

GEOLOGIC MAP OF THE VENEZUELA PART OF THE PUERTO AYACUCHO 2°×3° QUADRANGLE, AMAZONAS FEDERAL TERRITORY, VENEZUELA

By

Jeffrey C. Wynn,¹ Steven D. Olmore,² Vicente Mendoza,³ Andrés García,⁴ Inés Rendón,⁵ Yasmin Estanga,⁵ Haydée Rincón,⁵ Félix Martínez,⁵ Elis Lugo,⁵ Nelson Rivero,⁵ and Paul Schruben⁶

1994

AUTHOR AFFILIATIONS

¹U.S. Geological Survey Saudi Arabian Mission, Unit 62101, APO AE 09811-2101.

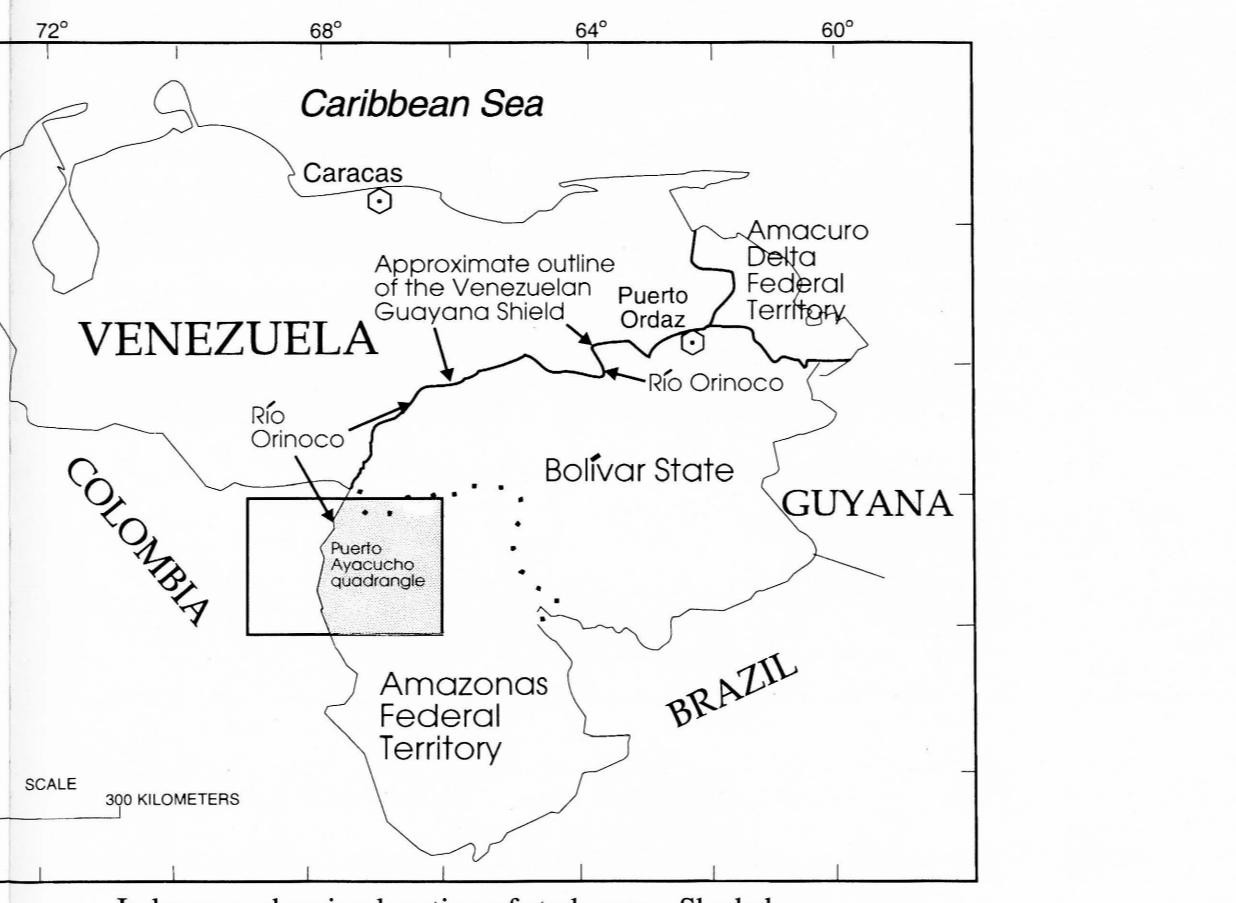
²434 Flora Way, Golden, CO 80401.

³Corporación Venezolana de Guayana, Técnica Minera, C.A., c/o Chillexim, Piso 2, Puerto Ordaz, Venezuela.

⁴Department of Geology, Colorado School of Mines, Golden, CO 80401.

⁵Corporación Venezolana de Guayana, Técnica Minera, SEDDE CVG, Calle Guerrera, Cd. Bolívar, Venezuela.

⁶U.S. Geological Survey, 920 National Center, Reston, VA 22092.



Index map showing location of study area. Shaded area is area shown on geologic map

Correlation of Map Units

Qal	Unconformity	CENOZOIC
d	Yxr	MESOZOIC
	Unconformity	MIDDLE AND (OR) EARLY PROTEROZOIC
	Xc	
	Xcg	
	Unnamed orogeny (about 1,860 - 1,730 Ma)	
	Trans-Amazonian orogeny (about 2,150 - 1,960 Ma)	
	Xmo	EARLY PROTEROZOIC
	Xbc	

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
- Possibly polarized, buried, linear 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
- 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 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
- Axes 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 cooperation in the areas of the geologic mapping of parts of northern 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, Suriname, 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 (Bellizzi and others, 1976; Pimentel de Bellizzi, 1984) did not utilize geophysical information during their compilation and therefore lack information on the critical third or buried dimension. From 1959 to 1976, the Venezuelan Ministry of Energy and Mines (MEM) compiled a series of aeromagnetic maps and later also radiometric maps 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 American Geodetic Survey and Simon Bolívar University, have carried out gravity surveys within Venezuela (Peramau 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 survey of the Amazonas 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 format. 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 Bellizzi and others (1976). We then incorporated a 1:250,000-scale Side-Looking Airborne Radar (SLAR) sheet. Gravity data were also available for this 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, as well as new data obtained from the ongoing aeromagnetic and radiometric 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 drawn 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 geophysical results can be controlled by geologic features such as deep faults, shear zones (parallel 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 techniques and tertiary uplift related to the Caribbean and Andean systems 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 them. 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 data can be used to infer the size and 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, and they are not easily accessible due to the dense jungle cover. In the region, 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 format, we used the 1:100,000-scale gravity data from the same areas in northeastern Bolivia, 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 1:50,000, 1:100,000, and 1:200,000. This required a time-consuming analysis to obtain geologic contacts and body outlines. These analyses are supported by a number of computer-calculated models, both experimental and field-based models as well as least-squares 2-D and 1/2-D model fits along profile lines. We also used the 1:100,000-scale gravity data to generate interpreted boundaries and contacts were digitized using GSMAP program version 6.03 (Selner and Taylor, 1989) and completed 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 terrain boundaries were drawn on each sheet so as to facilitate digitizing information as a guide. These results were then compiled in the form of an interpreted geology 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.

ACKNOWLEDGMENTS

The authors have been fortunate to have advice from senior Venezuelan geologists and geophysicists who have shared much information with us informally during the compilation stages of our effort. These include Galo Yáñez of TECMIN and the Universidad Oriente, Ciudad Bolívar; Alfredo Menéndez of Prominur, C.A., Caracas; and Victor Graterol of the Universidad de Simon Bolívar, Caracas.

REFERENCES CITED

- Bellizzi-G., Alirio, Pimentel-M., Nelly, and Bao-O., R., 1976, Mapa geológico estructural de Venezuela: Caracas, Ministerio de Minas e Hidrocarburos, Dirección Geológica, scale 1:500,000.
- Cordell, Lindreth, and Grauch, V.J.S., 1985, Mapping basement magnetization zones from aeromagnetic data in the San Juan basin, New Mexico: In Hinze, W.J., ed., The utility of regional gravity and magnetic anomalies in geology: Society of Exploration Geophysicists, Tulsa, Oklahoma, p. 181-197.
- Cordell, Lindreth, and McCafferty, A.E., 1989, A terracing operator for physical property mapping with potential field data: *Geophysics*, v. 54, p. 621-634.
- Gaudette, H.E., and Olszewski, W.J., 1981, Geochronology of the basement rocks, Amazonas Territory, Venezuela: I Simposium Amazonico, Puerto Ayacucho, Territorio Federal Amazonas, Venezuela.
- , 1985, Geochronology of the basement rocks, Amazonas Territory, Venezuela, and the tectonic evolution of the western Guayana Shield: *Geologie in Mijnbouw*, v. 64, p. 131-143.
- Gaudette, H.E., Mendoza, Vicente, Hurley, P.M., and Fairbairn, H.W., 1978, Geology and age of the Parguaza granite, Venezuela: *Geological Society of America Bulletin*, v. 89, p. 1335-1340.
- Ghosh, Santos, 1985, Geology of the Roraima Group and its implications: I Simposium Amazonico, Caracas, Publicación Especial 10, p. 31-50.
- Graterol, Victor, 1988, Mapa de anomalias de Bouguer de la Frontera entre el Territorio Federal Amazonas y el Territorio Federal Bolívar, Venezuela: Boletín de Geología, Publicación Especial 7, v. 4, p. 3035-3044.
- Hurley, P.M., Fairbairn, H.W., Gaudette, H.E., Mendoza, Vicente, Martín, Cecilia, and Espíago, Aníbal, 1977, Progress report on Rb-Sr age dating in the northern Guayana Shield, in *Memoria de la Segundo [II] Congreso Latinoamericano de Geología*, Caracas, November 11-16, 1973, Venezuela, Ministerio de Energía y Minas, Dirección de Geología, Boletín de Geología, Publicación Especial 7, v. 4, p. 3035-3044.
- Marcano, Iris, Lugo, Elis, and Rivero, Nelson, 1991, Geología y geomorfología de la frontera con Colombia, entre la Piedra de Cucuy y Maracatu, al noreste del Territorio Federal Amazonas, Venezuela: CVG-TECMIN, Guayaquil, Ecuador.
- Mendoza-S., Vicente, 1977, Evolución tectónica del Escudo de Guayana, in *Petzall, C., ed., Memoria de la Segundo [II] Congreso Latinoamericano de Geología*, Caracas, November 11-16, 1973; Venezuela, Ministerio de Energía y Minas, Dirección de Geología, Boletín de Geología, Publicación Especial 7, v. 3, p. 2237-2270.
- Peramau-M., A., and Graterol, Victor, 1981, Red Gravimétrica Amazonas: I Simposium Amazonico, Puerto Ayacucho, Venezuela, March 22-26, 1981, p. 1.
- Pimentel de Bellizzi, Nelly, 1984, Mapa geológico estructural de Venezuela: Caracas, Ministerio de Energía y Minas, Dirección de Geología, scale 1:2,500,000.
- Selner, G.L., and Taylor, R.B., 1989, GSMAP Version 6.03: U.S. Geological Survey Open-File Report 89-373B, 2 diskettes, 4 p. text.
- Sidder, G.B., and Mendoza-S., Vicente, 1991, Geology of the Venezuelan Guayana Shield and its relation to the entire Guayana Shield: U.S. Geological Survey Open-File Report 91-141, 59 p., 2 p. text.
- Teggan, D.E., Manzetti, M., and Palacios, G., 1985, Un estudio preliminar de la geología de la Piedra de Cucuy, en *Geología de la Piedra de Cucuy*, Rio Orinoco, Venezuela, ed. P. Gómez, C. Cárdenas, R. Ríos, F.-J.H. Pimentel de Bellizzi, Nelly, and Parlo, A.S., eds., Petrografia, geoquímica, y geocronología: VI Congreso Geológico Venezolano, Caracas, September 29-October 6, 1985, Memoria, v. 4, p. 2195-2206.
- Vacquier, V., Steenland, N.C., Henderson, R.G., and Zeiter, I., 1951, Interpretation of aeromagnetic maps: *Geological Society of America Memoir* 47, 151 p.
- Wynn, J.C., McCafferty, A.E., and Salazar, Edison, 1989, Geologic information derived from digital aeromagnetic data: *Proceedings Volume, Simposio Sudamericano de COGEODATA*, Caracas, April 20-23, 1989, 15 p.
- Wynn, J.C., Sidder, G.B., Gray, Floyd, Page, N.J., and Mendoza-Vicente, in press, The cooperative project between the U.S. Geological Survey and the Corporación Venezolana de Guayana, Técnica Minera, C.A., in the Venezuelan Guayana Shield, Estado Bolívar and Estado Amazonas, Venezuela, in *Ed. Sidder, G.B., García, Andres, Stoer, J.W., Page N.J., and Wynn, J.C., eds., The geology and mineral deposits of the Venezuelan Guayana Shield*: U.S. Geological Survey, in press.
- Yáñez, G., 1988, Geología y geomorfología del Grupo Roraima en el sureste de Venezuela, in *Espíago, Aníbal, Ríos, F.-J.H. Pimentel de Bellizzi, Nelly, and Parlo, A.S., eds., Petrografia, geoquímica, y geocronología: VI Congreso Geológico Venezolano*, Caracas, Ministerio de Energía y Minas, v. 2, p. 1243-1307.