade of 8 to 10 percent P_2O_5 and extends for nearly 2,000 meters south of the mine opening, but is unknown at other locations in this area. Careful study including trenching and drilling is yet needed to obtain data to resolve the unanswered questions and prove or disprove the existence of the phosphorite resource believed to exist here.

Studies by Cathcart and Zambrano (written communication, 1968) have shown the feasibility of concentrating to acid grade (31% P_2O_5) material averaging 17 percent P_2O_5 collected in channel samples from the total 3.6 meters thickness located within the first 100 meters of the mine entrance.

Table 4. Phosphorite reserve at Turmequé, Boyacá

Block	Description	Bed	Grade in percent P_2O_5	Thickness in meters	Reserve in metric tons	
1	Adit level to surface	upper	10	1.5	720,000	Indicated
		lower	22	1.4	672,000	Indicated
2	Adit level to synclinal axis	upper	10	1.0	750,000	Inferred
		lower	22	1.4	1,050.000	Indicated
3	West flank of syncline	upper	-	0	0	
		lower	20	1.3	1,730.000	Inferred
				Total	4,822,000	

Reserves are indicated in Table 4 and calculated for three blocks based upon the following criteria: Block 1 extends laterally up-dip from the level of the mine opening to the surface and has a known longitudinal extent of 600 meters and other exposures indicating a continuation for 2,000 meters to the south. Thickness of the lower bed is believed to continue uniformly 1.4 meters. The upper bed is believed to average about 1,5 meters. Block 2 extends down-dip from the level of the mine opening to the axis of a syncline lying to the west. Thickness of the lower bed of 1.4 meters is believed to continue more or less uniformly, and the upper bed is assumed to average 1.0 meters in this block. Because there is considerable doubt of the factual extent and thickness of this upper bed, the reserve for it in block 2 is inferred. Reserve block 3 is the entire western flank of the syncline where thickness of 1.3 meters was measured for the lower bed at one point and this bed is assumed to extend 2,000 meters to the south. The upper bed has not been located in exposures on the western flank of the syncline.

The mine is located on the east flank of a syncline where the strata dip 45^{o} .W. It is near both the highway to the north from Bogotá and the railroad to the northeast (Bogotá to Paz del Río.) The road through Turmequé extends down the valley of the Rio Batá nearly to the Eastern Llanos.

Iza-Tota, Boyacá

A phosphorite horizon is exposed west of Lake Tota near the towns of Iza, Cuitiva, and Tota between 14 and 21 kms south of Sogamoso in the Department of Boyacá. Stratigraphic sequence and lithologic similarity indicate that this is a continuation of the same level being mined at Turmequé and suggest that it is probably a continuation of the lower Galembo horizon from the north in Santander. The phosphatic horizon is composed of two units that are 3.0 meters thick and average 20-25% P_2O_5. The lower one meter thick unit is sandy and cherty, of lower tenor than the upper, and laterally changes facies to phosphatic cherty sandstone.

A detailed study in this area (Ospina, 1968) indicates that this phosphorite horizon can be followed in exposures that extend northwestward on the west flank of a syncline from the town of Tota for 7 kms. to a point east of the town of Iza. The phospho rite horizon, 2 meters thick is also exposed about 5 kms. in the road from Sogamoso to Lake Tota and the Eastern Llanos and is projected to extend 3.5 kms south to where this horizon is also 2 meters thick in another exposure.

The phosphorite reserves in this area (Table 5) are calculated from data presented in the study of Carlos Ospina (1968). The area is conveniently divided into three blocks. Blocks A and B each represent roughly triangular areas bounded by exposures on the west, the axis of a syncline on the east, and bases to these two

The mine is adjacent to the road along the Rio Páez from southern Huila northeast to Cali. The rock is trucked to Cali where it is ground for use dirently as fertilizer and for production of phosphoric acid.

R e f e r e n c e s

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