Magnetic Map of Puerto Rico

By

Andrew Griscom and Nami E. Kitchen

INTRODUCTION

Detailed contoured aeromagnetic surveys are available for approximately half of the island of Puerto Rico; other less detailed magnetic data are listed in Hill (1986). The accompanying index map and table describe four individual detailed magnetic surveys and their flight specifications. The north coast survey (Briggs, 1961) is the only one that has been published, but copies of the other maps have been generously made available to us from the files of the Commonwealth of Puerto Rico and of the Kennecott Copper Company. The contoured magnetic data were digitized by the U.S. Geological Survey from maps at scales of 1:20,000 and 1:50,000. The data were in general digitized along flight lines and include both contour line values and local maxima and minima. Following digitizing the data were gridded, contoured by computer, and compared with the original maps, after which we corrected any observed errors and, where necessary in areas of relatively flat magnetic field, added enough additional digital data to reproduce the original contours. The final magnetic map of Puerto Rico was compiled by merging the various data sets, a process that involved interpolating the data to form a 0.2-km grid of data points and then arbitrarily adjusting datum levels and merging the contour lines between

adjacent maps with a series of computer programs. Because of the intricate detail on these maps flown at altitudes of 153 m (500 ft) above ground, it was necessary to smooth them mathematically before attempting to present the data at our publication scale of 1:200,000. The smoothing was done by continuing the data upwards (except for the north coast survey) a distance of 500 m. The result is a data display that approximately duplicates a magnetic survey flown at a height of 653 m above the ground surface.

INTERPRETATION

Magnetic minerals, where locally concentrated or depleted, may cause a high or low magnetic anomaly that can be a guide to mineral occurrences or deposits. The most important magnetic mineral is magnetite, although a few magnetic anomalies are caused

by ilmenite and pyrrhotite concentrations. The magnetic anomalies on the magnetic map of Puerto Rico are produced by magnetite-bearing volcanic rocks, plutonic igneous rocks, serpentinites, magnetite-bearing skarns, and, to a lesser extent by some sedimentary and volcaniclastic rocks that contain substantial amounts of volcanic debris. In general, the rock units including large amounts of massive mafic lava flows, predominantly basalt and andesite, produce the largest magnetic anomalies. Many of the volcanic units, because they chill rapidly from a melt, also possess a large remnant magnetization in addition to their induced magnetizations. The vector of this remnant magnetization may be in the normal or reversed direction and, where the rocks have been folded or tilted, may also be rotated into other directions. In those areas where the remnant vectors point upwards, strong magnetic lows may show on the magnetic map.

Kitchen and others (1991) reported magnetic susceptibilities of 71 rock samples that are older than mid-Tertiary and that were collected from the south half of the island. The volcanic, plutonic, and metamorphic rocks all have, as expected, moderately high average susceptibilities ranging from l to 2 x 10-3 emu/cm3, but, as is usually the case, the considerable scatter in the results precludes useful average values. The serpentinites of southwestern Puerto Rico have been studied by several investigators. Kitchen and others (1991) reported an average susceptibility of 1.5 x 10-3 emu/cm3 for six serpentinite samples. Griscom (1964) reported on 49 samples of serpentinite having an average susceptibility of about 2.64 x 10-3 emu/cm3 and average remnant magnetization of about 1.22 x 10-3 emu/cm3. Cox and others (1964) reported an average susceptibility of 1.1 x 10-3 emu/crn3 and average remnant magnetization of 0.5 x 10-3 emu/cm3 for 43 specimens from 15 samples of serpentinite core taken from the Mayaguez drill hole.

NORTH COAST MAGNETIC SURVEY

An interpretation of the north coast magnetic survey (Agocs, 1958) is available in a private report to A.D. Fraser; a copy of the report is on file at the Department of Natural Resources, Puerto Rico. The purpose of the survey was to investigate the structure of the north coast sedimentary basin and to obtain more information relating to its petroleum potential. The wording of the report suggests that an interpretive map may have accompanied the text but we have

not located a copy of this map. The interpretation identifies certain east- and northeast-trending faults, all down to the north; it finds basement depths at the shoreline of more than 1.52 km (5,000 ft) in the Manati area, more than 1.22 km (4,000 ft) near Cuecibo, and more than 0.92 km (3,000 ft) northwest of Quebradillas; and it describes certain broad structural features in general agreement with the earlier reflection seismograph survey. This latter survey was made in 1947 by United Geophysical Company for the Puerto Rico Industrial Development Company and is described by W.H. Myers in a report that is reportedly (Briggs, 1961, p. 11) on file at the Department of Natural Resources, Puerto Rico. This report has not been located by the writers and the full title is unknown to them.

CENTRAL PUERTO RICO SURVEY

The central Puerto Rico aeromagnetic map was interpreted in a series of private reports to A.D. Fraser by W.D. Bergey (Bergey, l957a, b, 1960, 1963). The "Central Concessions," or central map area lying approximately between long 66°12' W. and long 66°30' W. was interpreted by Bergey (1960), who pointed out that much ground work remained to be done before this extremely detailed and complicated map can be understood or even properly prospected. Bergey (1960, p. 8) emphasized "two conspicuous regional features:

l) strong magnetic highs in the central and north-central put of the area caused by basic volcanic rocks ; and

2) east-west to northwest linear trends of highs and lows related to zones of faulting and associated alteration.

The geological complexity is apparent in the magnetic pattern. Anomaly trends tend to be discontinuous except where they reflect the regional faulting. In a region underlain by volcanic rocks that have been subjected to intense deformation, infusion and hydrothermal alteration, complex anomaly patterns are to be expected. The interpretation of these patterns requires a considerable amount of geological control.

Bergey (1960) demonstrated that the plutons in this area (he described eight stocks) are for the most part weakly magnetic or nonmagnetic. Only the

Cuyon stock (lat 18°07' N., long 66°.15' W.) produces a magnetic anomaly. At least two plutons, the Cuyon and the Morovis stock (lat 18°20' N., long 66°19' W.) appear to display magnetic anomalies that are caused by older rocks outside the contacts and yet the anomalies extend across puts of the pluton. Bergey (1960) suggested that such features may be caused by trains of inclusions locally extending through the stocks. The larger magnetic anomalies thus appear all to be caused by volcanic rocks, the basalts of the Perchas Formation producing anomalies as large as 4500 nT at 153 m (500 ft) above the terrain. Bergey (1960) described several different types of mineralization that he
observed to be visible as anomalies on the magnetic map. Contact metamorphism adjacent to some plutons can cause magnetic highs due to increased amounts of magnetite in the metamorphosed rocks. Where limestone may be in contact with plutons, magnetite-bearing skarns can form; Bergey suggested skarn as a possible cause of magnetic highs on the south side of the Pinas stock (lat 18°12' N., long 66°14' W.) and the north side of the Coamo Arriba stock (lat 18°08' N., long 66°22' W.). Hydrothermal alteration can destroy magnetite, the iron ending up as non-magnetic pyrite and chalcopyrite; such alteration was described by Bergey (1960) as being associated with local magnetic lows at the north sides of the Cuyon stock (lat 18°07' N., long 66°15' W.) and of the Cedro Abajo stock (lat 18°17' N., long 66°17' W.). The Cuyon stock in this assessment is considered favorable for porphyry copper-molybdenum mineralization. Another major source of magnetic lows are the west- and northwest-trending altered zones associated with fault zones in the eastern half of the island. Bergey (1960) identified such an area north and northeast of the Cedro Abajo pluton for distances of at least 8 km, and in fact a pronounced magnetic low here is displayed.

East of long 66°12' W. the detailed aeromagnetic map of the central area was described by Bergey (1957a, b). He demonstrated that the plutonic rocks are considerably more magnetic than those of the "Central Concessions" area

discussed previously. The San Lorenzo batholith and associated plutons produce substantial anomalies. Large-amplitude, short-wavelength anomalies observed on the detailed aeromagnetic map near the contacts of these plutons are favorable for possible sources that may be copper-bearing iron skarn deposits. At least six such anomalies are near lat 18°11' N., long 65°50' W., and several others are observed on the north and southwest sides of the batholith. Bergey (1960) mentioned that promising areas of copper mineralization also can contain pyrrhotite (rather than magnetite) as a gangue mineral sufficiently abundant to produce magnetic anomalies. The extreme northeast corner of the magnetic survey covers the southwest quadrant of a Cretaceous or Tertiary pluton associated with the headwaters of streams containing placer gold. This pluton is very magnetic, producing an anomaly of more than 1,000 nT, and may have copper-bearing magnetite-rich skarns near its contacts. Local sharp magnetic anomalies observed adjacent to the pluton on the detailed aeromagnetic map may be caused by such skarns. Hydrothermal alteration is also present in this eastern area and may cause pronounced magnetic lows. A major linear low trends about N 80° W at latitude 18°15' N between long 65°45' W and long 66°00' W; this low is associated with a major alteration zone. The altered zone extends N. 75° W. across northeastern Puerto Rico and is associated with a corresponding zone of high aeroradioactivity (see map of MacKallor, 1965). The magnetic low and the high aeroradioactivity indicate the possibility that potassium has been introduced by the hydrothermal fluids.

UTUADO BATHOLITH SURVEY

The detailed aeromagnetic survey of the Utuado batholith area in west-central Puerto Rico was generously provided by the Kennecott Copper Company to the U.S. Geological Survey and the Commonwealth of Puerto Rico. This survey was flown primarily to search for gold-bearing porphyry-copper deposits (Cox, 1985) made up of inner alteration zones that contain abundant magnetite and outer alteration zones that are depleted in magnetite; the deposits are

localized in tonalite porphyry stocks of late Eocene age. These deposits form a belt along the south margin of the Cretaceous Utuado batholith. Many of the geophysical studies performed by private companies in this area are not presently available to the public, but one geophysical report by Wilson (1966) for the Kennecott Copper Company is on file at the Department of Natural Resources, San Juan, Puerto Rico. The areas favorable for porphyry copper-gold, porphyry copper-molybdenum, and epithermal quartz-alunite gold deposits are associated with regional magnetic highs along the south side of the Utuado batholith. The general sources of the highs are magnetic volcanic rocks, whose magnetizations may locally be increased due to contact metamorphism by the batholith. The regional highs thus probably reflect an environment suitable for the mineral deposition but are not specifically caused by the mineralization, which, where studied, is considerably younger than the batholith. Superposition of the detailed aeromagnetic map (not reproduced in this report) shows that local aeromagnetic highs are observed over the known porphyry copper deposits (Tanama and Helecho) and their associated Eocene plutons as well as over known areas of copper mineralization nearby and that lows are associated with outer alteration zones. In addition, some of the small tonalite porphyry plutons appear to cause aeromagnetic anomalies even though they may not be mineralized, and other local magnetic highs observed on the map have at present no explanation. It is apparent that more geologic investigations combined with geophysical studies in this area may locate additional porphyry copper deposits.