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MINERAL OCCURRENCES OF THE GUIANA SHIELD, VENEZUELA

by

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INTRODUCTION

The U.S. Geological Survey has been assisting the Corporacion Venezolana de Guayana-Compania Tecnica Minera (CVG-TECMIN) since 1987 in its assessment of and exploration for new mineral deposits in the Precambrian Guiana Shield of Venezuela. This text accompanies the map "Mineral Occurrences of the Guiana Shield, Venezuela" (Plate 1). The map has been compiled in order to better evaluate the known mineral resources and to direct a mineral resource assessment and exploration program.

Venezuela currently produces three metallic minerals (gold, iron, and aluminum from bauxite) as well as diamonds (Newman, 1989). Kaolin, sand and gravel, building stone, and other nonmetallic mineral commodities are produced from deposits in the Guiana Shield, but they are not discussed in this report. The location and type of commodity for all known metallic mineral occurrences, prospects, mines, and mining districts in the Venezuelan Guiana Shield are shown on Plate 1, and Table 1 lists all of the known occurrences. Information for the occurrences varies from a location and a commodity symbol only (unnumbered on the map) to a location, commodity symbol, and a name (numbered occurrences), commonly with site-specific, detailed geologic descriptions and in some cases tonnage reserve data. A short summary of the commodities and occurrences identified on the map follows. The map has been digitized and plotted with the computer program GSDRAW 5.0 (Selner and Taylor, 1988).

GOLD

Venezuela has a long history of gold production. Total reported gold production between 1829 and 1971 was 187 metric tons (mt) (Locher, 1974). Reported gold production in 1985 totalled 2,214 kg, about 2,511 kg in 1986, and about 3,347 kg in 1987 (Newman, 1989). However, the actual level of production is not well known. It is estimated that rudimentary sluices worked by mineros (small-scale miners) produced 15 mt of gold in 1987 (Engineering and Mining Journal, 1987; Hennius, 1988). Newspaper and unofficial reports imply that more than 10 mt of the mineros' production are smuggled out of the country. Indeed, as much as 10 mt of Brazil's reported gold production may have been obtained from mineros working in the Venezuelan Guayana region (Engineering and Mining Journal, 1987; Hennius, 1988).

Mendoza (1985) proposed that as much as 8,000 mt of gold had yet to be discovered in the Venezuelan Guiana Shield, and Newman (1989) reported that Venezuelan gold reserves presently total an estimated 358 mt. The similarity between the geology of the Precambrian Guiana Shield and the Precambrian shields in Canada, Australia, and South Africa, supported by information from regional reconnaissance exploration (Gibbs and Barron, 1983; Sidder and others, 1988; Sidder, 1990) indicates that good potential exists for new discoveries of gold and other mineral deposits in Venezuela. However, the number of undiscovered deposits and amount of contained metal have not yet been determined quantitatively.

The richest gold lodes mined to the present are in the El Callao mining district (no. 37 on map). The El Callao mine was the most productive gold mine in the world during the latter part of the Nineteenth Century (Newhouse and Zuloaga, 1929). Cumulative production between 1829 and 1980 was 124 mt of gold (Bellizzia and others, 1981). Peak production was in 1885 when 8,194 kg were produced (Locher, 1974). MINERVEN (a Venezuelan government-owned mining company) produced 2,300 kg in 1986 (Rodriguez, 1987). Locher (1974) estimated that potential gold reserves in the El Callao district are about 84,000 kg from 4.6×10^6 mt with an average grade of 18.33 g/mt gold. Reserves to a depth of 250 m at the underground Colombia Mine (being mined by MINERVEN in 1989) are estimated to be about 14,300 kg from 1.55×10^6 mt with an average grade of 9.2 g/mt gold (Engineering and Mining Journal, 1988).

Precambrian greenstone belt rocks are historically the richest source of gold in Venezuela. More than 260 gold-bearing quartz veins are present in the El Callao district. These veins cut Early Proterozoic meta-igneous and metasedimentary rocks that are metamorphosed to the greenschist facies and locally the amphibolite facies (Menendez, 1968). The protoliths consisted of submarine sequences with mafic-ultramafic intrusions, mafic to felsic volcanic rocks, and volcaniclastic, turbiditic, and chemical sedimentary rocks of the Pastora Supergroup and the Botanamo Group. Both tholeiitic and calc-alkaline chemical trends are present in the volcanic rocks. Faults and shear zones localized the mineralization. Mafic metavolcanic and metavolcaniclastic rocks and metasedimentary rocks commonly host the ore. Native gold and minor to trace amounts of pyrite, tetrahedrite, chalcopyrite, bornite, and scheelite are present in the quartz-tourmaline veins. Carbonate alteration of the wall rocks, as well as propylitization and silicification, extends several meters away from the veins (Banerjee and Moorhead, 1970; Menendez, 1974). The low-sulfide gold-quartz vein model (Berger, 1986; Bliss and Jones, 1988) best characterizes the mineralization in the El Callao district.

The Kilometer 88 (nos. 99, 100, and 104) and the Lo Increible (no. 38) mining districts are two other areas of mining activity in 1989. The mines in the Lo Increible district exploit gold-quartz-tourmaline veins similar to those in the El Callao district (Ferrand and others, 1984). Rocks in the Kilometer 88 district are intensely weathered, and the geology is not as well understood. Hydraulic methods are used to mine the ore. Pedro Lira (Ministry of Energy and Mines, personal communication, 18 August 1988) described the weathered host rocks as schists similar to those in the El Callao area. The veins in the Kilometer 88 area contain native gold and pyrite with traces of chalcopyrite, and with gangue of quartz, dolomite, hematite, tourmaline, and sericite. Wall rock alteration consists of propylitization, carbonatization, and argillization. Faults and shear zones localize the mineralization. Gold production in 1987 at the Cristina 5 mine in the Kilometer 88 district was 1,700 kg, from about 142,000 mt with an average of 12 g/mt gold, 0.36 percent copper, and 50 ppm lead (P. Lira, personal communication, 1988). High-grade ore contains as much as 23 g/mt gold, 7.3 percent copper, and 7.0 percent lead.

TECMIN is currently exploring several properties in eastern Venezuela. Bochinche (no. 24), Marwani (nos. 26, 27), and Marwani-Los Caribes (no. 31) all have quartz-tourmaline vein occurrences similar to those described in the El Callao district. The host rocks at Bochinche include a sequence of mafic tuffs and turbiditic graywacke, whereas those at Marwani consist of mafic to felsic volcanic and volcaniclastic rocks, siliceous exhalite, lean iron formation or ferruginous chert, and phyllite. Píston de Uroy (no. 98) contains quartz ±carbonate-sulfide veins (without tourmaline) that cut a mafic-ultramafic complex of cumulate rocks. Gold has been mined from placers in streams that drain these areas. It is likely that these occurrences are in greenstone belts separate from and possibly not contemporaneous with that (those?) in the El Callao district (Sidder, 1990). Nevertheless, the low-sulfide gold-quartz vein deposit type best characterizes these gold-bearing quartz veins. Exhalative chemical sedimentary rocks associated with a quartz-tourmaline vent breccia in the Marwani area (Sidder and others, 1988) indicate that stratabound Algoma-type banded iron formation-hosted gold deposits, as well as bedded barite, antimony, and mercury deposits, are also possible at Marwani. These deposits may also be present in other areas within the greenstone belts. Associated deposits might also include volcanogenic massive sulfide. However, exploration in the Venezuelan Guiana Shield to the present has not identified base metal sulfide occurrences in the greenstone belts.

Other lode occurrences of gold identified on Plate 1 are small prospects without any or with only minor production of gold. La Camorra (no. 91) reportedly contains about 3,100 kg of gold that grades from 9.1 to 24.4 g/mt (Engineering and Mining Journal, 1988). The gold is hosted in quartz-tourmaline veins that cut Early Proterozoic schistose rocks metamorphosed to the greenschist facies. Gold in the prospect at Cerro La Pinto (no. 58) is present in shear zones that cut a sequence of mafic volcanic rocks and in a thin sequence of sheared exhalative rocks. These deposits also may be represented by the low-sulfide gold-quartz vein model (Berger, 1986; Bliss and Jones, 1988). Vuelvan Caras (no. 25) is the only gold deposit known to occur in granitic rocks, which are of uncertain, but likely Early Proterozoic, age. Vuelvan Caras may be a porphyry-type gold occurrence.

Placer deposits of gold have been mined extensively in the Venezuelan Guiana Shield. The mining methods used for the different occurrences vary from panning and amalgamation with mercury to large dredges with a series of shaker tables, jigs, grizzlies, sorters, and mercury plates. It has been suspected that the basal quartz pebble conglomerate of the Early to Middle Proterozoic Roraima Group is the source for modern placer gold and diamond deposits (Mendoza, 1985). Pre-Roraima Early Proterozoic metaquartzite and metaconglomerate such as rocks of the Los Caribes and Cinaruco Formations are also possible exploration targets for gold, uranium, and diamonds. Recent field work by John Dohrenwend (personal and written communications, December, 1989) in the southern Gran Sabana area identified three types of placer occurrences: 1) diamond placers within modern channels of major rivers; 2) gold and diamond placers in colluvial-alluvial deposits of low-order drainages; and 3) gold and diamond paleo-placers associated with conglomeratic lenses and beds that occur at several different levels within the lower part of the Roraima Group (lower 500 to 600 m of the Uairen Formation). Holocene paleo-placers (possibly about 8,000 to 10,000 years old) have also been mined in some areas, for example Chiricayen (no. 134), and are apparently the immediate source of gold in some modern alluvial placers.

A few gold placer occurrences such as La Planada (no. 13) are within the area of outcrop of the Archean Imataca Complex or are near the Guri Fault, which separates the Imataca Complex from the Early Proterozoic greenstone belt rocks. The Imataca Complex contains deposits of Superior-type banded iron formation. The precious metal content of these deposits is reportedly poor (Engineering and Mining Journal, 1987), although trace amounts of gold have recently been discovered at Cerro Bolívar (no. 52; Cesar Bertani, personal communication, June, 1989). Hence, the source of the gold in placer deposits within the Imataca Province is uncertain. It is assumed that the greenstone belt rocks are the source of the gold because the placers are downstream from these rocks.

Epithermal and bonanza-type precious metal vein deposits are uncommon in Precambrian rocks (Hutchinson, 1987). However, the felsic to intermediate composition and pyroclastic character of volcanic rocks in the Early Proterozoic Cuchivero Province and geochemical anomalies of silver (to 3 ppm), bismuth (to 1000 ppm), and molybdenum (to 20 ppm) in quartz-sulfide veins such as at Merevari (no. 151) imply that epithermal deposits are permissive in these rocks (Sidder and Martinez, 1989). Cover of the volcanic rocks soon after their deposition by sedimentary rocks of the Early to Middle Proterozoic Roraima Group may have preserved deposits of this type in the Guiana Shield.

DIAMONDS

Diamonds are recovered from placer mining operations throughout the Venezuelan Guiana Shield. Production in 1986 totalled 212,000 carats, with about 20 percent gem quality and 80 percent industrial quality, and production in 1987 dropped to about 113,000 carats with about 36 percent and 64 percent gem and industrial quality, respectively (Newman, 1989). This compares with peak production of 1,248,979 carats in 1974, and total production of 13,570,917 carats between 1913 and 1987, with about 25 percent of gem quality (Anez, 1985; Baptista and Parra, 1985; Newman, 1989). The Quebrada Grande area (no. 66) and the San Salvador de Paúl mine (no. 81) have been the largest producers. The former accounted for about 3,654,830 carats between 1975 and 1980, or 76 percent of all diamond production, whereas the latter totalled about 823,920 carats, or 17 percent (Anez, 1985). The majority of deposits are along the Caroni River (for example, nos. 9, 17, 18, 20, 41, 80, 82, 117, 118, 120, 121, 124, and 146) and along the Icabaru River and on the south end of the Gran Sabana area (for example, nos. 125-130, 132, 133, and 135-145). All of the diamonds have been recovered from placer deposits. Those in the Gran Sabana area in particular have produced gold as well as diamonds.

The source of the diamonds in Venezuela has been a subject of discussion for many years. Some authors have proposed that conglomerates of the lower Roraima Group are the source to modern placer deposits, whereas others have suggested that eroded kimberlites, possibly in Brazil or even west Africa, are the source (Reid, 1974; Briceño, 1984). Studies at San Salvador de Paúl (Briceño, 1984) and elsewhere along the Caroni River and in the Gran Sabana area (Reid, 1974; Reid and Bisque, 1975; Dohrenwend, 1989, personal and written communications) confirmed that conglomerates of the Uairen Formation within the Early to Middle Proterozoic Roraima Group are the source of the alluvial diamonds. Briceño (1984) stated that the conglomerates in the Uairen Formation were themselves paleo-placers and were the source for diamond-bearing gravels deposited about 8,000 years ago at San Salvador de Paúl. These

Holocene paleo-placers appear to be the source of diamonds in some deposits in currently active drainages.

Minerals indicative of kimberlites such as chrome pyrope and magnesian ilmenite have been identified recently in the Quebrada Grande area (no. 66), as noted by Baptista and Svisero (1978) and Malcolm McCallum (Colorado State University, personal communication, 2 November 1988). Nixon (1988) and Nixon and others (1989) reported that more than a dozen diamond-bearing kimberlitic dikes and sills with chrome pyrope, Ti-rich phlogopite, chromite, and yimengite [$(K(Cr,Ti,Fe,Mg)_{12}O_{19})$, a rare alteration product of chromite previously recognized only in kimberlites from China] have also been discovered in the Quebrada Grande area. Dates obtained from the kimberlitic and lamproitic or lamprophyric dikes indicate that these intrusions may have been emplaced at two different periods. One occurred between about 2.06 and 1.9 Ga, and the other at 850 Ma (Nixon, 1988; Nixon and others, 1989). Although kimberlites or their indicator minerals have not been identified elsewhere in Venezuela, it is possible that other diamond-bearing kimberlites intruded along north-northwest fractures that extend throughout the western part of the Guiana Shield in Bolívar State, the Amazon Federal Territory, and into Brazil. Sedimentary rocks of the Roraima Group may have incorporated diamonds from the older Proterozoic kimberlites during their transport and deposition.

IRON

Deposits of enriched banded iron formation (BIF) in the Guiana Shield provide Venezuela with abundant resources of iron. Production of iron in Venezuela between 1950 and 1987 totalled approximately 552 million mt (Suarez and others, 1981; Rodriguez, 1987; Newman, 1989). Reserves at Cerro Bolívar (no. 52), San Isidro (no. 51), Los Barrancos (no. 53), and the surrounding area are greater than 1,855 million mt and grade about 63 percent iron. At a 55 percent cut-off grade, reserves total an additional 8,000 to 10,000 million mt (Rodriguez, 1986, 1987). Deposits with greater than 55 percent iron, such as Cerro Bolívar and San Isidro, are generally located in hills that are between 400 and 700 m in altitude, whereas those located at altitudes less than 400 m are small and contain grades less than 55 percent iron (Rodriguez, 1986).

The beds of BIF are associated with the Archean Imataca Complex. The complex consists of metasedimentary and meta-igneous rocks of amphibolite to granulite facies, with about 80+ percent quartzo-feldspathic gneiss and granulite, 10 to 15 percent intermediate to mafic gneiss, granulite, and charnockite, 1 percent metamorphosed banded iron formation, and minor dolomitic marble and anorthosite. The protolith age of the Imataca Complex is about 3700 to 3400 Ma (Dougan, 1976; Montgomery and Hurley, 1978). The beds of BIF vary in thickness from a few centimeters to 10 meters, and uncommonly to 200 m. Some individual beds extend for 20 km along strike, such as at Cerro Bolívar. The entire stratigraphic sequence of the Imataca Complex has been isoclinally folded, and enriched BIF ore generally occupies the limbs and centers of synclines. Oxide facies BIF predominates, with hematite and magnetite as the dominant iron minerals. The iron-rich beds are intimately interbedded with layers of silica, present as quartz, and iron-bearing silicate minerals such as greenalite, grunerite, cummingtonite, chlorite, and sericite. Enriched ore is composed predominantly of goethite and limonite (Gruss, 1973; Ascanio, 1985; Moreno and Bertani, 1985b). These deposits conform most closely to the Superior-type banded iron formation model (Cannon, 1986a). Dougan (1977) identified laminated calc-silicate quartzite associated with laminated quartz-magnetite and orthopyroxene-quartz-magnetite iron formation near Cerro Bolívar. The calcareous rocks may represent carbonate facies BIF or carbonate alteration in BIF. Interestingly, BIF-hosted gold deposits are commonly associated with carbonate facies rocks (Phillips and others, 1984).

Ascanio (1985) recognized three types of iron ore occurrences in the Imataca Complex based on the grain size of the BIF: 1) coarse grained (>1 mm); 2) medium grained (about 1 mm); and 3) fine grained (<1 mm) Examples of coarse grained deposits include El Pao (no. 16), Las Grullas (no. 10), and Piacoa (no. 7). Cerro Maria Luisa (no. 19) is a medium grained deposit, and Cerros Bolívar, San Isidro, Los Barrancos, El Trueno (no. 59), Altamira (no. 49), Redondo (no. 47), Toribio (no. 46), Arimagua (no. 45), and others in the immediate area of Cerro Bolívar represent the fine grained type of ore. These three types are separated geographically, with the coarse grained deposits located north of the El Pao fault towards the east, medium grained deposits between the El Pao and Guri faults, and fine grained deposits toward the west located south of the Guri fault. It is likely that the grade of metamorphism affected the grain size of the BIF protore and subsequently the enriched ore because both decrease toward the west (Gruss, 1973).

Deposits of Algoma-type banded iron formation (Cannon, 1986b) may be present in the Early Proterozoic greenstone belts. Reported occurrences of "ferruginous quartzite", "hematitic-manganiferous siliceous shale", and "jasper" in volcano-sedimentary sequences of turbiditic graywacke and felsic to intermediate tuffs (Menendez, 1968; Aguilar, 1972; Lira and others, 1985) indicate that these deposits are possible. BIF-hosted gold and kuroko-type massive sulfide deposits are commonly associated with this type of BIF (Cannon, 1986b), as noted previously in the section on gold.

High-grade magnetite-rich ores of mid-Proterozoic age (1600 to 1000 Ma) are associated with subalkaline to alkaline granites and rhyolites in several localities around the world such as Olympic Dam, Australia, Kiruna, Sweden, and the St. Francois Mountains, Missouri (Meyer, 1988). Hematite, apatite, pyrite, barite, monazite, fluorite, actinolite, and chlorite are commonly intermixed in varying amounts with the magnetite ore, and Au, Ag, Cu, U, Th, light rare earth elements (LREE), P, Ba, Mo, V, and F are typically enriched in anomalous to economic concentrations. These Olympic Dam-type Fe-Cu-U-Au-REE deposits occur within tensional basins on the margins of Archean shields, and they are genetically related to anorogenic magmas that were derived from postorogenic lower crustal melting (Sims and others, 1987; Sims and others, 1988). The granite-rhyolite terrane of the Cuchivero Group in the area near Alto Paragua (no. 149) consists of rhyolitic to dacitic and trachytic ash-flow tuffs and flows and small plutons of granite to granodiorite (Sidder, unpublished data; see the section on tin for a more detailed description of the Alto Paragua occurrence). Small plutons and dikes of altered alkali gabbro and diabase, probably related to the Proterozoic Avanavero Suite, intrude the rhyolites. The type and composition of volcanic rocks and their post-Trans-Amazonian intracratonic tectonic setting indicate that these felsic volcanic rocks are permissive for Olympic Dam-type deposits. Aeromagnetic data would be extremely helpful in identifying structures and lineaments as well as locating possible magnetite-rich deposits in this area.

ALUMINUM

The development of bauxite ore and processing of alumina in Venezuela currently represents the second largest source of foreign currency revenue after petroleum (Newman, 1988). The production of alumina and aluminum metal as unalloyed ingot in 1987 totalled about 1,347,000 mt and 428,000 mt, respectively, (Newman, 1989). The principal occurrences of bauxite are: 1) Los Pijiguaos (no. 64); 2) Upata (no. 15); 3) Nuria (no. 22); 4) Los Guaicas (no. 79); and 5) in the Gran Sabana (nos. 105-107, 131).

Deposits of bauxite and aluminum-rich laterite are products of intense weathering of granitic, gabbroic, and diabasic rocks in the Guiana Shield. The deposit of bauxite at Los Pijiguaos developed on the Middle Proterozoic Parguaza rapakivi granite (Moreno and Bertani, 1985a). The protolith granitic rocks contain between 65 and 73 percent SiO_2 with 13.5

to 15 percent Al_2O_3. Mining started at Los Pijiguaos in 1987, and Bauxita Venezolana C.A. (BAUXIVEN) produced about 217,000 mt of ore. BAUXIVEN expects to produce 3 million mt of bauxite per year by 1990 and 6 million mt per year by 1992 (Newman, 1989). Initial measured and indicated reserves of bauxite were 201.8 million mt with a grade of 48.7 percent Al_2O_3 and 10.9 percent SiO_2, which include reserves of 70.1 million mt with 51.8 percent Al_2O_3 and 6.4 percent SiO_2 (Menendez and others, 1985). Newman (1989) reported that proven (200 million mt) and probable (500 million mt) reserves of 700 million mt are present in the Los Pijiguaos area. The ore averages about 7.5 m in thickness, and overburden, where present, is less than 1 m in thickness. Gibbsite is the dominant ore mineral with lesser kaolinite; the proportion between gibbsite and kaolinite decreases with depth.

The richest ore at Los Pijiguaos occurs at an erosional level (known as the Nuria erosion surface) that is at elevations between 620 and 690 m, and it formed during an intense weathering cycle in the Upper Cretaceous and Lower Tertiary (Short and Steenken, 1962; Menendez and Sarmentero, 1985). This weathering cycle corresponds to that which formed the enriched iron ore at Cerro Bolívar, San Isidro, Altamira, and other deposits of enriched BIF, as well as the bauxite deposits at Nuria, Upata, and Los Guaicas. Structural and topographic features such as joints, fractures, and steepness of slope control the intensity of enrichment of Al_2O_3 and depletion of SiO_2 in the granitic rocks (Moreno and Bertani, 1985a). Those ore zones most enriched in alumina and depleted in silica correlate with zones of highest fracture density. A slope gradient between 1° and 10° is most favorable for the formation of ore, and it affects the thickness of ore and the intensity of silica leaching more than the degree of alumina enrichment (Moreno and Bertani, 1985a).

The Upata district (no. 15) contains thirteen deposits of bauxite, of which five are considered possibly economic (Candiales, 1961). These include El Chorro, La Mesa de la Carata, El Baúl, Los Guamos, and Cerro No. 11. El Chorro has reserves of 1,259,250 mt, and the other four together have a total of 2,904,666 mt. The grade of alumina varies between 39 and 67 percent alumina, and the grade of iron and silica varies from 3 to 29 percent and from <1 to 23 percent, respectively. The ore is apparently a weathering product of gabbro or amphibolite (Candiales, 1961).

Nuria is a high plateau that forms an amphitheater, with a flat center and an elevated ring-like perimeter. The hills are between 600 and 700 m in altitude. Granitic gneiss comprises the central part of the structure, and diabase (or possibly gabbro) forms the peripheral hills. Intense chemical weathering has enriched the mafic rocks in alumina and has formed a low-grade ore deposit. Total measured, indicated, and inferred reserves are 50 million mt with 37.5 percent Al_2O_3, 28.9 percent Fe_2O_3, and 8.7 percent SiO_2 (Candiales, 1961; Bellizzia and others, 1981).

Deposits of aluminum-rich laterite and locally bauxite at Los Guaicas and in the Gran Sabana are weathering products of Middle Proterozoic and possibly Mesozoic diabasic intrusions (Bellizzia and others, 1981; Rodriguez, 1986). These deposits are relatively low grade (about 35% Al_2O_3, 30 to 40% Fe_2O_3, and 3 to 9% SiO_2) and generally small (<<100 million mt). The deposit at Los Guaicas contains 3.1 percent TiO_2 (Bellizzia and others, 1981). The erosion surface in the Gran Sabana area is located at elevations between 990 and 1,100 m and is called the Kamarata Surface. It is tentatively correlated with the Kanuku Surface in Guyana, which developed during or prior to the Jurassic (Menendez and Sarmentero, 1985).

MANGANESE

Secondarily enriched deposits of manganese are associated with rocks of the Early Proterozoic greenstone belts and with banded iron formation of the Archean Imataca Complex. The deposits at San Cristobal (no. 23) and La Esperanza (no. 56) are in the area of outcrop of greenstone belt rocks, and those at El Palmar (no. 11), Guacuripia (no. 12), El Manganeso (no. 14), Upata (no. 15), and El Pao (no. 16) occur within the Imataca Complex (Bellizzia and others, 1981).

The manganese deposits at San Cristobal are secondarily enriched residual accumulations (Aguilar, 1972). Metamorphosed manganiferous chert and siliceous manganiferous rocks of sedimentary origin that have been correlated with the Caballape Formation of the Early Proterozoic Botanamo Group form the protore. These rocks are intercalated with beds of ferruginous quartzite, dark gray phyllite, greenish chloritic phyllite, bluish gray clay, kaolinitic clay, argillite, and siltstone. The beds of siliceous manganiferous rocks vary from 0.2 to 2.0 m in thickness, and beds of metachert reach a maximum thickness of 15 cm. The protore consists of manganese silicates, and enriched secondary ore contains psilomelane, pyrolusite, cryptomelane, wad, and spessartine. Samples of siliceous manganiferous rocks and metachert contain 17.93 and 6.87 weight percent MnO, respectively, whereas residual ore contains about 50 percent MnO. Aguilar (1972) determined that the poorly developed weathering profile and the thinness of the beds make these deposits subeconomic. Descriptions of the regional geology, the local stratigraphic sequence, and correlations with the surrounding area suggest that mineralization occurred in an island arc environment. The manganese occurrences at San Cristobal are similar to those at Matthews Ridge in Guyana and Serra do Navio in Brazil (Nagell, 1962; Carter and Fernandes, 1969; Damasceno, 1982), and they are most compatible with the Cuban-type volcanogenic manganese model (Mosier and Page, 1988).

Beds of manganiferous rocks in the Upata-El Palmar-Guacuripia area are interstratified with rocks of the Imataca Complex. These beds crop out within a stratigraphic sequence that is less than 500 m in thickness, and they have strike lengths to 20 km or longer (Drovenik and others, 1967). Individual manganiferous beds are generally less than 10 m in thickness. Manganese protore, which contains between 11 and 30 or more percent MnO, consists of spessartine garnet, quartz, and graphite (typical of rocks classified as gondite) and rhodonite-spessartine-rich rocks that are associated with quartzite, ferruginous quartzite, feldspathic gneiss commonly containing cordierite and sillimanite, quartz-biotite schist, and amphibole-bearing schist. Dolomitic marble with as much as 3 weight percent MnO also occurs in the stratigraphic sequence and is commonly in direct contact with manganese-rich horizons as at Guacuripia. Sulfide minerals such as pyrrhotite, pyrite, chalcopyrite, sphalerite, valeriite ($2(Fe,Cu)_2S_2 \cdot 3(Mg,Al)(OH)_2$), and millerite (NiS) are present to 2 modal percent in gondite as small grains between 0.001 and 0.15 mm in size. The beds of manganese protore in the Upata-El Palmar-Guacuripia area are not intimately associated with banded iron formation. However, the iron deposits at El Pao and Los Barrancos are enriched in manganese with to 34 percent Mn and 4 to 16 percent MnO_2, respectively (Drovenik and others, 1967). The sedimentary-nonvolcanogenic manganese deposit model best represents the protore occurrences of manganese in the Imataca Complex.

The manganese orebodies in the Upata-El Palmar-Guacuripia area are secondarily enriched deposits. The ore consists of manganese and iron oxide and hydroxide minerals such as cryptomelane, psilomelane, pyrolusite, goethite, lithiophorite [$(Al,Li)MnO_2(OH)_2$], and nsutite (or gamma-MnO_2) [$(Mn_{1-x}^{+4}Mn_x^{+2}O_{2-2x}(OH)_{2x})$] (Drovenik and others, 1967). These minerals are associated with quartz and silicate minerals such as spessartine, mica, and clays. Minor amounts of hypogene minerals such as magnetite, mangano-magnetite, spessartine, rhodonite, braunite, hausmannite, and rarely rhodochrosite are also present. Drovenik and others (1967) recognized four types of ore: 1) earthy; 2) hard; 3) pisolitic; and 4) detrital. The first two types form beds with relict protore textures, whereas the latter two are present on the surface only. Estimated total reserves in the area are: 434,000 mt of earthy ore that averages 25 percent Mn, 25 percent Fe, and 10 percent SiO_2; 21,700 mt of high grade metallurgical grade hard ore; 441,000 mt of pisolitic ore with 20.9 percent Mn, 17.8 percent Fe, 12.41 percent SiO_2, and 14.63 percent Al_2O_3; and 104,910 mt of detrital clastic ore that contains 27.96 percent Mn, 14.97

percent Fe, and 13.49 percent SiO_2 (Drovenik and others, 1967). These ores do not constitute a large resource. However, some of these reserves have been mined in small quantities during the past twenty years.

The manganese occurrences at La Esperanza are similar to those described for San Cristobal. The protore in bedded manganiferous quartzite (apparently metachert of exhalative origin) has been secondarily enriched to form a residual deposit that contains reserves of about 40,000 mt of relatively low-grade ore of about 20 to 30 percent MnO (Martin, 1976; Bellizzia and others, 1981).

TIN

Placer, eluvial, and lode occurrences of tin with tantalum, niobium, zirconium, and titanium have been identified in the extreme western part of Bolívar State and in the Amazon Federal Territory. The best studied area is that surrounding Caño Aguamena (no. 63). A sequence of highly weathered complex pegmatite dikes, quartz veins, and aplite cuts the Middle Proterozoic (about 1545 Ma) Parguaza granite near to or along large regional north-northwest faults (Gaudette and others, 1978; Rodriguez and Perez, 1982; Perez and others, 1985). These granitic bodies are massive, unmetamorphosed, coarsely crystalline, and porphyritic with rapakivi (wiborgite-type) texture, and they are apparently anorogenic in origin. The Parguazan granitic rocks correlate in age and composition with the Agua Boa batholith in northern Brazil, which hosts the world's largest tin mine at Pitinga (Daoud and Antonietto, 1985; Thorman and Drew, 1988). Pegmatites and quartz veins in the Caño Aguamena area host the mineralized lode occurrences identified thus far, unlike the ore at Pitinga, which is hosted by greisenized granite. Neither hydrothermal alteration nor greisenization of granite have been detected in the Caño Aguamena area. Minerals recognized in the pegmatites and quartz veins include cassiterite, Ta-rich rutile or struverite, Ta-Nb-Fe-Mn-bearing rutile, tantalite-columbite, and stanniferous tantalite or ixiolite (Aarden and Davidson, 1977). In addition, Hf-rich zircon, simpsonite ($Al_4(Ta,Nb)_3(O,OH,F)_{14}$), and a U-bearing lead tantalate are present as inclusions in rutile. Tungsten-bearing minerals and sulfide minerals have not been observed in any samples. Resources of tin or other metals have not been defined to date. However, analyses of shallow drill holes in hills near Caño Aguamena indicate that 11 to 13 kg of heavy minerals per cubic meter are present, with 0.01 to 0.77 percent Sn, 0.01 to 0.23 percent Nb, 1.8 to 29.0 percent Ti, and 0.5 to 11.1 percent Zr (Perez and others, 1985). Exploration is continuing throughout the Amazon Federal Territory and western Bolívar State for secondary alluvial and eluvial deposits as well as primary pegmatite- or granite-hosted deposits (Rodriguez and Perez, 1982).

Cassiterite in rhyolitic volcanic rocks and in panned concentrates characterizes the tin occurrence at Alto Paragua (no. 149). Cassiterite, barite, apatite, and Cu-bearing pyrite occur as small (to 8 *um* x 4 *um*) disseminated grains in a sample of rhyolitic tuff, and several grains of cassiterite are present in the heavy mineral suite collected from creeks that drain into the Paragua River. These volcanic rocks are correlated with the Early Proterozoic Caicara Formation of the Cuchivero Group (Mendoza and others, 1975; Sidder, 1990)

NIOBIUM, TANTALUM, RARE EARTH ELEMENTS

Some occurrences of niobium, tantalum, and rare earth elements are associated with complex pegmatites in the Parguaza granite (see map, occurrence near no. 63) as discussed in the section on tin, and with pegmatites in the Imataca Complex (see map, occurrences near Ciudad Bolívar). However, the richest resource of rare earth elements, niobium, thorium, and barium in Venezuela is Cerro Impacto (no. 67).

The Cerro Impacto prospect is interpreted to be a deeply weathered carbonatite (Aarden, Iturralde de Arozena, Navarro, and others, 1978). It is an oval ring structure about 10 km in diameter that consists of three prominent topographic features that are open to the west. The complex is in proximity to large northwest-striking fractures. In fact, these northwest-striking fractures may be coextensive with the kimberlites in the Quebrada Grande area (no. 66), and they are parallel to large regional fractures that apparently controlled the emplacement of pegmatitic dikes into the Parguaza granites. These fractures extend throughout the western part of the Guiana Shield in Bolívar State, the Amazon Federal Territory, and into Brazil. The age of the intrusion at Cerro Impacto is unknown. Mendoza and others (1977) suggested that the carbonatitic complex intruded plutonic rocks of the Cuchivero Group during the Mesozoic between 150 and 80 Ma ago; however, the dates of about 1.9 to 2.06 Ga and 850 Ma reported by Nixon (1988) and Nixon and others (1989) for kimberlites in the Quebrada Grande area reveal that the carbonatite at Cerro Impacto may be much older than Mesozoic. It may in fact correspond in age with the Early Proterozoic kimberlites, which are only slightly older than other carbonatites emplaced elsewhere in the world during the period from about 1800 to 1650 Ma (Meyer, 1988). A thick lateritic cover at Cerro Impacto extends to at least 200 m in depth, and it does not retain any traces of the original rock (Garcia and Aarden, 1977). The laterite is enriched in Fe (to 61 wt %), Mn (to 35 wt %), Al (to 25 wt %), Ba (to 58 wt %), Th (to 0.5 wt %), Nb (to 1.5 wt %), REE (Ce to 7 wt %, La to 3 wt %, and Nd to 0.8 wt %), Ti (to 7 wt %), Zn (to 0.8 wt %), Pb (to 0.5 wt %), and other elements. Rocks that crop out in the area immediately surrounding the enriched laterite are alkaline granite, monzonite, granodiorite, quartz diorite, tonalite, and gabbro, some of which are fenitized. Fragments from the bottom part of some drill holes consist of fenitized rock, barite, and quartz pseudomorphs after carbonate crystals. Other minerals and mineral fragments present in the laterite include goethite, pyrolusite, wad, gibbsite, kaolinite, gorceixite ($BaAl_3(PO_4)_2(OH)_5{\cdot}H_2O$), goyazite ($SrAl_3(PO_4)_2(OH)_5{\cdot}H_2O$), florencite ($CeAl_3(PO_4)_2(OH)_6$), bastnaesite [$(Ce,La)CO_3(F,OH)$], and monazite (Aarden and others, 1973; Aarden, Iturralde de Arozena, Moticska, and others, 1978). These characteristics suggest that an intensely weathered carbonatite is present at Cerro Impacto.

URANIUM

Reconnaissance geologic and airborne geophysical investigations for uranium in the Guiana Shield have detected numerous radiometric anomalies (Pasquali, 1981). However, viable resources have not been identified to date. The Churuata ring structure (no. 152) in the Amazon Federal Territory is a Middle Proterozoic (about 1300 Ma) alkaline complex that intrudes sedimentary rocks of the Roraima Group (Soares, 1985). The plutonic rocks, which include syenite, quartz syenite, nepheline syenite, granite, and alaskite, are deeply weathered. Uranium ranges in concentration from <1 to 165 ppm. Uranium-bearing minerals have not been observed, and it is assumed that the uranium is associated with refractory minerals such as zircon or monazite. Other elements such as Sn, La, Y, As, Pb, Zn, W, Zr, Ti, Rb, and Nb are enriched in eluvial and alluvial material (Soares, 1985). Two other uranium occurrences on Plate 1 are located from airborne radiometric anomalies possibly related to Parguazan granitic rocks.

Radiometric anomalies related to gneiss of the Imataca Complex and conglomerate of the Roraima Group have been detected during reconnaissance surveys (Pasquali, 1981). For example, Dougan (1975) observed samarskite in pegmatitic phases of granitic migmatite within the Imataca Complex. Wyant and others (1953) analyzed samarskite in pegmatitic veinlets that cut rocks of the Imataca Complex and measured 230 ppm equivalent uranium. Chip samples of granitic gneiss contained 50 ppm equivalent uranium. Although these occurrences are of scientific interest, they have not led to the discovery of any uranium prospects. However, if the Imataca Complex was slightly enriched in uranium, its rocks may have served as a source to deposits in younger sedimentary rocks within the Orinoco Basin or in small intracratonic basins on the Guiana Shield (Audemard, 1977).

Radiometric anomalies have been measured in rocks of the Roraima Group on the south end of the Gran Sabana between Santa Elena de Uairen and Icabaru (no. 139). Sedimentary rocks of the Roraima Group were deposited uncomformably in the eastern part of the Venezuelan Guiana Shield on Early Proterozoic greenstone belt and related granitic rocks, on foliated Early Proterozoic metasedimentary rocks of the Cinaruco and Los Caribes Formations, and on felsic volcanic and plutonic rocks of the Cuchivero Group. The Roraima Group in the western part of Bolívar State and in the Amazon Federal Territory was deposited unconformably on Parguaza granite and on granitic gneiss, foliated granite, and metasedimentary rocks of undetermined, but probable Early Proterozoic, age (Ghosh, 1985). The apparent similarity of the basal conglomerate of the Roraima Group to the gold-uranium bearing conglomerates of the Witwatersrand, South Africa, Jacobina, Brazil, and Blind River, Canada, and the reported occurrence of authigenic pyrite (Gallagher, 1976; Bellizzia and others, 1981) have led to the proposal that the basal conglomerate of the Roraima Group is a viable exploration target for gold and uranium deposits as well as a possible source for younger alluvial deposits (Mendoza, 1985). Similarly, Ghosh (1985), based on sedimentological studies of pre-Roraima metasedimentary rocks such as the Los Caribes and Cinaruco Formations, indicated that these rocks are lithologically identical to those of the Roraima Group and that they represent the same environment of deposition. Thus, these are a viable target for gold and uranium, too. Recent field work (Dohrenwend, 1989, personal and written communications) identified gold and diamond paleo-placers associated with the lower part of the Roraima Group. However, the uranium potential has not been evaluated systematically.

MOLYBDENUM

Molybdenum is rarely reported as a trace metal in any descriptions of mineral occurrences or deposits in the Venezuelan Guiana Shield. It is uncommonly present in occurrences of tin associated with the Parguaza pegmatites, and it is a trace metal associated with vanadium, gallium, and tin at Cerro Impacto (Bellizzia and others, 1981). The occurrences on the accompanying map are taken from the metallogenic maps of Venezuela (Rodriguez and others, 1976; Bellizzia and others, 1980). These are identified as small isolated occurrences in veins that cut Middle Proterozoic felsic granitic rocks. Mendoza and others (1977) reported that molybdenite is a relatively common mineral in contact zones between felsic volcanic rocks and biotite granites of the Cuchivero Group. Field evidence indicates that shallow porphyritic granitic intrusions into volcanic rocks of the Caicara Formation in western Bolívar State and the Amazon Federal Territory are favorable for porphyry copper-molybdenum-type deposits.

TITANIUM

Ilmenite and rutile are reportedly abundant in heavy mineral concentrates from numerous rivers in the Guiana Shield. However, titanium has not been produced anywhere. Rio Nichare (no. 68) is an alluvial prospect that contains abundant ilmenite. Creeks that drain into the Marwani River (no. 28) contain high concentrations of rutile (Sherman Marsh, personal communication, 27 April 1988). Exploration is continuing in other areas for mineable deposits of titanium (Charles Connolly, personal communication, 4 January 1989).

PLATINUM

Occurrences of platinum group elements (PGE) are not well documented in Venezuela. Rodriguez (1987) reported that a newly discovered alluvial gold province in the area of the Guapuchi River (see PGE symbol on Plate 1) in central Amazon Federal Territory contained high values of palladium. Other alluvial gold and diamond deposits in the eastern and northern parts of the Venezuelan Guiana Shield are said to contain high values of PGE (Connolly, personal communication, 4 January 1989). The recent discovery by TECMIN and the USGS of cumulate mafic-ultramafic rocks in the Píston de Uroy area indicates that the occurrence of PGE possibly associated with deposits of nickel-copper sulfides in these and similar rocks elsewhere in the Guiana Shield is possible.

OTHER METALS

Occurrences of metals such as tungsten or chromium are associated with deposits or occurrences of other metals. For example, the tungsten ore mineral scheelite has been identified in trace amounts within gold-quartz veins in the El Callao and Botanamo districts, and minor geochemical anomalies of tungsten have been detected in the occurrences of tin-niobium-tantalum in the Parguaza granites (Korol, 1961; Bellizzia and others, 1981).

Trace amounts of chromium (to 0.5 wt percent Cr_2O_3) occur in mafic and ultramafic rocks of the Imataca Complex and in the greenstone belts. Minor amounts of chromite have also been discovered by TECMIN in alluvium within the area of outcrop of the Imataca Complex. The cumulate mafic-ultramafic rocks at Píston de Uroy are also permissive for chromite.

SUMMARY

The Guiana Shield of Venezuela is a poorly explored, apparently metal-rich area. The map (Plate 1) accompanying this text is the most up-to-date compilation of mineral occurrences in Venezuela. Descriptions of the occurrences in this text may provoke new thinking in mineral exploration of the Guiana Shield. For example, gold associated with banded iron formation might be present within the Imataca Complex in areas of carbonate $\pm$ sulfide facies rocks such as in the Upata-El Palmar-Guacuripia area and near Cerro Bolívar, or in ferruginous chert and other exhalative rocks associated with greenstone belt rocks such as at Marwani, San Cristobal, La Esperanza, and Cerro La Pinto. Epithermal vein deposits of precious metals may be present in felsic to intermediate volcanic rocks of the Cuchivero Group in the upper Caura River area, and Olympic Dam-type Fe-Cu-U-Au-REE deposits may be associated with the granite-rhyolite terrane of the upper Paragua River area. Cumulate mafic and ultramafic rocks in the Píston de Uroy area are permissive for nickel-copper sulfide, platinum group element, and (or) chromium deposits. Diamonds and rare metals may be related to other kimberlites and carbonatites that intrude the Cuchivero Group in the western part of the shield. TECMIN and the U.S. Geological Survey are continuing joint efforts in exploration and evaluation of new mineral deposits in the Venezuelan Guiana Shield.

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Table 1. Principal mining districts, mines, and mineral occurrences in the Guiana Shield, Venezuela

1 Wausa (Au, Al)
2 La Linea (Fe)
3 San Juan de Macuro (Fe)
4 Rio Acure (Al)
5 Rio Aroi (Al)
6 Manoa or Cerro Yaguasimoina (Fe)
7 Piacoa or Catalino (Fe)
8 Morocota (Fe)
9 Caruachi (diamonds)
10 Las Grullas (Fe)
11 El Palmar (Al, Mn)
12 Guacuripia (Mn)
13 La Planada (Au)
14 El Manganeso (Mn)
15 Upata (Al, Mn)
16 El Pao (Fe, Mn)
17 Playa Blanca (diamonds)
18 Rio Claro (diamonds)
19 Cerro Maria Luisa (Fe)
20 El Merey (diamonds)
21 Potosi (Au)
22 Nuria (Al)
23 San Cristobal (Mn)
24 Bochinche (Au)
25 Vuelvan Caras (Au)
26 Marwani I (Au)
27 Marwani IV (Au)
28 Rio Marwani (Au)
29 Agua Negra (diamonds, Au)
30 Macapa (Au, diamonds)
31 Marwani-Los Caribes (Au)
32 San Antonio (Au)
33 Botanamo (Au)
34 Carmen Rosa (Au)
35 Carmen Rosa (diamonds)
36 Sua-Sua (Au)
37 El Callao (Au)
38 Lo Increible (Au)
39 Cicapra (Au)
40 Mandingal (Au)
41 Paviche (diamonds)
42 La Estrella (Fe)
43 Cerro Azul (Au)
44 El Grillero (Au)
45 Cerro Arimagua (Fe)
46 Cerro Toribio (Fe)
47 Cerro Redondo (Fe)
48 Ciudad Piar (diamonds)
49 Cerro Altamira (Fe)
50 Cerro Frontera (Fe)
51 San Isidro (Fe)
52 Cerro Bolivar (Fe)
53 Los Barrancos (Fe)
54 Rio Aro (diamonds)
55 Real Corona (Fe)
56 La Esperanza (Mn)
57 Rio Aro (diamonds)
58 Cerro La Pinto (Au)
59 El Trueno (Fe)
60 Cerro Etuna (Fe)
61 Sipao (Au)
62 Guaniamo (diamonds)
63 Caño Aguamena (Sn, Nb, Ta)
64 Los Pijiguaos (Al)
65 Rio Suapure (diamonds)
66 Quebrada Grande (diamonds)
67 Cerro Impacto (Nb, Th, REE, Ba)
68 Rio Nichare (Ti)
69 Veri (diamonds)
70 Dori (diamonds)
71 Manaima or Los Picachos (Au)
72 Enei (diamonds)
73 El Casabe (diamonds, Au)
74 El Pao de La Fortuna (diamonds)
75 La Libertad (diamonds)
76 Asa (diamonds)
77 Leoncio or Felipe (diamonds)

78 Campo Grande (diamonds)
79 Los Guaicas (Al, Ti)
80 Caroni (diamonds)
81 San Salvador de Paúl (diamonds)
82 San Pedro de Las Bocas (diamonds)
83 Guariche (Au)
84 Parapapoy (Au)
85 La Estrella (Au)
86 Guatuaima (Au)
87 Guaito (Au)
88 Payapal (Au)
89 El Placer (Au)
90 La Lombriz (Au)
91 La Camorra (Au)
92 Canaima (Au)
93 La Lira (Au)
94 Aponao (Au)
95 El Foco (Au)
96 Chivao (Au)
97 Chicanan (diamonds)
98 Piston de Uroy (Au)
99 Km 88-Las Claritas (Au)
100 Cristina-Bizkaitarra (Au)
101 Venamo (Au)
102 Salto Araguai (Au)
103 San Juan (diamonds)
104 El Pauji (Au)
105 Gran Sabana (Al)
106 Gran Sabana (Al)
107 Gran Sabana (Al)
108 Larinal (diamonds, Au)
109 Kamarata (diamonds, Au)
110 Barrialon (diamonds)
111 Chiguao (diamonds, Au)
112 Kamu (diamonds, Au)
113 Karum (diamonds, Au)
114 Caura (diamonds)
115 La Paragua (diamonds)
116 Pao (Au)
117 Parupa (diamonds, Au)
118 Guacharo (diamonds)
119 La Sabanita (diamonds)
120 Avequi (diamonds)
121 Guacharaquito (diamonds)
122 Capaura (diamonds)
123 Los Frijoles (diamonds)
124 Yiguiripin (diamonds)
125 Conoroto (diamonds, Au)
126 Gran Sabana (diamonds)
127 Gran Sabana (diamonds)
128 Gran Sabana (diamonds)
129 El Loco (diamonds)
130 Flora Blanca (diamonds)
131 Divina Pastora (Al)
132 Santa Elena de Uairen (diamonds)
133 La Peña (diamonds, Au)
134 Chiricayen (Au)
135 La Faisca (diamonds, Au)
136 El Polaco (diamonds, Au)
137 La Hollada or Surukun (diamonds, Au)
138 Cinco Ranchos (diamonds, Au)
139 Icabaru (Au, diamonds)
140 Uaiparu (diamonds, Au)
141 Los Caribes (diamonds)
142 La Bandera (diamonds, Au)
143 Hacha (diamonds, Au)
144 San Luis (diamonds, Au)
145 Uonan (diamonds, Au)
146 Pereden (diamonds)
147 Pumpiri (Au)
148 Maijia (diamonds)
149 Alto Paragua (Sn)
150 Paramichi (diamonds)
151 Merevari (Au, Ag)
152 Churuata (U, Th, REE)