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An aerial radiometric and magnetic survey of the Sierra Ancha Wilderness, Salome study area, Gila County, Arizona

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The U.S. Geological Survey has flown an aerial radiometric and magnetic survey of the Sierra Ancha Wilderness, Salome study area, and vicinity, Gila County, Arizona to aid an evaluation of the mineral potential of the area. Radiometric data were obtained because uranium deposits are known in the area and uranium mineralization is thought to be widely distributed in the upper member of the Dripping Spring Quartzite and possibly in the upper member of the Mescal Limestone (Granger and Raup, 1969a,b). The magnetic data were obtained because iron deposits are known in the area and because iron mineralization occurs in association with known asbestos deposits (Shride, 1967, 1969). The radiometric and magnetic data are presented as contour maps overlaid on geologic and topographic maps.

METHOD

An aerial radiometric survey measures gamma radiation from the decay products of the radioelements K-40, U-238, and Th-232. The distribution of these elements and their decay products are controlled by the complex interaction of geological and geochemical processes such as hydrothermal fluid movement, groundwater flow, weathering, erosion, and transportation. Because of this relationship to geologic processes, measurements of the radioelement distributions can be used to aid geologic mapping and mineral exploration.

The measurement of the radioelement distributions is made using scintillation detectors with associated electronic equipment. The survey aircraft generally follows the contour of the ground with a ground clearance of no more than 220 m (700 ft). The low ground clearance is necessary for statistically valid measurements because the gamma rays are absorbed at an exponentially increasing rate as the thickness of the air beneath the aircraft increases. Because the gamma-ray absorption by the surface materials also increases exponentially, the measurements reflect the radioelement concentrations only in the uppermost 0.5 m (1.5 ft) of rock and soil at the ground surface.

An aerial magnetic survey measures the total intensity of the Earth's magnetic field. Variations in total intensity can be related to the distribution of magnetic minerals at and near the Earth's surface. Magnetic mineral concentration varies widely with rock type and can be a significant characteristic of a rock type. Measurement of the variation in total magnetic intensity by an aerial survey provides data that aids in geologic mapping and the understanding of geologic processes. The magnetic field decreases as the distance from the source increases, but is not significantly attenuated by intervening materials. For this reason, effects due to magnetic bodies as deep as 40 km (25 mi) beneath the ground surface can be detected where the bodies are very large.

EQUIPMENT

The equipment used for this survey consists of a four-channel gamma-ray spectrometer with its associated electronics, a large-volume (113.3 liter) plastic detector (Duval and Pitkin, 1978), a proton-precession magnetometer, a radar altimeter, a digital magnetic-tape recorder, an analog strip-chart recorder, and a 35-mm flight-track-recovery camera. Data from the spectrometer, magnetometer, radar altimeter, and a digital clock were measured during one-second time intervals and recorded on magnetic tape. The 35-mm camera photographed the flight path of the aircraft at two-second intervals. All equipment were mounted in a single-engine Pilatus Porter STOL aircraft.[1]

SURVEY PARAMETERS

All data were measured at a nominal ground clearance of 122 m (400 ft) and a speed of about 160 km/hr (100 mi/hr). The effective ground area measured by the radiometric equipment at this height above the ground is a strip along a flight line about 244 m (800 ft) wide. Fifty-five flight lines, 5 to 32 km (3 to 20 mi) long, were flown along a northwest-southeast direction at intervals of 0.8 km (0.5 mi) (see Map A). This direction approximately parallels the geologic strike in parts of the area, and also parallels the topographic grain. Flying parallel to the topographic grain was necessary in

[1] The use of commercial trade names is for descriptive purposes only and does not constitute endorsement of these products by the U.S. Geological Survey.

order to be able to do contour flying at 122 m (400 ft) above the ground surface because topographic relief in the area is greater than 1000 m (3300 ft).

DATA REDUCTION

The data were processed to obtain contour maps of the apparent surface distributions of potassium (K), equivalent uranium (eU), equivalent thorium (eTh), the ratios eU/eTh, eU/K, eTh/K, and the residual total magnetic field. These maps are shown on maps B through H. The radiometric data as presented are fully corrected and are expressed in arbitrary units. The "e" preceding the "U" and "Th" refers to the fact that these measurements reflect equivalent or apparent distributions of the elements. The measurements are of gamma rays from the decay of Bi-214, a daughter product of U-238, and from the decay of Tl-208, a daughter product of Th-232. Because these elements and other predecessors in the decay chains can behave differently in the geochemical environment and become physically separated from the parent elements, U-238 and Th-232, the measurements may not accurately reflect the parent-element distributions. For this reason the measurements are designated as being apparent or equivalent measurements.

Corrections applied to the radiometric data include background subtraction to remove counts due to cosmic rays and aircraft contamination, and altitude normalization to remove variations caused by changes in the ground clearance. The corrected radiometric data were reduced to apparent surface distributions of the radioelements using equations based upon calibration data obtained on the calibration pads established by the U.S. Department of Energy at Walker Field airport, Grand Junction, Colorado (Ward, 1978).

Corrections applied to the magnetic data include removal of the diurnal variations in the earth's magnetic field as measured by a base-station magnetometer and removal of the regional magnetic gradient. The regional gradient removed was that of the International Geomagnetic Reference Field (Barraclough and Fabiano, 1978) updated to the time of the survey. Map H shows the residual total magnetic intensity.

GEOLOGY

The geologic report and map for the study area are by Bergquist and others, (1980). The geologic map used as a gray-tone base for this report was modified from Bergquist and others (1980), and from unpublished maps and notes of A. F. Shride. For this report the geology was generalized and some of the smaller outcrops were dropped from the map. The locations of known mineralizations were taken from Granger and Raup (1969a, b), and Shride (1969).

The lithologic units in the study area consist of Quaternary-Tertiary alluvial and colluvial deposits, small outcrops of Devonian-Cambrian sandstone, and rocks of Precambrian age. The oldest outcrops are the Ruin Granite, which is a dominantly coarse-grained quartz monzonite. The Apache Group, which includes the Pioneer Formation, the Dripping Spring Quartzite, and the Mescal Limestone, overlie the Ruin Granite. The Pioneer Formation is predominantly maroon to purple tuff and pink to gray siltstone and sandstone, and is generally present only as narrow outcrops within the study area. The Dripping Spring Quartzite consists of siltstone and very fine- to medium-grained feldspathic- to arkosic-sandstone and orthoquarzite. Granger and Raup (1969b) determined that siltstone in the upper part of the Dripping Spring Quartzite is the most favorable host rock for uranium mineralization, and that it also contains potassium oxide concentrations greater than 10 percent. The Mescal Limestone is massive dolomite and limestone with siltstones and shales and locally abundant chert and feldspar. In some areas basalt remnants locally overlie or occur within the Mescal. Shride (1967) measured potassium oxide concentrations greater than 10 percent in the argillite member of the Mescal, and Shride (1967) and Granger and Raup (1969b) observed that asbestos mineralization in the Mescal commonly has magnetite associated with it. The Troy Quartzite overlies the Apache Group and is predominantly light-colored quartzite and sandstone with conglomerate horizons. Precambrian diabase sills and dikes intrude all of the older Precambrian rocks, but are found mostly within the Mescal, Dripping Spring, and Pioneer Formations of the Apache Group.

The structural features within the survey area include numerous faults that are shown on the maps and two generally north-south trending monoclines that are not explicitly indicated on the maps. One of these monoclines is parallel to, and approximately along, the Globe-Young highway. The other monocline follows the Cherry Creek canyon. Shride (1967) briefly discusses these monoclines.

DISCUSSION

eU map (Map B)

This is a contour map of the apparent surface distribution of equivalent uranium (eU) with values ranging from 1 to 40 (arbitrary units). Values of eU greater than 18 occur mostly in two generally north-south trending zones. Most of the eU values greater than 18 appear to correlate spatially with the Mescal, Dripping Spring, and Pioneer Formations of the Apache Group and many of them are associated with the Dripping Spring Quartzite and the diabase intrusive.

East of the Globe-Young highway most of the eU values less than 16 are associated with Troy Quartzite and diabase. Generally lower eU values also occur west of Salome Creek in an area of extensive diabase that lacks rocks younger than the Dripping Spring Quartzite. In this area, the Dripping Spring is mostly lower and middle members which are less radioactive than the upper member. Some of the high eU values northwest of Castle Peak occur over Troy Quartzite and Mescal Limestone.

Much of the Ruin Granite-Pioneer Formation have high eU values but in the vicinity and west of Salome Creek the values are significantly lower.

eTh map (Map C)

This is a contour map of the apparent surface distribution of equivalent thorium (eTh) with values ranging from 2 to 50 (arbitrary units). The most obvious features on the eTh map are areas with values greater than 20. Almost all of these areas are associated with the Ruin Granite and the undivided Pioneer Formation and Ruin Granite. The Troy Quartzite has eTh values generally in the range 12-16. The other geologic units do not exhibit consistent patterns.

K map (Map D)

Map D is a contour map of the apparent surface distribution of potassium (K) with values ranging from 0.4 to 3.6 (arbitrary units). This map shows a large area with K values greater than 1.8 in the southwestern part of the survey area. Most of this part of the area is mapped as diabase. Values greater than 1.8 also occur in the upper part of Salome Creek, along the Cherry Creek canyon, and in localized areas to the east of the Globe-Young highway. Some of the rocks in the survey area are known to contain high concentrations of feldspar. Shride (1967) measured potassium concentrations (potassium oxide) greater than 10 percent in the argillite member of the Mescal Limestone. Granger and Raup (1969b) found potassium oxide concentrations greater than 10 percent in siltstone of the upper member of the Dripping Spring Quartzite.

This map also indicates that the Ruin Granite-Pioneer Formation in the western part of the survey area has a higher concentrations of K than outcrops in the eastern part of the area.

eU/eTh map (Map E)

This is a contour map of the ratio eU/eTh with values ranging from 0.4 to 6 (arbitrary units). This map shows two approximately parallel, generally north-south trending zones with values of eU/eTh greater than 1.6. Two similar shorter trends with lower maximum values occur to the west of the Globe-Young highway, trending to the south and southeast from the general vicinity of Greenback Peak. An isolated area with values greater than 1.6 occurs in the southwest part of the survey area to the east of Salome Creek.

eU/K map (Map F)

This is a contour map of the ratio eU/K with values ranging from 2 to 34 (arbitrary units). This map shows several northwest-southeast-trending zones that have eU/K values greater than 12. This map also shows that almost all of the lowest eU/K values (less than 6) occur in the western part of the survey area. The linear low along the west side of Cherry Creek Canyon may be a reflection of the monocline; however, because it parallels the flight line direction, it could also be caused by a level shift in the data. Overall this map is similar to the eU/eTh map.

eTh/K map (Map G)

Map G is a contour map of the ratio eTh/K with values ranging from 4 to 30 (arbitrary units). The dominant feature of this map is a ridge of eTh/K values greater than 12 trending northwest-southeast approximately parallel to and west of the Cherry Creek canyon. Except in the southeast corner where these values are apparently associated with the outcrop of the Ruin Granite, these higher values are generally associated with the Troy Quartzite and much of the Troy Quartzite in the northeastern part of the map also has values greater than 12. Where the Troy is intruded by diabase in the vicinity of Aztec Peak, the eTh/K ratio does not differentiate the diabase from the Troy.

West of the Armer Mountain fault that extends southeast from the vicinity of Greenback Peak the values are generally less than 8, whereas east of the fault the values are generally greater than 8.

Residual magnetic intensity map (Map H)

In the area of this survey, the magnetic data can be expected to show variations of intensity caused by one or more of the following:

1) The diabase which is widely distributed in the area is presumed to be magnetic (in the absence of susceptibility measurements), because diabase usually is magnetic. Because the diabase occurs as deeply eroded sills and feeder dikes and varies in thickness from 0 to greater than 300 m (980 ft), the magnetic data can be expected to show variation related to it.

2) Where the Mescal Limestone comes into contact with the diabase, alteration has commonly produced local concentrations of magnetite and asbestos.

3) Local remnants of basalt flows within or above the Mescal Limestone may also produce localized magnetic highs.

4) The topography in the survey area is rugged with numerous deeply incised valleys that cut through many of the geologic formations. Where the diabase has been cut out, magnetic lows can be expected to occur over

the valleys.

Map H is a contour map of the residual magnetic intensity expressed in gammas. This map shows a linear feature that trends northwest-southeast along the east side of the Cherry Creek canyon and coincides with the Cherry Creek monocline discussed by Shride (1967). The map also shows a dominance of higher magnetic values to the west of the Armer Mountain fault. These high values are probably associated with the thick diabase intrusive in this area (A. F. Shride, oral commun., 1979).

The data in the center of the survey area show numerous linear magnetic lows that correlate with topographic lows along drainage systems. These magnetic reflect variations in the thickness of diabase.

The relatively high magnetic values east of the Cherry Creek monocline are possibly caused by the granite in this area which is thought to be more magnetic than the granite west of the Globe-Young highway.

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