UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Preliminary Results for Borehole GM-1, Granite Mountains, Wyoming

By

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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Introduction

The U.S. Geological Survey has been core-drilling a deep hole in the Granite Mountains, central Wyo., to test the theory (Rosholt and Bartel, 1969) that many of the nearby uranium ore bodies were formed from uranium which was leached out of the granite. Previous studies of surface and shallow-core samples have shown the Precambrian granite to be depleted in uranium relative to the daughter product lead (Rosholt, et al, 1973; Rosholt and Bartel, 1969). If the theory of deep leaching is correct, similar granites that were high in uranium and that are now high in radiogenic lead may provide guides for exploration either in the basins that surround the granite or as re-concentrations of uranium at depth within the granite.

Borehole GM-1 is located (fig. 1) approximately 10 km east of Jeffrey

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Figure 1.--NEAR HERE

City (SW 1/4 sec. 6, T. 39 N., R. 90 W.) on land released to the USGS from the Bureau of Land Management by a Special Land Use Permit. The hole is 405 m (1,340 ft) deep, with drilling terminated for the winter season. It is expected that the hole will be deepened to at least 610 m (2,000 ft) in the spring in order to determine the maximum depth of leaching. The gamma-ray, neutron-neutron, and magnetic-susceptibility logs were provided the Geological Survey by the Grand Junction Office of the Energy Research and Development Administration (formerly USAEC).

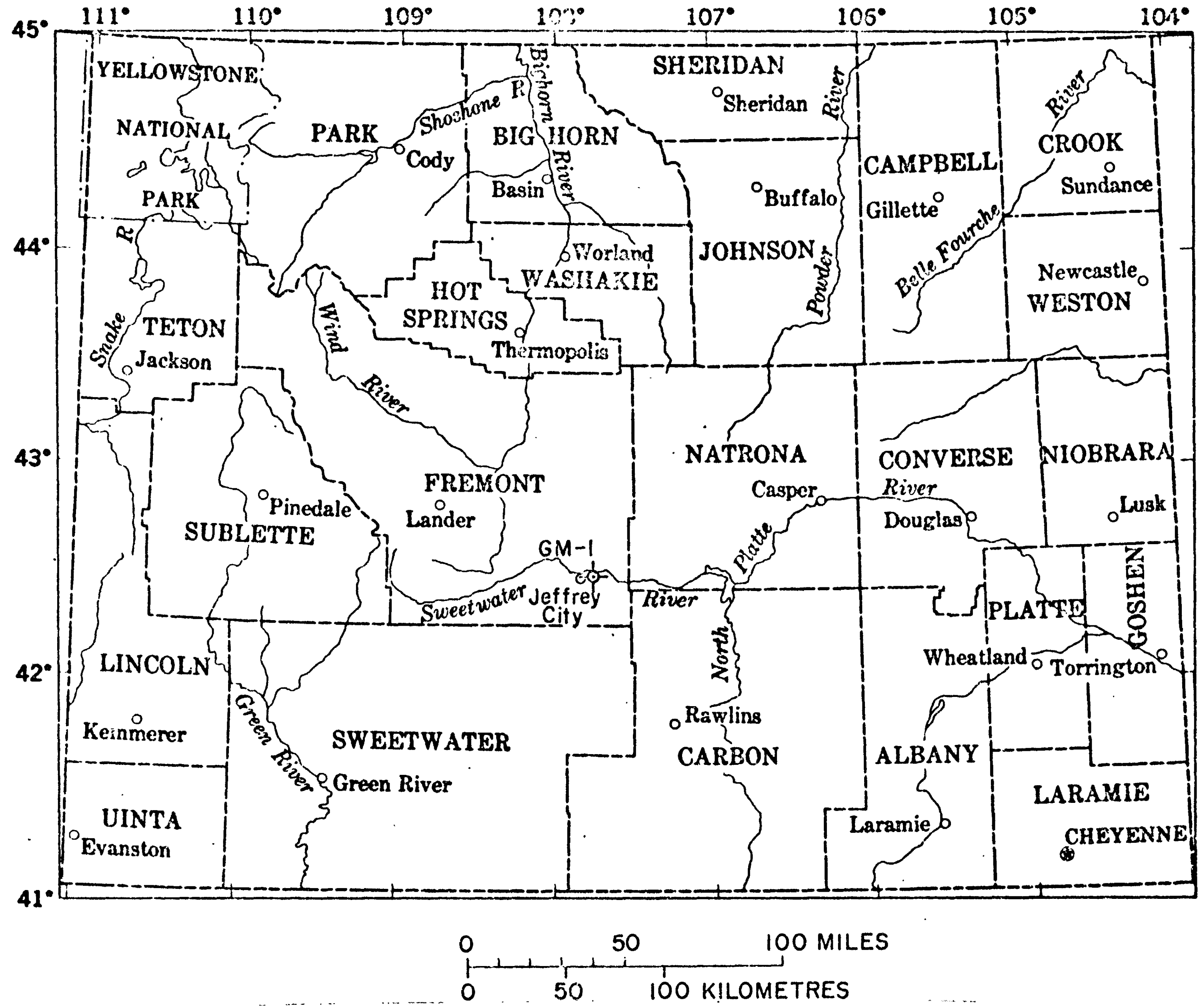

Figure 1. Index map showing location of borehole GM-1 near Jeffrey City, Wyoming

Chemical and petrographic data given in this report are based on samples taken at approximately 3-m intervals supplemented by in-hole geophysical logging and megascopic examination of the core. Gamma-ray spectrometry for U, Th, and K has been completed for approximately half of the core samples. X-ray florescence analyses for Pb, Rb, and Sr have been completed for the same suite of samples.

Results

Preliminary results show the granite to be quite variable in chemical and petrologic characteristics. The gamma radioactivity measured in the borehole (fig. 2) exhibits several small anomalies that suggest equivalent

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Figure 2.--NEAR HERE

U contents of 50 to 500 ppm. These intervals are generally very thin, ranging from 0.5 to 3 m in thickness, and appear to correspond to fracture zones that show up as lows on the neutron-neutron log (fig. 3). Several magnetic anomalies have been measured in the borehole (fig. 4). These

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Figure 3.--NEAR HERE

Figure 4.--NEAR HERE

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can be correlated with either large isolated crystals of magnetite or narrow intervals of disseminated magnetite.

Core samples can be grossly divided into two phases of granite: "normal" and "contaminated." The normal granite is petrographically similar to typical Precambrian granites, and is the dominant phase in the upper 215 m (705 ft) of the borehole. The contaminated phase is most common between the depths of 215 m (705 ft) and 350 m (1150 ft).

Samples of the normal phase display hypidiomorphic-granular texture and have subequal amounts of plagioclase and potassium feldspar. Plagioclase exhibits minor alteration to clays and muscovite, and myrmekite is rare or absent. Potassium feldspars are generally microcline with cross-hatch twinning, and perthite. Biotite is the only major mafic constituent and commonly contains small zircons with pleochroic halos. Identifiable trace constituents in the normal phase includes magnetite, clinozoisite, sphene, zircon, hematite, and muscovite. Apatite is remarkably rare or absent.

Chemically the normal phase is anomalously rich in uranium, thorium, and lead. The averages for these elements ± one sigma are 11.6 ± 8.3, 51.9 ± 14.7, and 53.5 ± 4.1 ppm, respectively. The average of the Th/U ratios for 38 samples is 6.0 ± 3.4; this is also high relative to most granitic rocks. If the uranium values are increased far enough to be in equilibrium with the radiogenic lead, the Th/U ratios would vary from 0.3 to 3.8, and most would be less than 2.

The average potassium content of the normal phase is 4.40 ± 0.45 percent which is only slightly above that of most granites. The averages for Rb, Sr, and the Rb/Sr ratios are 225.0 ± 18, 93.3 ± 6.3 ppm and 2.42 ± 0.17, respectively. These values are typical for granitic rocks. Although the normal phase as sampled in the drill hole GM-1 appears to be nearly homogeneous with respect to Rb, Sr, Pb, Th, and K, analyses of surface and shallow drill-hole samples from the normal phase exhibit wide variations.

The contaminated phase is highly variable in chemical and geophysical characteristics, but is consistently xenomorphic granular. Microcline of this phase is locally poikilitic with rounded quartz crystals. Plagioclase is not markedly different from that of the normal phase, except that within a single thin section there may be a marked difference in the degree of alteration of any two plagioclase crystals. The ratio of plagioclase to microcline is quite variable reaching a ratio of 0.25 with a corresponding K-content of 6.25 percent. Within the contaminated phase there are several zones that contain rounded and retrograded garnets, a few zones that contain minor pyrite concentrations, and a few zones that contain large (2 cm) magnetite crystals. Muscovite and (or) biotite are common minor or trace minerals while sphene and zircon are generally rare. Apatite is rare or absent.

Chemically the contaminated zone is poorer in uranium and thorium averaging 7.03 ± 5.12 and 6.84 ± 4.23 ppm, respectively. This is reflected in the gamma-ray log by the lower background level in the contaminated phase (fig. 2). The average of 18 Th/U ratios of 1.14 ± 0.72 is generally low when compared either with the normal phase or with typical granitic rocks. Limited data for potassium are more variable than in the normal phase, but have a similar average. Preliminary values for lead concentrations are similar to the normal phase, and suggest either extensive uranium leaching or a high common lead content.

A third phase of the granite is identifiable in surface outcrops, but was not encountered in the drill hole. This phase is extremely leucocratic, has a blocky weathering, and is termed the "silicified" phase. Potassium feldspar is strongly altered or absent. Biotite is partially to wholly replaced by clinozoisite and (or) epidote. In outcrop the silicified phase tends to occur as tabular bodies, concordant with the horizontal jointing of the granite or as small dike-like zones that cut the granite. The tabular bodies act as cap rocks for many of the granite knobs and may be as thick as 25 m (80 ft). The dike-like zones often form low ridges. Contacts between the normal and silicified phases may be sharp or gradational.

A single analysis for the silicified phase yields U = 13.0, Th = 43.9, K = 60, and Pb = 34.8 ppm. A single analysis for a granite sample adjacent to the silicified phase is similar to surface samples of the normal phase except that K and Pb are slightly low relative to the averages obtained in borehole GM-1.

Positive gamma-ray anomalies are found at most of the fracture zones. A sample taken in a fracture zone at 49 to 52 m consists of highly decomposed normal phase granite with plagioclase almost totally replaced by clays and sericite, and thin (1 to 40 mm) bands of gouge. X-ray diffraction analysis of the gouge yields a mineralogic composition of quartz, potassium feldspar, illite, and possibly plagioclase.

Chemically, this zone is quite different from the normal granite. U increases to 107 ppm; Th remains about the same at 56 ppm, and K, Pb, Rb, and Sr all decrease to 0.1 percent, 34, 19, and 38 ppm, respectively. Although data are limited, it seems that the abundance of these four elements decreases in altered zones--particularly those that show up as broad diffuse lows on the neutron-neutron log (fig. 3).

The uranium in the fracture zone at 49 to 52 m must have been concentrated during geologically recent times. If uranium had been concentrated in this zone at the time the granite crystallized, it would be reasonable to expect a comparable increase in Th. Furthermore, the Pb generated by the decay of uranium would be approximately ten times the lead currently found in the fracture zone.

Preliminary values for lead, uranium, and thorium concentrations, and lead isotopic compositions suggest a leaching of 50 to 75 percent of the uranium at depths as great as 390 m (1280 ft). This percentage of leaching is similar to that observed for surface and shallow drill-core samples.

The average amount of uranium leached from the granite is approximately 15 to 20 μg/g of rock. If the volume of the leached granite is at least equal to the current surface relief plus the depth of leaching in borehole GM-1 (915 m) times the present areal extent of the granite (1140 km^2), then a minimum of 4.1×10^{10} kg of uranium was leached. This amount is on the order of 1,000 times the estimated uranium concentrated in surrounding uranium districts. It is, therefore, plausible that the granite could have been the source rock for these uranium deposits.

References

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