

## GEOLOGIC MAP OF THE VENEZUELA PART OF THE PUERTO AYACUCHO 2°x3° QUADRANGLE, AMAZONAS FEDERAL TERRITORY, VENEZUELA

By

Jeffrey C. Wynn,<sup>1</sup> Steven D. Olmore,<sup>2</sup> Vicente Mendoza,<sup>3</sup> Andrés García,<sup>4</sup>  
Inés Rendón,<sup>5</sup> Yasmin Estanga,<sup>5</sup> Haydée Rincón,<sup>5</sup> Félix Martínez,<sup>5</sup> Elis Lugo,<sup>5</sup>  
Nelson Rivero,<sup>5</sup> and Paul Schruben<sup>6</sup>

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<sup>1</sup>U.S. Geological Survey, Saudi Arabian Mission, Unit 62101, APO AE 09811-2101.  
<sup>2</sup>434 Flora Way, Golden, CO 80401.

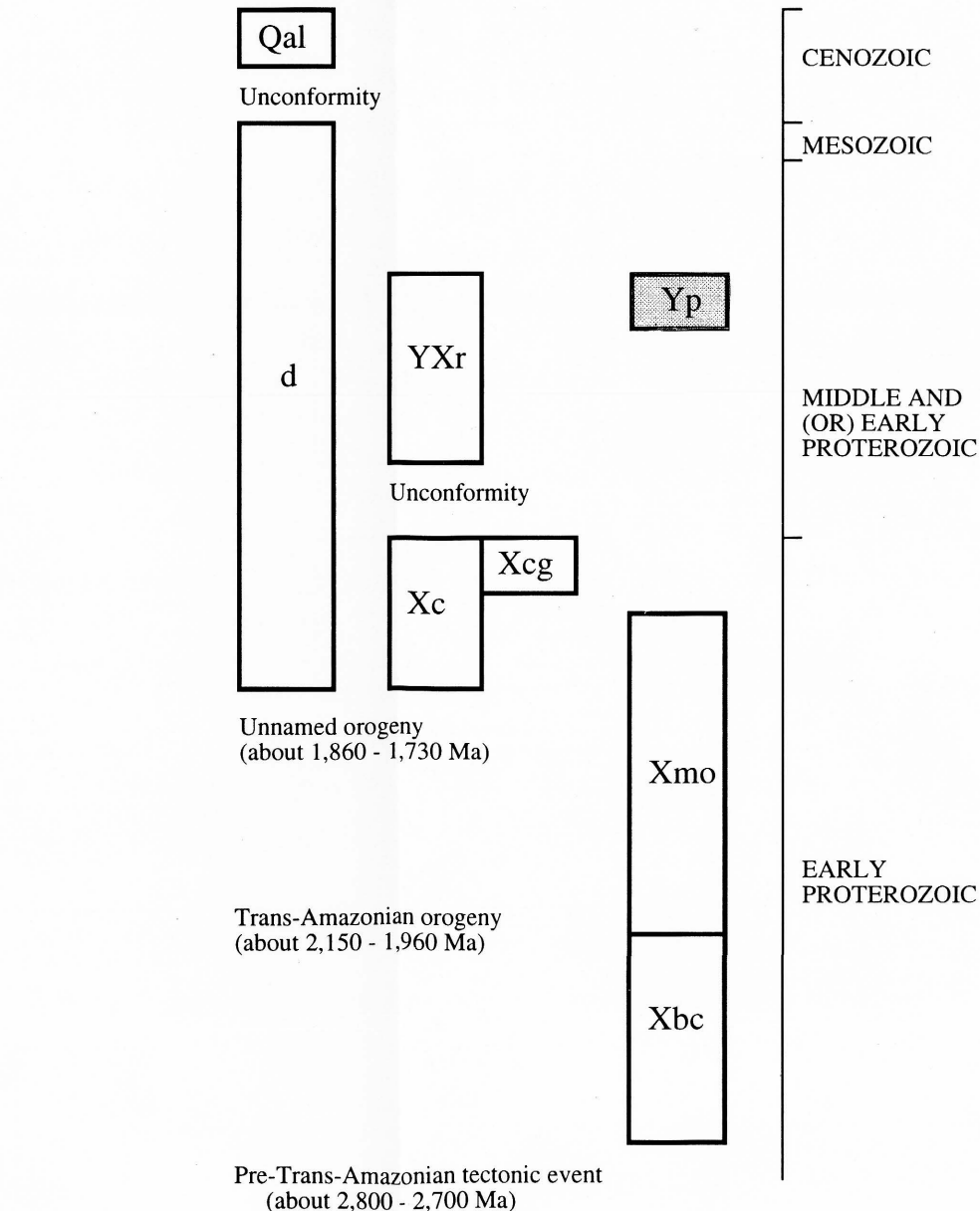
<sup>3</sup>Corporación Venezolana de Guayana, Técnica Minera, C.A., c/c Chillem, Piso 2, Puerto Ordaz, Venezuela.

<sup>4</sup>Department of Geology, Colorado School of Mines, Golden, CO 80401.

<sup>5</sup>Corporación Venezolana de Guayana, Técnica Minera, SEDE CVG, Calle Guerrero, Cd. Bolívar, Venezuela.

<sup>6</sup>U.S. Geological Survey, 920 National Center, Reston, VA 22092.

### Correlation of Map Units



### DESCRIPTION OF MAP UNITS

- Qal** Alluvium, colluvium, and river terrace deposits (Quaternary)
- d** Mafic dikes, undivided (Mesozoic to Middle Proterozoic)—Dark gray to greenish-gray, fine- to coarse-grained, tholeiitic. Occur as dikes, sills, and laccoliths. At least two generations of diabase dikes are mapped close to each other along the middle Rio Caroni in the Santa Elena quadrangle, south of San Salvador de Paila (about 5°30' N, 63°00' W). One is clearly folded by a regional metamorphic event, the other is not. On the basis of isotopic dating throughout the Guayana Shield, these dikes include rocks from about 1,743 to 1,422 Ma, as well as rocks dated at about 200 Ma (Teggin and others, 1985). Large areas in the Santa Elena quadrangle also have been mapped as sill-like bodies, some of the smaller of which have been subsequently identified as diorites. These rocks are characterized by strong, high-frequency, generally northeast-trending (in the Guri, Rio Mavaca, Santa Elena, and Puerto Ayacucho quadrangles) or northwest-trending (in the Atabapo, Santa Elena, and Piedra de Cocuy quadrangles) linear magnetic anomalies; rarely are they visible on the Side-Looking Airborne Radar (SLAR) imagery.
- Yp** Roraima Group (Middle and Early Proterozoic)—Platform sediments, often broadly folded on a 3- to 5-km wavelength scale, especially in the Gran Sabana region of southeastern Bolívar State. They are composed of quartz arenite, arkose, silty arenite, conglomeratic arenite, conglomerate, siltstone, and shale; crossbedded, laminated, or massive. Thickness locally may reach as much as 3,000 m. On the basis of isotopic dating in the Guayana Shield, some strata are at least 1,650 Ma, but the possible age of the entire group ranges from 1,900 to 1,545 Ma (Siddler and Mendoza, 1991). In the Santa Elena and northeastern Caura quadrangles, these rocks have been divided regionally by Yáñez (1985) into the Ayantepuy, Guaiquinima, and Canaima Formations. These rocks have no magnetic mineral content and are effectively transparent to the aeromagnetic data.
- Yp** Parguaza Granite (Middle Proterozoic)—Sodic granite to quartz monzonite, sometimes with Rapakivi texture, forming the large Parguaza batholith east of Puerto Ayacucho. Pegmatites found in the Parguaza contain tin, tantalum, nickel, and titanium; xenoliths that resemble Cuchivero volcanic and granitic rocks also have been observed (Gaudette and others, 1978). These rocks have been dated at about 1,545 Ma (Zir, 1978). These batholith-forming rocks are characterized by intermediate-frequency, low-amplitude magnetic anomalies without preferred trend. Internal to the batholith, several large, buried, generally east-west-trending bodies with negative magnetic polarization have been observed; modeling profiles over them typically give 1- to 5-km depths. In addition, narrow, mafic, dike-like bodies form radial stringer patterns around a deep, dense body seen only in gravity data that may be the batholith feeder or a later intrusion postdating the emplacement of the batholith (Wynn and others, in press).
- Xc** Cuchivero Group (Early Proterozoic)—Volcanic rocks consist of rhyolite ash-flow tuff, some crystal- and lithic-rich, rhyolite porphyry; andesite and basalt lavas, commonly hydrothermally altered; rhyolite granophyre; local mylonite. Vitroclastic and eutaxitic textures are well preserved; the rocks are only slightly metamorphosed. Dates range from 2,000 to 1,736 Ma (Rb/Sr age; Gaudette and others, 1978; Gaudette and Olaszewski, 1981, 1985). Steeply dipping flow banding is frequently seen. Several circular structures that are 5 to 10 km in diameter can be identified in the SLAR imagery (possible calderas?). These rocks are characterized by very strong, high-amplitude, and high-frequency magnetic anomalies without preferred trend.
- Xcg** Calc-alkaline to alkaline granitic rocks (Early Proterozoic)—These rocks crop out over a large area in the northwestern Guayana Shield and are spatially associated with the Parguaza batholith. They are predominantly silic igneous rocks and include the Santa Rosalia granite, which has a Rb/Sr age of 1,875 Ma (Hurley and others, 1977). Locally these rocks include hypabyssal porphyries with a microplitic groundmass. These rocks exhibit weak to moderate magnetic anomalies without preferred trend.
- Xmo** Moriche Formation (Early Proterozoic)—Characterized at its type locality (Cerro Moriche on the middle Rio Ventuari, 4°40' N, 66°25' W.) as metasedimentary conglomerates, possible remnants of an ancestral greenstone belt terrane eroded from the protolith (Ghosh, 1985). These rocks are highly magnetic and frequently follow major structural lows along the middle and upper Rio Orinoco and Rio Mavaca. They generally form long, linear bodies, that are sometimes folded by regional metamorphic events, and are usually visible in the SLAR imagery.

- Xbc** Basement complex (Early Proterozoic)—Well-foliated granite to granodiorite gneiss. Haydée Rincón described these rocks as migmatites on the lower Rio Pasimoni (1°40' N, 66°35' W.). On the middle Rio Negro (1°30' N, 66°55' W.), they are well-foliated, chloritized, quartz-rich, biotite-granite gneisses, and one description (Marciano and others, 1991) includes a "monzodiorite." These rocks are moderately magnetic without significant directional trends in the anomalies.
- EXPLANATION OF MAP SYMBOLS**
- Contact—Approximately located; dashed where inferred primarily from magnetic data
- Buried intrusive body inferred from magnetic data
- Fault—Linear feature visible in Side-Looking Airborne Radar; presumed to be a high-angle fault; dashed where inferred
- Fault—Presumed to be a transverse fault; arrows show relative movement
- Graben-bounding fault—Ticks point toward graben; dashed where inferred
- Major deep-penetrating shear zone inferred from geologic mapping and radar imagery
- Syncline
- Positively polarized, buried, linear magnetic source, presumed to be a mafic dike; where known, depth-to-top is shown in kilometers; s indicates depth-to-top is less than 1 km
- Negatively polarized, buried magnetic source, presumed to be a mafic body; where known, depth-to-top is shown in kilometers; s indicates depth-to-top is less than 1 km
- Deeply buried (4-8 km), dense body mapped from gravity data
- Circular feature of unknown origin visible in Side-Looking Airborne Radar—In some cases may represent a volcanic caldera
- Axis of strong, pervasive magnetic gradient—May represent major hidden fault that is, in some cases, dike filled

### INTRODUCTION

This map is one of a series of 1:500,000-scale maps that, along with several other products, stems from a cooperative agreement between the U.S. Geological Survey (USGS) and the Corporación Venezolana de Guayana, Técnica Minera, C.A. (TECMIN), a Venezuelan Government-owned mining and mineral exploration company. The agreement covered cooperative work carried out in the Precambrian Shield of southern Venezuela during 1987-1991 and included a geologic and mineral resource inventory, technology transfer, and scientific training (Wynn and others, in press). The Precambrian Guayana Shield (Escudo de Guayana, not to be confused with the neighboring country of Guyana) includes some of the oldest known rocks in the world (Mendoza, 1977) and also covers parts of neighboring Guyana, Surinam, French Guiana, Colombia, and Brazil. In Venezuela, it underlies most of Bolívar State and all of the Amazonas Federal Territory (see index map).

### INFORMATION AVAILABLE AND UTILIZED DURING MAP ASSEMBLY

An accurate geologic map is a key element in conducting a mineral resource appraisal. However, tectonic and geologic maps that had been published in Venezuela (Bellizgia and others, 1976; Pimentel de Bellizgia, 1984) did not utilize geophysical information during their compilation and therefore lack information on the critical third or buried dimension. From 1959 to 1972, the Venezuelan Ministry of Energy and Mines (MEM) contracted for a series of aeromagnetic (and later also radiometric) surveys of Venezuela that ultimately covered 75 percent of the Venezuelan Guayana Shield, including all but a tiny fraction of this quadrangle. Other organizations and institutions, among them the InterAmerican Geodetic Survey and Simon Bolívar University, have carried out gravity surveys within Venezuela (Perarnau and Graterol, 1981; Graterol, 1988). There are enough gravity stations within the quadrangle to permit the modeling of some important features. As part of its incorporating charter, TECMIN initiated in 1985 a reconnaissance geologic, hydrologic, soils, and vegetation inventory of the Amacuro Delta Federal Territory, Bolívar State, and the Amazonas Federal Territory. The new geologic information derived from the first 6 years of this 7-year program was made available to us during the compilation of this map.

Our access to the aeromagnetic data in this quadrangle was limited to computer-contoured maps; the data were not available in digital form. The aeroradiometric data were available only in interpreted form, that is, boundaries of anomalies only; the original data were not available. We began the compilation with the geologic map published by Bellizgia and others (1976). We then incorporated 1:250,000-scale Side-Looking Airborne Radar (SLAR) sheets. Gravity data were available for most of the quadrangle. These data were contoured and two zones of anomalous Bouguer gravity highs were modeled. The anomalous zones appear to be caused by deeply buried, dense bodies that, in one case, may represent the feeder or magma conduits for the Parguaza batholith. The authors also have carried out reconnaissance field mapping elsewhere in the Amazonas Federal Territory, which proved invaluable in augmenting the existing maps and integrating the geophysical information with the SLAR and geology.

### METHODOLOGY OF THE MAP ASSEMBLY

This map represents a new kind of geologic interpretation of the Venezuelan Guayana Shield. It incorporates all previously published information and also utilizes the latest geologic data obtained by the inventory mapping project (Grupo Inventario) of TECMIN and all aeromagnetic and radiometric data, made available through the MEM. Geophysical information, where available, is incorporated into this map to provide information on buried features not visible in the surficial geology. Geologic boundaries are shown in areas of little or no outcrop by using geophysical signatures (these include primarily texture; preferred strike, if any; amplitude; and spatial frequency observed in the magnetic, gravity, and SLAR data) to guide the lithologic separation.

Because the distribution of mineral resources can be controlled by geologic features, such as deep faults, shear zones (single and intersecting), volcanic calderas, and intrusive bodies, the geophysical interpretive information was incorporated to make a quasi-three-dimensional representation of the geology and structure, that is a two-dimensional geologic map with elements of the third or buried dimension added that were gleaned from the geophysical data. Our intent is to present all information available, representative as much as possible of the entire upper 10 to 15 kilometers of the crust, not just the surface as in conventional geologic maps. Thin-plate tectonics and Tertiary uplift related to the Caribbean and Andean orogenies were used in interpreting the geophysical and SLAR information in producing this map.

Many granite bodies and most intermediate to mafic volcanic and intrusive bodies have sufficient magnetic susceptibility contrast with the surrounding rocks to produce substantial variations in the magnetic field measured above the surface. These variations are readily apparent in the aeromagnetic data of this quadrangle. Outlines for these discrete bodies are shown on the map as either dashed lines (for partially buried, larger plutons) or a line pattern (for smaller, discrete bodies). Magnetic polarization of the source bodies can be discerned in the shape of the magnetic anomaly, and this can help to separate adjacent bodies that must therefore represent separate events. In many cases, the magnetic data are of sufficient quality to permit depth-to-source calculations using the method of Vacquier and others (1951). The results are shown on the map with

numbers indicating approximate depth-to-top in kilometers where available. Several discrete features observed in the gravity data were modeled and also are incorporated in this map with approximate depth-to-top indicated in the cross section.

About 90 percent of the mapped region is heavily vegetated, and there is only one road, barely extending into the northwestern corner of the quadrangle. Away from the navigable rivers, extensive regions are accessible only by helicopter. Contrary to popular belief, there are significant outcrops inland from the rivers, because the region is largely in a state of on-going erosion, but they are not easily accessible due to the dense jungle cover. In these regions geophysical information, along with geomorphologic interpretations derived from SLAR imagery, black-and-white photos, and LANDSAT images, are generally the only accessible sources of information about the underlying rocks.

In Venezuela, the inclination of the Earth's field is about 35° to 40° from the horizontal, and the declination ranges from -11° to -22° (west from true north (part of this latter variation represents secular change over the past 30 years). The shallow inclination makes it difficult to interpret magnetic data directly, especially where there are closely spaced multiple sources. Because almost none of the magnetic data in Venezuela were available to us in digital form (the one exception is a 1:500,000-scale sheet of the Bochinche area in northeastern Bolívar State, which was manually digitized for experimental purposes (Wynn and others, 1989)), we could not carry out standard reduction-to-the-pole and horizontal-gradient conversions on the data. In this quadrangle, we only had access to contour maps at scales of 1:500,000, 1:100,000, and 1:200,000. This required anomaly-by-anomaly analysis to obtain geologic contacts and body outlines. These analyses are supported by a number of computer-calculated models, both experimental forward-models as well as least-squares 2-D and 2 1/2-D model fits along profiles of data digitized along flightlines from the magnetic contour maps. Interpreted boundaries and contacts were digitized using GSMAP program version 6.03 (Selner and Taylor, 1989) and compiled at a scale of 1:500,000 for incorporation in the Puerto Ayacucho map.

Compilation began with the digitization of principle and some subsidiary drainages from planimetric maps; structural features were then digitized from SLAR sheets. Owing to poor geodetic registration of the mosaicked SLAR images, local areas of the SLAR imagery had to be registered to the drainages before the structural information was digitized. Aeromagnetic data were analyzed on a sheet-by-sheet basis, and magnetic terrane boundaries and outlines of discrete sources were digitized using modeling information as a guide. These results were then compiled in the form of an interpreted geologic map, that is, a map outlining discrete, SLAR- and geophysically-defined domains often not yet identified with a particular geologic unit (Cordell and Grauch, 1985; Cordell and McCafferty, 1989; Wynn and others, 1989). This map was then compared with available published and unpublished geologic data and recent field mapping by the authors working in the quadrangle to assign geologic units and assemble the correlation chart. Due to the coarse spacing of the gravity data (2.5 km typically), only deep sources could be identified and modeled. To assure consistency, boundaries were compared with neighboring maps that were being compiled simultaneously.

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