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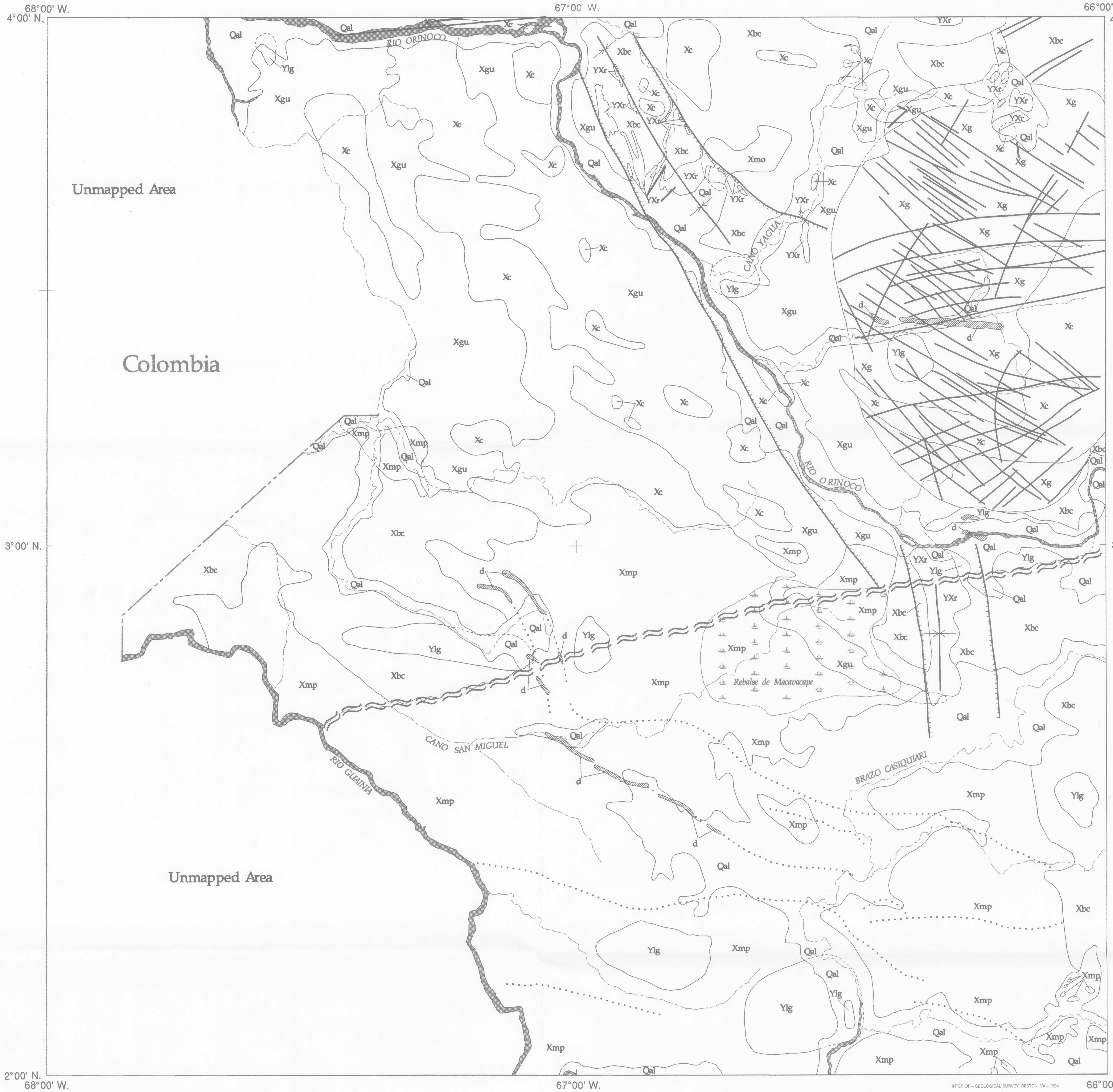

Base from C.V.G., Técnica Minera, C.A., Map no. NB 20–1, 1990
Equidistant Conic Projection based on standard parallels 4° N. and 9° N. and central meridian 66° W.

SCALE 1:500 000

10 0 10 20 30 40 50 MILES

10 0 10 20 30 40 50 60 70 KILOMETERS

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

By

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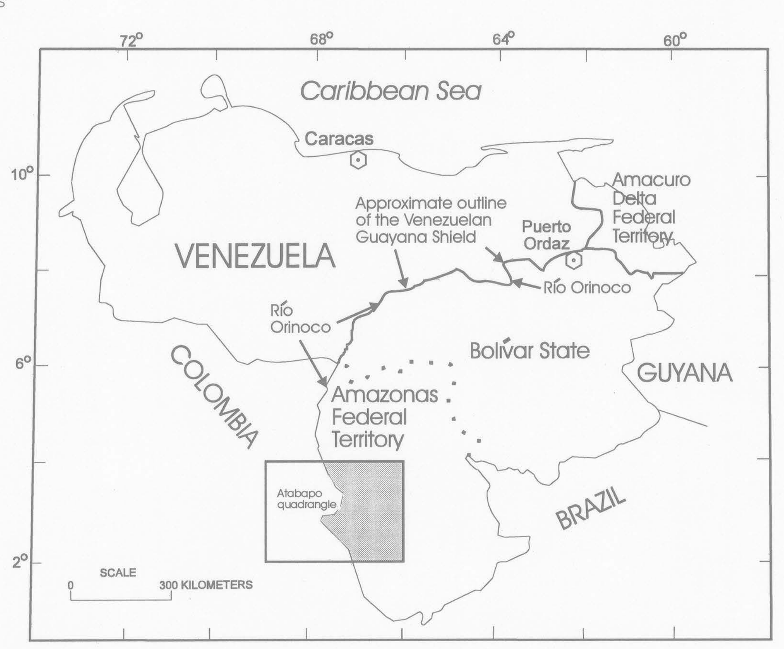
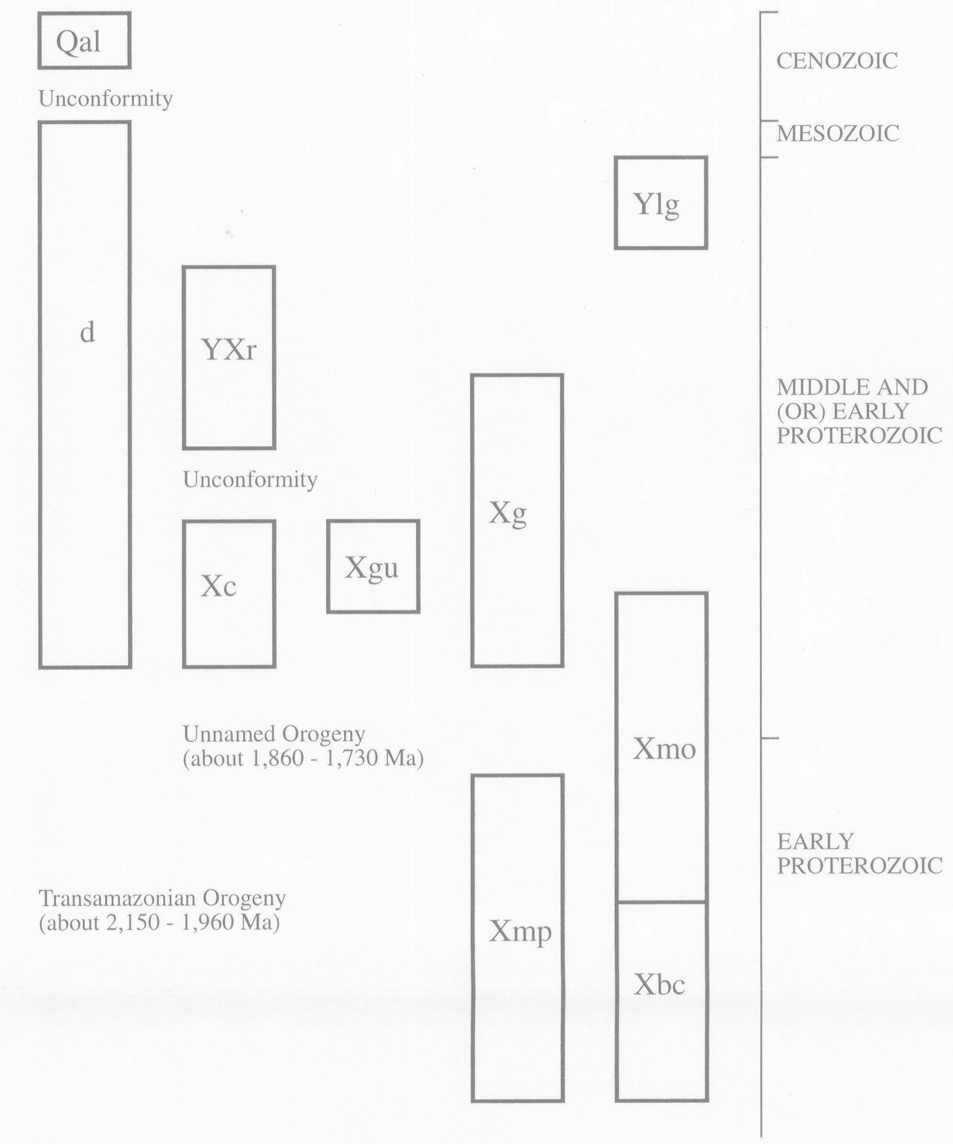


Index map showing location of study area. Shaded area is area shown on geologic map

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 Río Caroní in the Santa Elena quadrangle, south of San Salvador de Paúl (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, Río 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

Ylg Intrusive rocks typically penetrating through, and doming, Roraima sediments (Middle Proterozoic)--In Caño Yagua (3°25' N., 65°40' W.), one body was mapped as coarsely equigranular granodiorite with pronounced Rapakivi texture. In the southern part of the Río Negro (1°10' N., 66°50' W.), a similar body named the Piedra de Cocuy is described as a granodiorite with 20 percent biotite, 30 percent quartz, 40 percent feldspar, and 10 percent hornblende (Marcano and others, 1991). These rocks are characterized by small, subrounded, and generally strong magnetic anomalies and are often visible in SLAR imagery

YXr 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 Edo. Bolívar. They are composed of quartz arenite, arkose, silty arenite, conglomeratic arenite, conglomerate, siltstone, and shale; crossbedded, laminated, or massive. They weather to form high, flat-topped mesas called tepuis, and ledge and slope topography. 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 (Sidder and Mendoza, 1991). In the Santa Elena and northeastern Caura quadrangles, these rocks have been divided regionally by Yánez (1985) into the Auyantepuy, Guaiquinima, and Canaima Formations. These rocks have no magnetic mineral content and are effectively transparent to the aeromagnetic data

Xgu Intrusive rocks, undivided (Early Proterozoic)--Underlying water-inundated plains and jungle in the southeastern Amazonas Federal Territory. Where seen south and east of San Fernando de Atabapo (3°45' N., 67°40' W.), they are described as biotite hornblende granites and granite gneisses (Marcano and others, 1991). These rocks are weakly magnetic and have no apparent trend

Xg Calc-alkaline granite and other silicic plutonic rocks (Early Proterozoic)--Martínez (1991) described these rocks as massive, coarse-grained, gray, equigranular biotite granites with Rapakivi texture similar to the Parguaza batholith. These granites are seen west and north of Cerro Duida (4°00' N., 65°30' W.) in the Amazonas Federal Territory. These rocks are weakly to moderately magnetic, often with east-west to west-northwest trends in the magnetic anomalies. Pronounced west-northwest-striking lineaments in the SLAR imagery are characteristic, especially in this quadrangle

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, and granite. 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 Olszewski, 1981, 1985). Steeply dipping flow banding is frequently seen. Several 5- to 10-km diameter circular structures 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

Xmo Moriche Formation (Early Proterozoic)--Characterized at its type locality (Cerro Moriche on the middle Río 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 Río Orinoco and Río Mavaca. They generally form long, linear bodies sometimes folded by regional metamorphic events and are usually visible in the SLAR imagery

Xmp Intrusive rocks of the San Carlos metamorphic-plutonic terrane (Early Proterozoic)--Covering large parts of the southern Amazonas Federal Territory. These rocks are named for the type locality at San Carlos de Río Negro (1°50' N., 67°05' W.) and crop out along most of the Río Guainía and Río Negro. They are described as granite, granite-porphyry, granite-gneiss, and augen-gneiss with relatively abundant pegmatites (Marcano and others, 1991). These terranes are characterized by strong, sinuous, east-west- to N. 70° W.-trending, elongate magnetic anomalies stacked together

Xbc Basement complex (Early Proterozoic)--Well-foliated granite to granodiorite gneiss. Haydeé Rincón described these rocks as migmatites on the lower Río Pasimoni (1°40' N., 66°35' W.). On the middle Río Negro (1°30' N., 66°55' W.), they are well-foliated, chloritized, quartz-rich, biotite-granite gneisses), and one description (Marcano 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

Fault--Linear features visible in Side-Looking Airborne Radar; presumed to be high-angle faults

Graben-bounding fault--Ticks point toward graben

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

Axis of strong, pervasive magnetic gradient--May represent major hidden fault or suture

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, 1992). 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 (Bellizzia and others, 1976; Pimentel de Bellizzia, 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. 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). 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 magnetic data in the Atabapo quadrangle was limited to contoured maps; the data were not available in digital form. The aeroradiometric data were only available in interpreted form, that is, boundaries of anomalies only; the original data were not available. We began the compilation with the geology map published by Bellizzia and others (1976). We then incorporated 1:250,000-scale Side-Looking Airborne Radar (SLAR) sheets. The authors also have carried out reconnaissance field mapping in the Amazonas Federal Territory, which proved invaluable in augmenting the existing maps and integrating the geophysical information.

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 information 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 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 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 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 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).

About 90 percent of the mapped region is heavily vegetated and without roads. Away from the navigable rivers, extensive regions are accessible only by helicopter. Contrary to common 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 interpretation derived from SLAR imagery, black-and-white photos, and LANDSAT images when available, 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 1:50,000-scale sheet of the Bochinche area in northeastern Bolívar State, outside the boundaries of the Puerto Ayacucho quadrangle, which was manually digitized for experimental purposes), 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 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 actual data digitized 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 Atabapo map.

Compilation began with the digitization of principle 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 geology map, that is, a map outlining discrete, 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 table. To assure consistency, boundaries were compared with neighboring maps that were being compiled simultaneously.

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