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A STUDY OF SILICIC PLUTONIC ROCKS IN THE ZUNI AND FLORIDA MOUNTAINS TO EVALUATE THE POSSIBLE OCCURRENCE OF DISSEMINATED URANIUM AND THORIUM DEPOSITS

RADIOGENIC HEAT CONTRIBUTION TO HEAT FLOW FROM POTASSIUM, URANIUM, THORIUM IN THE PRECAMBRIAN SILICIC ROCKS OF THE FLORIDA MOUNTAINS AND THE ZUNI MOUNTAINS, NEW MEXICO

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98

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by

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High heat flow (2.0-2.5 HFU) has been reported by Reiter et al. (1975) for an area of the Zuni Mountains, NM. Laughlin and West (1975) have suggested that a buried felsic pluton may account for this high heat flow and, further, urge consideration of the area for hot dry rock geothermal exploration. U, K, Th data for sixty samples of Precambrian silicic rocks from outcrop and from shallow drill holes, representative of all major rock types, yield radiogenic heat contribution values from 2.72 to 11.25 ucal/g-yr (X = 7.23 ucal/g-yr). The mean is significantly higher than the continental crust radiogenic heat average value (4.7 ucal/g-yr) and higher than the mean for some 60 granitic rocks from the western U.S. reported by Tilling and Gottfried (1969; weighted mean 6.5 ucal/g-yr) although higher (X = 8 ucal/g-yr) values have been reported for some granitic rocks. Th/U ratios yield a mean of 4.55 and the mean U content is 3.75 ppm. There is no evidence from surface or shallow drill hole samples of widespread K, U or Th redistribution. The importance of the K, U, Th data is that the radiogenic heat contribution may be significant to the high heat flow reported unless it can be demonstrated that the Zuni Precambrian silicic rocks do not persist to significant depth or that K, U, or Th values diminish with depth; gravity surveys and deep drilling are needed to resolve these problems.

The K, U, Th data for the Florida Mountains yield a range in radiogenic heat generation from 2.92 to 13.88 ucal/yr (mean: 5.46 ucal/yr) for 32 samples. These rocks are somewhat anomalous as the syenitic rocks contain less U than granitic rocks, hence the mean radiogenic heat value may be too low as a somewhat disproportionately high number of syenites relative to granites were sampled. Regional heat flow near the Floridas is higher than in the Floridas proper but this discrepancy cannot be explained at present.

Radiogenic Heat Production and Heat Flow in the Florida Mountains, NM

Heat flow in the Florida Mountains is less well defined than that in the Zuni Mountains. Further, the geologic history of the Florida Mountains is not well known. Part of the uncertainty lies in the relationship of various rocks studied by Corbitt (1974), Corbitt and Woodward (1974) and Brookins (1974). Rb-Sr ages (Brookins, *ibid.*) confirm the presence of Precambrian granitic rocks south of the Cordilleran Thrust Belt which bisects the Florida Mountains (Corbitt and Woodward, 1974) but Rb-Sr and K-Ar ages north of this thrust coupled with recent petrographic study indicate a complex pattern of Precambrian rocks with either mid- to early-Paleozoic syenitic rocks or else an even more complex scenario involving Paleozoic re-setting of Precambrian isotopics or possibly mixing of Mesozoic rocks with re-worked Precambrian material. None of these (and other) possibilities can be precluded at present and more field and laboratory work are needed.

It is not surprising, thus, to note from Table Two a range in heat generation values from 2.92 ucal/g yr to 13.88 ucal/g yr with a mean of 5.46 ucal/g yr for 32 samples. Brookins et al. (1978) report a mean U content of 3.12 ppm for 90 samples and a mean Th/U ratio of 3.97 for 66 samples. The mean Th content for 66 samples is 12.23 ppm which is significantly lower than the 17.53 ppm Th for 25 Zuni Mountains samples. Since the Florida Mountains contain more rocks with syenitic affinities higher Th content would be expected; further, appreciably higher Th/U would also be expected. This information coupled with the complex geochronology pattern may argue for mixing of Th and U depleted rocks to account for both the presence of the syenites and low Th and U.

The Florida Mountains occur in an area of high heat flow at about the longitude dividing the high heat flow region west of the Rio Grande Rift to that marking the probable start of true basin and range structure. The heat flow map of Reiter et al. (1975) places the Florida Mountains thus in a broad area of about 2.0 - 2.5 HFU (Note: One anomalously high value of 9.7 HFU is reported by Reiter et al., 1975; from north of the Florida Mountains. No other values in south-central New Mexico near the Mexican Border are above 2.6, however.). Geophysical data for the Florida Mountains are too meager to warrant extensive discussion and the areal extent of the Florida Mountains is also restricted. The possible heat contribution from K, Th and U to the regional heat flow from the alkalic and silicic rocks of the Florida Mountains is thus interpreted to be much lower than in the Zuni Mountains. This conclusion is reached by noting that approximately half the mountain range is due to overthrusting thus indicating lack of persistence of these rocks to depth and no good data to suggest that the rocks north of the thrust persist to depth either.

The data for the Florida Mountains may be used with caution to suggest that if the rocks can indeed be demonstrated to continue to depth, to be tightly sealed, and to meet other criteria, they may be suitable for DHR experimentation/exploitation.

Radioactive Heat Contribution to High Heat Flow in the Zuni Mountains

The Zuni Mountains are located in that part of the Zuni Uplift for which high heat flow (2.0 - 2.5 and higher HFU) has been determined (Reiter et al., 1975). Laughlin and West (1975) have suggested that the presence of a buried felsic pluton may account for this high heat flow and, further, have proposed consideration of the high heat flow area for possible dry hot rock (DHR) geothermal study. This proposed DHR study is proposed in part because of the projected energy needs of the Grants, NM, area due to accelerated growth in population in turn due to increased uranium mining and milling north of Grants in the Grants Mineral Belt.

The high heat flow in the vicinity of the Zuni Mountains is attributed to two regional sources. High heat flow is noted west of the Rio Grande Rift and is presumably due to magmatic sources in the upper mantle associated with the depression (Reiter et al., 1975). Another less well defined zone of high heat flow occurs in a northeasterly trend from midway along the Arizona-New Mexico border to the Zuni Mountains; most of the Zuni Mountains are in this latter high HFU area. Evidence for above normal heat flow in the Zuni Mountains is also recorded by the presence of hydrothermal mineralization, igneous dikes, and mantle-derived inclusions in mafic igneous rocks. Laughlin and West (1975) have discussed these geologic arguments for above normal heat flow in more detail.

The Zuni Mountains have been considered as a possible source for uranium for some or much (?) of the deposits in the Grants Mineral Belt and Brookins and Rautman (unpub.) have addressed this problem in conjunction with other total uranium budget, etc. Their data allow evaluation of the radioactive elements of the Zuni Mountains (i.e., K, Th, U) in terms of contributing to the proposed DHR study is obvious. If the high heat flow is due to a high abundance of K, Th, U then one must consider any DHR study in terms of a finite heat reservoir; alternately, if the radioactive elements contribute only a small amount of the total heat then the high heat flow is due to lower crustal or mantle sources and, therefore, an infinite heat reservoir. This will be elabroated on below.

Radiogenic heat production from K, Th and U can be estimated by Birch's (1954) estimate of heat generation from these elements: 1 ppm Th = 0.20 microcalories per gram per year (ucal/g yr); 1 ppm U = 0.73 ucal/g yr; 1 percent K = 0.27 ucal/g yr. If K, Th and U data are available for each sample then the heat generation calculations are rigorous. If only U (usually as eU from gamma counting) contents are known, approximate heat generation estimates can be made by assuming Th/U = 4.0 and estimating total K by petrographic examination. While this approach has been used by numerous investigators (See discussion in Birch et al., 1968) it will not be used here as the diversity of rock types, uncertainties in petrographic estimates of K content (i.e., due to weathering, etc.), and other factors (i.e., wide range in Th/U due presumably to erratic U distribution from sample to sample) would almost certainly introduce large errors. For these reasons heat budget will be given only for those samples for which chemical analyses of K, Th and U are available.

Standard chemical techniques were employed for K, Th and U determinations. K was determined by x-ray fluorescence spectrography at the New Mexico Institute of Mining and Technology and Th and U by delayed neutron activation analysis (DNAA) at the Los Alamos Scientific Laboratory. The K data are precise to ± 1 percent (one sigma) and the Th and U data to ± 5 percent (one sigma). U. S. Geological Survey standards were employed for purposes of calibration and monitoring of unknowns. The data for K, Th, U and heat generation are reported in Table One.

Although U data are available for 57 samples and Th data for 25, K, Th and U data are available for only 20 samples. These 20 samples are, however, widespread in occurrence and representative of the major rock types which occur in the Zuni Mountains.

The total heat generation due to radiogenic K, Th and U ranges from 2.72 to 11.25 ucal/g yr with an average of 7.23 ucal/g yr. Wasserburg et al. (1964) suggest a value of 8.2 ucal/g yr for granitic rocks although this value may be too high as Tilling and Gottfried (1969) summarize data for 38 granodiorites and 12 granites and quartz monzonites from the western United States at 5.0 and 7.6 ucal/g yr respectively. The calculated value for the continental crust (ibid.) is 4.7 ucal/g yr. Variation within various facies of silicic plutonic rocks usually ranges from low values for tonalitic to granodioritic rocks (2 to 5 ucal/g yr) and much higher values for granites and quartz monzonites (to 10 ucal/g yr). Very high heat generation has been reported for granitic rocks from many locations by Tilling and Gottfried (1969). With regard to the Precambrian plutonic rocks of the Zuni Mountains it is interesting to note that the average Th/U ratio for 25 samples is 4.55 and the average U content for 57 samples is 3.75 ppm. The U content is within the range for granitic rocks but the Th/U ratio (average value) is somewhat higher than the commonly cited value of 3.7 ± 0.5. If this is interpreted to indicate that there has been some U loss while K and Th have been retained then the calculated heat value of 7.23 ucal/g yr is too low and should therefore be considered as a minimum value.

The mean heat flow for the earth is 1.5 ± 0.15 ucal/cm^2 sec (Lee and Uyeda, 1965) which is lower than the suggested high of 2.0 to 2.5 HFU (1 HFU = 1 ucal/cm^2 sec) for the anomaly in the vicinity of the Zuni Mountains (Reiter et al., 1975; Laughlin and West, 1975).

The problem here, however, is to attempt to determine how much of the high heat flow is due to near-surface or surface heat from radiogenic K, Th and U relative to mantle-derived heat. Since the geometry of the Zuni Mountains is not known as a function of depth one must rely on the rather uniform K, Th, U and Th/U values reported for surface or shallow drill hole samples and assume that little if any variation occurs with depth. Laughlin and West (1975) also report gravity and ERTS imagery evidence which suggest the presence of a buried felsic rock mass beneath much of the Zuni Mountains. While it is not possible to state whether or not this rock mass represents buried Precambrian rocks equivalent to those sampled at or near the surface as opposed to an entirely different rock mass, the lack of felsic Laramide plutons and younger silicic volcanics may then be used as an indirect argument that the buried felsic rocks may be equivalent and parts of the exposed Precambrian granitic rocks of the Zuni Mountains. The significance of the possible persistence of these rocks to depths can be appreciated by the studies of Tilling and Gottfried (1969) on the Boulder Batholith. Their data convincingly demonstrate that the high surface heat flow of 2.1 to 2.2 HFU can be entirely explained by the radiogenic heat from K, Th and U if the batholith persists to a depth of 35 kilometers (note: the depth to the Moho under the Boulder Batholith is 45 kilometers). The few geophysical data for the Boulder Batholith indicate persistence of the silicic rocks to a depth of no more than 15 kilometers or so and the presence of more mafic material between 15 and 45 kilometers. Since this mafic material in all probability is gabbroic its heat generation is on the order of only about 1.0 ucal/g yr which, in turn, suggests that the source for much of the heat must be mantle-derived with a significant contribution from the Boulder Batholith itself.

Collectively the heat generation from radiogenic K, Th and U may be a significant contributor to the total heat flow for the Zuni Mountains. This can and should be substantiated or refuted by deep drilling coupled with geophysical study as suggested by Laughlin and West (1975).

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TABLE ONE

Radiogenic Heat Budget for the Florida Mountains

Sample	K (%)	Th (ppm)	U (ppm)	Q (ucal/g yr)
FM5-1	4.18	13.65	3.08	6.11
FM5-3	3.78	35.8	7.80	13.88
FM5-5	3.76	15.0	3.65	6.68
FM2-1	4.20	16.4	4.03	7.36
FM7-3	5.59	2.40	1.58	3.14
FM8-1	4.52	12.9	2.88	5.90
FM2-2	3.88	15.0	2.80	6.10
FM7-4	5.23	3.70	2.39	3.90
FM7-2	5.22	3.63	1.77	3.43
FM2-4	3.88	18.2	4.81	8.19
FM1-6	4.05	17.4	3.03	6.79
FM7-1	5.46	3.15	1.42	3.14
FM7-6	4.52	30.8	7.08	12.54
FM-11	4.10	18.6	3.89	7.67
FM7-8	5.14	4.26	1.83	3.57
FM8-1	4.50	17.1	3.69	7.32
FM2-8	4.49	18.4	4.22	7.97
FM7-5	5.41	3.69	1.65	3.40
FM1-3	3.83	24.6	5.44	9.94
FM7-~~5~~7	5.41	13.0	2.76	6.08
FM4-1	4.81	7.26	1.87	4.12
FM5-6	3.62	19.8	4.18	7.98
FM1-2	3.90	23.1	4.56	9.01
FM1-7	4.28	12.9	2.33	5.43
FM2-5	4.32	11.5	2.57	5.35
FM1-5	4.05	16.3	4.17	7.40
FM4-4	4.79	2.67	1.50	2.92
FM4-2	4.51	5.08	1.25	3.15
FM4-3	4.57	3.29	1.47	2.96
FM5-2	3.98	18.9	2.77	6.88
FM2-3	4.23	14.5	3.15	6.34
FM1-4	3.96	16.2	3.35	6.75

TABLE TWO

Radiogenic Heat Budget for the Zuni Mountains

Sample	K (%)	Th (ppm)	U (ppm)	Q (ucal/g yr)
ZM1-1	4.35	22.8	2.91	7.85
ZM1-2	4.47	18.8	5.98	9.33
ZM1-4	4.37	21.9	4.02	9.70
ZM1-5	4.62	20.5	3.65	8.01
ZM1-6	4.37	18.0	3.37	8.44
ZM1-7	4.26	20.2	3.64	7.86
ZM6-1	3.24	12.0	3.46	5.80
ZM6-2	3.29	14.0	2.97	5.80
ZM6-3	3.18	12.2	3.67	5.98
ZM6-4	3.46	16.5	4.44	7.48
ZM7-6	3.47	13.6	3.46	6.19
ZM7-7	2.77	17.5	3.28	6.64
ZM7-8	3.76	13.4	2.64	5.63
ZS-1	3.91	16.0	3.53	6.83
ZS-2	4.03	30.4	5.60	11.25
ZS-3	2.20	4.07	1.79	2.72
ZS-4	3.71	7.92	2.14	4.15
ZS-5	3.84	11.3	3.49	5.84
ZS-7	3.69	18.3	5.33	8.54
ZS-8	4.04	28.6	5.02	10.48

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