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**PRELIMINARY PETROGRAPHIC AND GEOPHYSICAL
INTERPRETATIONS OF THE EXPLORATORY GEOTHERMAL
DRILL HOLE AND CORE, REDSTONE, NEW HAMPSHIRE**

By
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Date Published—June 30, 1977

Work Performed Under Contract No. EY-76-S-02-2720

University of New Hampshire
Department of Earth Sciences
Durham, New Hampshire

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Division of Geothermal Energy

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As a result of the encouragement of Governor Thomson and the members of his Mineral and Energy Resources Council and the interest of the National Energy and Research Administration in testing all energy potentials a proposal was submitted to drill a 3000-foot borehole and recover a 1 7/8" core from the uranium-thorium-bearing Conway Granite in north-central New Hampshire.

The principal investigator wishes to acknowledge the interest and support of John Gabelmann, formerly of ERDA and many of ERDA's administrative personnel in the Geothermal Division.

Permission to drill the exploratory borehole was given by Mr. Andrew Fletcher, Fletcher Brothers Granite Company, North Chelmsford, Massachusetts and Mr. David Swenson, the John Swenson Granite Company of Concord, New Hampshire. Many services and courtesies were given by Mr. Harry Mason of Redstone, New Hampshire, the caretaker of the property.

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ABSTRACT

A 3000 foot diamond drill hole was drilled in the Conway Granite in Redstone, New Hampshire. A comprehensive detailed petrographic and physical study of this core has been made. The purpose of this study is to supply a sound data base for future geothermal and uranium-thorium studies of the drill core.

An estimate of the heat flow potential of the Redstone drill hole gives a heat flow of 1.9 HFU. If only the red phase of the Conway Granite been intersected the heat flow may have been as much as 2.7 HFU, reaching a temperature of 260°C at 6 km.

The drill hole intersected four lithologies; the green and red phase of the Conway Granite, the Albany quartz syenite and a medium-grained, hastingsite-biotite granite. The red phase has the highest and most irregular radioactivity. The irregularity is mainly due to minor variations in lithology.

The drill core intersected several alteration zones up to a thickness of 150 feet. These alteration zones represent passage of low to medium temperature fluids which might have been mineralized.

The Conway Granite has the physical and chemical characteristics necessary for the formation of vein type uranium deposits. The presence of unexplained radiometric anomalies lends support to the existence of such deposits.

INTRODUCTION

Purpose of the Drill Hole

The purpose of the Redstone drill hole was primarily to evaluate the heat flow and the geothermal potential of the Conway Granite. In addition, other significant aspects of the Conway granite were investigated, such as evaluating the Conway Granite not only as a source of energy but as a potential source of uranium and thorium and assessing the possibility that vein-type uranium deposits may be associated with the Conway Granite.

The primary purpose of this study was to make a detailed petrographic and physical analysis of the drill core in order to prepare a sound base for any future investigations.

Recommendations for Further Work

Studies on the Redstone drill core

The Redstone drill core intersected four major lithologies, as well as many minor rock types of the White Mountain plutonic-volcanic series. The freshness of this core allows many investigations to be performed which otherwise would not be possible. The following studies are recommended as follow up work on this drill core.

- (1) Chemical study of the alteration zones.
- (2) Chemical study of the "mushy" zones.
- (3) Chemical study of the fine-grained granite and aplite dikes.
- (4) Chemical study of the major lithologies.

A traverse of alteration zones and contact wall rock of the core should be sampled and analysed for uranium, thorium, lead, zinc, silver and copper. These analyses will allow one to determine whether these metals were removed from, concentrated in or rearranged within the alteration zones.

Analysis for uranium and thorium in the "mishy" zones with comparisons of the enclosing contact rock will determine the extent of depletion of uranium and thorium and the relative mobility of these elements. This analysis will allow one to make some conjectures as to the composition of the magmatic fluids which may have occupied these zones.

The fine-grained granite and aplite dikes have a radioactivity between the red and green phases of the Conway Granite. The source of the magma which generated these dikes is not known. Rare earth and uranium and thorium analyses of these rocks may better define their origin.

A rare earth study of the major and minor lithologies will allow one to determine if the different rock types can be related to a similar magma source or whether different magmas were responsible for the formation of these rock types.

Age dating of the different lithologies might determine the time interval between magmatic events, time of cooling and age of the hydrothermal fluids.

Studies on the White Mountain plutonic-volcanic rocks

Studies into other aspects of the White Mountain plutonic-volcanic series that would be advantageous include the following.

- (1) Detailed mapping of the White Mountain plutonic-volcanic series rocks.
- (2) Chemical studies of the different lithologies and phases of the Conway Granite.
- (3) Dating of the different phases of the Conway Granite.

(4) Detailed gravity work on the White Mountain batholith.

(5) Heat flow measurements should be made across the White Mountain batholith.

It is necessary to better define the geographic location of the different phases of the Conway Granite. Work is proceeding along these lines in several areas of the White Mountains (Hoisington, personal communication, Rivers and Creasey, 1977). However, a coordinated cost effective mapping effort of the entire area needs to be made. Along with this detailed mapping, comprehensive chemical and geophysical investigations of the White Mountain plutonic-volcanic series should be conducted.

Detailed rare earth, uranium, thorium and age dating of the different phases of the Conway Granite and other White Mountain lithologies should be made to determine the distribution and genetic relationship among the rock types.

Detailed gravity investigations of the White Mountain batholith should be made to determine the depth characteristics of the different lithologies. Work along these lines is proceeding in the North Conway quadrangle (Wetterauer and Bothner, 1977).

Heat flow measurements should be performed systematically on a grid across areas underlain by the White Mountain plutonic-volcanic series. Comparison of the heat flow, gravity, lithological and chemical data should define these areas of high geothermal potential.

Studies relating to the possibility of uranium vein type deposits associated with the Conway Granite

Vein deposits of several different metals are found around the contacts of White Mountain series rocks. These deposits include

prospects and former mines such as the Jackson(Tin) Mine, Iron Mountain Mine in Bartlett, Shelburne Silver Mine, Madison Lead Mine, the North Woodstock Silver Mine and possibly the Franconia Iron Mine. These deposits and the surrounding terrane should be mapped in detail to ascertain whether uranium mineralization is associated with these deposits.

ERDA conducted an airborne radiometric survey along the southern boundary of the White Mountain National Forest in 1976. The northern part of the Forest was done by the Atomic Energy Commission in 1958-1960. These studies indicate several anomalous areas which should be investigated in detail. It is recommended that detailed geologic mapping of these areas be conducted. Publication of the results on the proposed NURE stream sediment and ground water program will undoubtedly indicate other anomalous areas. Detailed radiometry, geologic mapping and geochemistry should be conducted in the anomalous areas.

In summary the White Mountain batholith has a unique lithology in which many diverse investigations have been conducted. A comprehensive multi-discipline investigation of this area, along the lines as outlined previously, is recommended.

GENERAL GEOLOGY

Description of the White Mountain Plutonic-Volcanic Series

The Conway Granite belongs to the White Mountain plutonic-volcanic series of Triassic to Cretaceous age. The rocks of this plutonic-volcanic series can be classified into volcanic, plutonic and dike rocks. The volcanic rocks consist of flows of tuffs and breccias of basalt, andesite,

trachyte and rhyolite. The plutonic rocks consist of gabbro, norite, diorite, quartz diorite, monzodiorite, monzonite, nepheline syenite, syenite, quartz syenite and various granites. The dike rocks include diabase, kersantite, diorite, camptonite, spessartite, syenite, bostonite, paisanite and various granites (Billings 1956).

The rocks of this plutonic-volcanic series can be easily distinguished from rocks of the older magma series in New England by the following features:

- (1) The rocks are massive and seldom show foliation or banding.
- (2) They have a hypidiomorphic granular texture.
- (3) The rocks are characterized by the persistence of amphiboles and pyroxenes with occasional olivines occurring in some syenites and granitic rocks.
- (4) Muscovite is absent.
- (5) Pegmatites are rare.

The White Mountain plutonic-volcanic series has been forcefully injected as ring dikes, stocks and a large batholith. The source of the magma is not known. The large volume of granitic and syenitic rocks, and small volume of gabbroic rocks, suggest that all of the rock could not have been derived by fractional crystallization of an upper mantle basalt. Most opinions are that a magma was produced by assimilation of siliceous sediments followed by fractional crystallization.

Description of the Conway Granite

The Conway Granite is typically a pink biotite granite, ranging from a coarse- to a fine-grained rock. The different phases include the following (partly from Billings, 1956):

(1) A coarse-grained phase, which is typical of the quarry at Redstone, has pink crystals of microperthite averaging 6 mm in diameter. The quartz grains are conspicuously smoky and smaller in diameter than the microperthite. Biotite flakes average 2 mm in diameter.

(2) The porphyritic phase has feldspar crystals 5 to 20 mm in diameter with quartz from 2 to 5 mm in diameter. The groundmass minerals are .5 to 1 mm in diameter.

(3) A medium-grained phase has feldspars averaging about 2-3 mm in diameter with quartz averaging about 2 mm in diameter.

(4) A fine-grained phase has feldspar and quartz grains ranging in size from .2 to 1 mm in diameter.

(5) A green medium-grained phase exists in the Redstone Quarry and might be genetically related to the Mt. Osceola granite.

Ages of the White Mountain Plutonic-Volcanic Series

The rocks of the White Mountain plutonic-volcanic series vary in age from 240 million years to about 90 million years. The Conway Granite has been dated at many localities throughout New Hampshire, Vermont and Maine and these dates vary from 194 to 110 m.y. (Foland and Faul, submitted for publication). The dates for the main batholith, of which the Redstone Quarry is a part, vary from 180 to 168 m.y. The variable ages indicate that the Conway Granite probably did not originate from a single magma chamber, but originated from several different chambers. Alternatively a single chamber may have been dormant over a long time, becoming active periodically perhaps due to a build up of heat generated by radioactive decay.

The lamprophyre dike at a depth of 2009 feet was dated for Stone and Webster Engineering Company by Krueger Enterprises, Inc. The K/Ar method was used and the resultant date is 93.9 ± 4.0 m.y. This age agrees with the ages of some of the youngest members of the White Mountain plutonic-volcanic series in New Hampshire.

Radioactivity of the Conway Granite

The study by Billings and Keevil (1946) was the first to demonstrate that the Conway Granite has a uranium concentration 2 to 4 times that of the average granite. Many subsequent investigations on the Conway Granite and other members of the White Mountain plutonic-volcanic series have confirmed this initial observation.

Adams et al. (1962) magnified the importance of the Conway Granite as a possible low grade uranium and thorium resource. Rogers (1964) compared New England granites with granites in other parts of the United States. He found New England granites, especially the White Mountain plutonic-volcanic series granites are enriched in thorium and uranium relative to other granites. He estimated the average thorium and uranium content of the United States granites to be 15 ppm and 3 to 5 ppm respectively. All lithologies of the White Mountain series, averaged according to relative abundance, have thorium and uranium contents of 33 and 6.9 ppm respectively. Whereas the Conway granite averages 48 and 9.5 ppm thorium and uranium respectively.

Because of these investigations three drill holes in the Conway Granite were drilled in 1962 and deepened in 1963. These drill holes were designated A, B, and C and were all 1000 feet or less in depth. The purpose of these drill holes was to make measurements on the heat flow of the Conway granite and to investigate the uranium and thorium variation at depth.

Roy et al. (1968) found a good correlation between radiogenic heat production and heat flow for these three cores, and suggested that about 60% of the heat flow resulted from radiogenic heat in the upper crust. These three drill holes had an average heat flow of 2.1 HFU (heat flow unit = 10^{-6} cal/cm² sec.). However, unpublished data from the Redstone drill hole indicates a heat flow of only 1.9 HFU (Eggers, D.E., 1976, Appendix I). This decrease is probably due to the presence in the core of lower radioactive lithologies, particularly the green phase of the Conway Granite, the Albany quartz syenite, the hornblende-biotite granite at the bottom of the borehole, and the numerous dike rocks. If the location of the drill hole had been selected in an area which intersected only the coarse-grained red phase, a higher heat flow might have been found. More detailed mapping and surface heat flow measurements need to be made before an optimum location could be determined.

Rogers et al. (1965) measured the thorium, uranium and potassium concentrations of the core from the three previously drilled holes in the Conway Granite, drill holes A, B, and C. They noted that uranium was generally lower in the top part of the core (upper 350-500 feet) than in the bottom section. The lithology of the core was not described in detail. They attributed this behavior to weathering. However, Brimhall and Adams (1969) reinvestigated in detail core A and found that the bottom 500 feet of the core consisted of quartz stringer alteration, which had a higher amount of uranium than normal. They conceded that the upper part had not necessarily lost uranium but that hydrothermal fluids may have increased the uranium content of the bottom 500 feet. This relationship is in complete contrast to the earlier paper by Rogers et al. (1965).

Richardson (1964) investigated the thorium distribution over the surface of the White Mountain batholith and found that it was lognormally distributed. He assumed this meant that the surface of the batholith was homogeneous with respect to thorium. He found that the surface rock samples had lost uranium relative to thorium by leaching due to weathering processes. Accessory minerals in biotite were found to be the main mineral source of the alpha emitters.

Frye (1965) suggested that more than one magma was responsible for the generation of the granites designated as Conway Granite. He found that field relationships between the red and green phases indicated that both magmas were molten during emplacement and that neither magma contained abundant volatile constituents. However the late stage fluids that were generated had high fluorine, sulfur, CO_2 concentrations and a f_{O_2} low enough to have produced minerals containing ferrous ion. It was found thorium was not redistributed by the late stage fluids but that uranium probably migrated substantially.

A recent study by Liese (1973) indicates the western half of the White Mountain batholith represents the latest stage of fractionation. This concept would presumably mean that the magmatic fluids associated with this magma would have higher uranium contents. However, according to recent radiogenic dating by Foland and Paul (submitted for publication) the more highly fractionated rock in the western edge appears to be the older part of the batholith.

FIELD STUDIES IN AND ADJACENT TO THE REDSTONE QUARRY

Geologic Contact Revision

According to the 1956 Geologic Map of New Hampshire by Billings the contact between the Conway Granite and the binary granite trends north-

easterly from Whitton Pond, near the western edge and in the northwest corner of the Ossipee Lake Quadrangle, toward Pequawket Pond; and then easterly toward the western shore of Conway Lake in the northeast corner of the Ossipee Lake Quadrangle (Fig. 1). From the eastern shore of Conway Lake the contact trends northeasterly then northerly along the eastern edge of the mountainous region northeast of the village of Conway and east of the village of North Conway.

Some questions have been asked about the accuracy of this contact. In 1969, Wilson prepared a detailed geologic map of the Ossipee Lake Quadrangle, but did not indicate any contact relations beyond a point about 1.5 miles northeast of Whitton Pond. From this point one might infer that the contact could trend northerly along the west side of Pequawket Pond. Because Wilson illustrates that outcrops of the binary granite occur on the south end of Pine Hill, about 1.5 miles northeast of the village of Conway, one might infer that the Conway Granite-binary granite contact would continue northerly along the west side of Pine Hill and then turn abruptly to the southeast along the east side of Pine Hill.

During the summer of 1976 numerous traverses were made in the vicinity of the borehole to ascertain more information about the contact relations. Outcrops of pegmatite and binary granite were found on the top and northern slope of Pine Hill, about one mile southwest of the borehole. The quartz-rich pegmatite may represent a resistant capping and produced a small, isolated hill within the Saco River Valley.

Traverses made along the Saco River indicate that outcrops of binary granite were intruded by pegmatites. In some outcrops both the granite and pegmatites are intruded by lamprophyre dikes. In addition Billings (1928) shows a small area of binary granite along the Saco River.

Figure 1 Location map showing proposed contact revisions

The binary granite is fine-grained, has a white to gray color and contains both biotite and muscovite mica.

The most distinctive features in these outcrops are the lamprophyre dikes which range in thickness from 2 to 4 feet. They strike approximately N 15° E and dip from 85° southeast to 90°. One of the large dikes contains inclusions of pegmatite, granitic rocks and some dark colored, coarse-grained rocks which may be diorite. The irregular shaped inclusions range in size from less than 1 foot to as much as 2 feet in diameter. One dike has a fine-grained contact zone which ranges from 1 to 2 feet wide.

The pegmatites are coarse-grained and contain microcline-perthite, quartz and some muscovite. Some pegmatites strike N 70° W and others strike N 60° E. All pegmatites are vertical or dip very steeply.

The most prominent joints in the binary granite strike N 60° W and dip 70° northeast and N 20° E with a dip of 90° or very steeply northwest.

The binary granite outcrops on the top and northern slope of Pine Hill together with the outcrops along the Saco River lend support to a local revision of the contact relations between the Conway Granite and the binary granite in the vicinity of the exploratory diamond drill hole. In addition, the thinness of the red phase of the Conway Granite and the appearance of a porphyritic syenite and an amphibole granite in the lower part of the drill core may contribute additional support to the contact relations of the batholith as suggested above.

Scintillometer Survey of the Redstone Quarry

To compare some of the more specific data obtained by the radiation logs of the exploratory borehole, a generalized, but informative, survey

was made in the Redstone quarry with a scintillometer. In addition, some geological observations are described briefly.

The base station, where the instrument was set, is on the edge of the valley floor filled with sand and gravel estimated to be 50 feet thick. The instrument was set so that the needle would make a moderate deflection several hundred feet from outcrops in the quarry and from granite waste piles.

The radio-elements in the green phase of the Conway Granite generate a consistent gamma radiation of 7-9 cps (counts per second). For the red phase the average counts per second are 14-15 (Fig. 2). These differences in gamma radiation in the quarry are comparable to the differences recorded during the geophysical logging of the borehole (Appendix VI).

The predominant alteration zones in the quarry occur in the red phase and at or near the contact between the green and red phases. The zones near the contact are believed to be separate zones even though their location on the pace and compass map (Fig. 2) indicates that they could be continuous. The northern zone lies above the southern zone. Both dip to the southeast and were probably not intersected by the borehole.

The radiation from each zone is very similar to the green phase. Within a distance of 50 feet east of the northern zone (upper zone) the radiation ranges from 8-12 cps, and at a distance of about 150 feet farther east, the red phase is 14-15 cps.

At the alteration zone near the center of the quarry the radiation is 19-20 cps. In another outcrop about 400 feet to the southwest another alteration zone has a count of 16-17 cps. Both zones strike N 35° - 40° W and dip between 70° - 80° southwest. Because of the southwesterly dip this zone was not intersected by the borehole. Exact comparisons cannot be

made between the feldspars in the alteration zone with those in the core because the outcrops have been subjected to considerable surface weathering. Some silicification can be recognized, and in places, small discontinuous quartz veins parallel the strike of the zone and some quartz crystals were observed in small cavities, 1-3 inches in diameter.

The highest radiation recorded in the quarry was 30 cps, in the southern corner near the eastern edge. This high count is believed to be the result of radioactive minerals present in an aplite dike which contains small patches and grains of very dark smoky quartz. The strike of the dike is N 15° E and dips 70° northwest. The radiation count decreases markedly as the dike is traced northward. Eighty feet north of the point of the highest count, the radiation dropped to 15-18 cps. This decrease may be reflected by a change in the color of the fluorite in the dike. In the vicinity of maximum radiation the fluorite is green and becomes colorless northward along the strike. The content of smoky quartz also decreases northward.

The contacts between the aplite dike and the Conway Granite are sharp and the thickness ranges from 4 to 10 inches.

The predominant joints in the green phase of the Conway Granite strike N 35° E and N 55° W and dip between 80°-90° northwest and southwest respectively. The "bedding" joints (sheeting) have an average strike of N 75° E and dip from 5°-25° southeast. The spacing between these joints ranges from about 5 to 20 feet, but the average is 10-12 feet.

The predominant joints in the red phase strike N 45°-55° W and north to N 20° E. They generally dip from 70° to 80°, southwest or northwest respectively. In places, the dip is northeast at steep angles. The "bedding" joints (sheeting) have a similar strike as those in the green

phase, N 65°-75° E. The dip is southwest and ranges from 5°-25°, the average is estimated to be 10° to 15° southwest.

In both the green and red phase some of the steeply dipping joints are very closely spaced, 2 to 4 inches in places, and some have been mineralized discontinuously with quartz and lesser amounts of calcite. These closely spaced joints may have acted as channelways of hydrothermal solutions which deposited small amounts of mineralization and caused only slight alteration of the feldspars.

Although these geologic features cannot be directly correlated with alteration zones, shear zones, cavities, aplite dikes and joints in the core, one can recognize mineralogical, petrographic and structural similarities. For example, calcite has been identified as filling some of the joints in the core, and, patches of calcite still remain on the faces of some joints in the quarry.

The general variations of the radiation between the red and green phases in the quarry are similar to those recorded in the borehole; in both the red phase has a higher count.

The "hot spots" in the quarry, the borehole logs and the core appear to be related to concentrations in the content of the radioactive minerals in the granite, aplite dikes and along some of the joints.

The details of some of the petrographic and mineralogical features in the core will be described in the section, "Description of the drill core."

HEAT FLOW POTENTIAL IN THE CONWAY GRANITE

The Conway Granite has between 2 to 4 times, or more, the uranium and thorium content of "average" granites (Billings and Keevil, 1946) and consequently has higher than normal heat flow (1.8 - 2.2, Roy et al., 1968).

By drilling this hole to a depth of 3000 feet it was felt that a better estimate of the geothermal gradient could be made. Eggers (1976, Appendix I) calculated the radiogenic heat production from the gamma spectra made by a borehole gamma spectrometer. He gives a weighted mean radiogenic heat production over the entire depth of the hole of 14.5 heat generation units ($\text{HGU} = 10^{-13} \text{ cal/cm}^3 \text{ sec.}$). The heat flow of this hole can be estimated from this data by use of a model developed by Roy et al. (1968). The heat flow for this hole should be about 1.9 heat flow units ($\text{HFU} = 10^{-6} \text{ cal/cm}^2 \text{ sec.}$). The temperature at the base of the drill hole was 33°C .

The heat production was less than might have been expected because the drill hole intersected rock types other than the highly radioactive coarse-grained red phase. An estimate of the heat production, if the drill hole had intersected only the red phase, can be made by averaging the data given by Eggers (Appendix I). After neglecting dike rocks and other non red phase lithologies a heat production of 25 HGU is obtained. Assuming that the red phase extended to a depth of 7.2 km, the resultant heat flow would be 2.7 HFU and the temperature at a depth of 1000 m would be 44.5°C . At a depth of 6 km the temperature would be approximately 260°C , well above that necessary for successful production of some types of geothermal power. The question now arises, is there an area in the White Mountain batholith and outlying stocks which contains only the highly radioactive red phase, typical of the red Conway Granite at the Redstone Quarry, for a total depth of 7.2 km? Recent studies by Wetterauer and Bothner (1977) indicate that the Conway Granite extends to a depth of 2.4 km near the Redstone Quarries and becomes deeper toward the center of the batholith.

It is becoming apparent that the Conway Granite does not represent a rock from a single magma source, but rather a series of intrusions whose age is variable from 196 to 100 m.y. Petrographically there are subtle differences between the Conway granite in one area to the Conway Granite in another area. The uranium and thorium concentrations are also variable. In order to locate areas of greater geothermal potential the following studies should be performed.

- (1) Numerous heat flow measurements must be made.
- (2) Gravity, magnetic and seismic studies in the White Mountain area should be made to help determine lithological and depth characteristics.
- (3) Geochemical analyses of most occurrences of Conway Granite should be made. The rare earth contents may indicate which outcrops are derived from similar magmas.
- (4) The different occurrences of Conway Granite should be dated.

Comparison of the above data may indicate which occurrences of Conway Granite are favorable sites for potential geothermal energy. New holes should be drilled in these favorable areas to determine if the above studies have indeed indicated favorable geothermal areas.

PRELIMINARY RADIOMETRIC STUDIES OF THE REDSTONE HOLE

A preliminary study of the gamma spectra was made by Eggers of the U.S. Geological Survey (Appendix I). The analysis of the gamma spectra was done in an estimated manner and is subjective in nature. This procedure was necessary since there was no reference spectra. Recent radiometric analyses of the core done by the U.S.G.S. were provided by Eggers (written communication 1977, Appendix II). A comparison of these results and the gamma spectra results at approximately similar depths (Appendix I)

show a good agreement with most samples. The only major exception is the comparison between the chemical analysis at 1323.5 feet and the gamma analysis at 1321 feet. A very large difference is found between these two analytical techniques at this depth. Petrographically there is no evidence for such large uranium and thorium values as expressed in the chemical analyses. It therefore appears that a twofold dilution error may have been made. Other differences in concentrations between the two techniques may be due to lithological differences, because the samples are taken from slightly different locations (Appendix III) or to inherent uncertainties in the two methods. The samples taken at 2811 feet and 2813.5 feet were just before and in an aplite zone respectively, accounting for the variable concentrations of uranium, thorium and potassium between the two sets of samples. If one can assume the methods are reasonably accurate then it appears uranium is concentrated preferentially to thorium in the aplite zone.

Samples of the core have been sent to several individuals and institutions and will be analysed for many parameters.

DESCRIPTION OF THE DRILL CORE

The core was studied by thin section petrography (125 sections) and detailed hand specimen analysis. The fresh nature of the core made it possible to observe many of the finer relationships between rock types. Appendix III is a detailed written log of the core. Appendix IV is a detailed graphical log of the core. For convenience Appendix V is a less detailed lithologic log at the same scale as the geophysical logs. This allows quick comparison of the various logs.

The drill core consists of four major rock types, the green phase

and the red phase of the Conway Granite, the Albany quartz syenite and a medium-grained biotite-amphibole granite.

Minor rock types encountered include a dark foliated fine-grained rock at a depth of 1260 feet, a mottled greenish rock at depths of 1410, 1600 and 1850 feet, lamprophyre dikes at depths of 1650, 1725, 1950, 2000, 2360 and 1545 feet, and aplite and fine-grained pink granite dikes at numerous locations.

Major Rock Types

Green phase of the Conway Granite

The green phase of the Conway Granite is a medium-grained hypidomorphic rock composed of altered green micro-perthite, smoky quartz, hastingsite, biotite, and minor plagioclase. The micro-perthite crystals usually average 3 to 5 mm and generally have an anhedral outline with some crystals having a tabular habit. They are often 10-30% altered (90% in some sections) to a green, cream or tan colored opaque material, probably kaolinite with varying amounts of iron oxide and other impurities.

The smoky quartz has occasional wavy extinction, contains some small inclusions and generally has an anhedral outline with a few euhedral crystals present. The grain size ranges from .5 to 2.5 mm.

Plagioclase, albite, is not very abundant and usually consists of euhedral lath-like crystals. Their size ranges from 1 to 2.5 mm. They are usually much less altered than the microperthite and the alteration is clearer or more crystalline.

The dark mineral is mainly amphibole, hastingsite, which is not well crystallized, which often has rather feathery edges and ranges in size from 1 to 3 mm. It is the first mineral to be altered by hydrothermal solutions.

Biotite is found as very irregular crystals, 1 to 2 mm in diameter usually adjacent to the amphibole crystals. Biotite usually is only about one-tenth as abundant as hastingsite. Common accessory minerals include zircon, fluorite and monazite.

Red phase of the Conway Granite

The red phase of the Conway Granite is a coarse-grained hypidomorphic rock composed of microperthite, smoky quartz, biotite, minor plagioclase and amphibole. The microperthite crystals usually average 4 to 7 mm in diameter and are commonly 40 to 90% altered to a cream to tan-colored opaque mineral which is probably kaolinite with varying amounts of iron oxide. The microperthite contains coarse stringers and irregular patches of albite rather than the normal finely interlaced microperthite.

The smoky quartz varies in diameter from 1 to 3 mm and has a slight wavy extinction with minor dusty alteration. The grains are usually anhedral and slightly rounded.

Plagioclase, albite, is mainly found as patches in the perthite and as small anhedral grains .5 to 1.5 mm in diameter. It is usually very slightly altered with often only the core being affected with a translucent alteration product.

The common dark mineral is biotite which is usually light brown with strong pleochroism and generally contains abundant inclusions of accessory minerals such as zircon, allanite, monazite and thorianite. The crystals of biotite range in size from 1 to 3 mm in diameter.

Accessory minerals include hastingsite, apatite, zircon, fluorite, allanite, monazite and thorianite.

Albany quartz syenite

This rock varies in color from dark blue-gray, pastel olive-green, light green-gray to a gray-pink. The color is mainly due to the color of the feldspars, which consist principally of an orthoclase mantled by a thin rim of potash feldspar. These mantled feldspars are what give this rock its characteristic appearance. Generally only a few mantled phenocrysts of anorthoclase are found, and these usually have a different color than the non-rimmed phenocrysts of microperthite.

The anorthoclase is up to 40% altered to a light brown to green opaque dusty alteration. The crystals are subhedral with very irregular boundaries showing considerable replacement by plagioclase, amphibole and small zoned quartz crystals. It also has a substantial amount of apatite and other accessory minerals as inclusions.

Plagioclase consists of many small crystals, .2 to .5 mm, as well as a few larger 2mm crystals. Most crystals are euhedral with albite twinning and having very little alteration.

Microperthite is found as fairly well developed anhedral crystals as well as the mantling on some of the anorthoclase crystals. They also have abundant brown opaque alteration similar to the anorthoclase. Microperthite is more abundant than anorthoclase in the thin sections.

Quartz consists of smoky anhedral crystals, .5 to 1 mm, and smaller euhedral quartz crystals "filling" spaces between the other crystals. Little alteration and few inclusions exist in the quartz.

The principal dark mineral is hastingsite. It occurs as anhedral badly corroded and fractured crystals. The crystals are about .5 to 1 mm in diameter and are found in groups of different orientation. Magnetite and apatite are commonly found as inclusions in the hastingsite.

A small amount of biotite is found in the sections, usually abutting the hastingsite. Some sections show biotite with a feathery outline partially replaced by hastingsite. Very few inclusions occur in the biotite, however a few anisotropic minerals with a square or prismatic outline and high birefringence (zircon) are found.

The main accessory minerals are fluorite, apatite, magnetite and abundant zircon.

Hastingsite-biotite granite

The bottom 200 feet of the drill hole consist of a hastingsite-biotite granite. In hand specimens the feldspar and quartz crystal edges or rims are not very easily discernable and the dark minerals are found mostly in clots. The feldspars are typically pink to gray in color. A modal analysis is given in Table 1.

The main feldspar is microperthite which is variable in size from 1 mm in diameter to crystals larger than 3 by 5 mm. These crystals have some dusty opaque alteration, 10-30%, and commonly have a sub-hedral outline with badly corroded edges, with very small crystals of quartz and plagioclase spearing these crystals.

The plagioclase is less abundant than the microperthite and consists of small 1 mm and smaller good euhedral crystals usually interstitial to the microperthite and amphibole crystals. The plagioclase has a clearer, less abundant alteration than that of the microperthite.

Quartz exists as large irregular crystals 2 mm in diameter and small rounded crystals .1 mm in diameter. The smaller crystals occur interstitially between the larger crystals and as poikilitic intergrowths in the other major minerals. The quartz hardly ever shows alteration and very few inclusions are found (mainly apatite).

TABLE 1 Modal Analyses

Sample Depth	1256'	1428'7"	1418'7"	2997'	2931'6"	2795'
Description	Fine-grained foliated granite	Mottled quartz syenite	Mottled quartz syenite	Amph-bio granite	Amph-bio granite	Amph-bio granite
Microperthite	49.0	66.2	68.5	57.0	53.3	54.9
Quartz	38.3	16.3	13.6	27.1	27.9	30.6
Plagioclase	3.7	7.1	7.4	8.1	9.0	5.4
Amphibole	7.2	8.0	9.6	2.3	3.7	8.5
Biotite				3.8	5.4	.3
Assessories	1.8	2.4*	.9*	1.8	.7	.3

* Mostly fluorite

Amphibole is brown to dark green and probably is hastingsite. The crystals are usually ragged but a few prismatic crystals exist and most crystals show a poikilitic intergrowth of quartz and plagioclase. Magnetite is frequently found as inclusions.

Biotite is less abundant than amphibole but is conspicuous in places. It has a similar ragged shape with poikilitic intergrowths of quartz and plagioclase. Inclusions in the biotite are mainly magnetite and zircon.

The accessory minerals are magnetite, zircon, apatite and very minor fluorite.

Minor Lithologies

Coarse-grained mottled syenite

A coarse-grained mottled rock is found in three locations, from 1409 to 1428 feet, 1594 to 1598 feet and 1849 to 1861 feet. In each occurrence the upper and lower contacts are bounded by fine-grained granite which appears to be a crushed, coarse-grained red phase of the Conway Granite. However, evidence of shearing is not present in the thin sections. The rock may have been molten enough to have healed all fractures.

The rock is composed of microperthite, plagioclase, quartz, amphibole and considerable fluorite. A modal analysis indicates that this rock is a quartz syenite (Table 1). The microperthite is found in crystals up to 6 mm in diameter showing very patchy plagioclase perthites with the microperthite up to 90% altered to a brownish clayey material. The edges of the microperthite are very ragged, probably replaced by quartz and plagioclase.

The plagioclase is found mostly in the microperthite. In the section at 1418'10" it almost completely replaces the microperthite. However, in the other two occurrences of this rock the plagioclase crystals are good lath-like, euhedral crystals which are largely free of alteration and are visible throughout the thin sections. Soda appears to replace the potash feldspar in all sections. The plagioclase generally forms very small crystals, 2 mm and smaller with most of them being less than .5 mm in diameter.

The quartz averages from 2 to 4 mm in diameter with most crystals much smaller, down to less than .1 mm in diameter. It is found unevenly distributed in the rock with the crystals usually clustered together. The quartz has a smoky color, is free of alteration and has few inclusions. The larger anhedral crystals have a very irregular outline. Many of the smaller crystals are equant and rounded.

The amphibole, olive to brown in color, is an anhedral and irregular mineral showing significant poikilitic intergrowth of quartz and plagioclase. The amphibole crystals are clustered together forming conspicuous clots which give the rock its mottled appearance. Inclusions of magnetite are common. Some of the amphibole is replaced by a red-brown mineral, which is slightly pleochroic with non-parallel extinction. The amphibole has also been replaced by a much lighter green, slightly pleochroic, highly birefringent mineral which is probably hedenbergite.

Biotite is not found in any of the thin sections taken from this rock type. The existence of uranium- or thorium-bearing minerals is not evident except in the section taken at 1410 feet. This section has several small (.1 mm) brown opaque, rectangular minerals which have

radiating fractures into the surrounding feldspar. This mineral probably accounts for the relatively higher radioactivity at this depth.

Perhaps the most significant accessory mineral found in this rock type is fluorite. Fluorite is easily visible in hand specimen and is a light amber color. In fact, the fluorite content ranges from 5% to 10% in the thin section taken at 1852 feet.

Fine-grained foliated granite

Fine-grained, foliated dark greenish-gray rock is found from 1253 to 1267'6". A modal analysis indicates it is of granitic composition (Table 1). The rock consists mainly of microperthite, quartz, hornblende, minor plagioclase and fluorite. The microperthite is 50% to 90% altered to a very dark alteration which is largely responsible for the rock's color. The microperthite crystals appear to be broken into many irregular chips which often are partially replaced by quartz grains. The feldspar grains average less than .5 mm in diameter and are usually bounded by irregular quartz grains.

The quartz grains are always less than .5 mm in diameter, are very irregular and are very clear with only a few fluid inclusions. The quartz grains do not display any undulatory extinction.

The mafic mineral is hornblende. It occurs as partially developed crystals about .5 mm in diameter and as small flakes less than .2 mm of very irregular outline. Both show poikilitic intergrowth of quartz.

The rock has a moderate amount of fluorite as small irregular grains "filling in" between other minerals. This rock has a recognizable foliation roughly parallel to the contacts with the coarse-grained red phase.

Lamprophyre dikes

Lamprophyre dikes are found exclusively between depths of 1638 and 2547 feet. Three steeply dipping dikes, probably greater than 10 feet thick are found at depths of 1650, 1725 and 2000 feet. Thinner dikes less than 1 foot in thickness are found at 1720, 1950, 2363 and 2546.5 feet. It is interesting to note that all lamprophyre dikes are found in less than 1/3 of the core and that all but one thin dike are found in the red phase of the Conway Granite. The significance of these observations is not known.

The lamprophyre dikes are generally camptonite containing crystals of barkevikite, augite, plagioclase and chlorite. These dikes have conspicuous vesicles filled with calcite. The contacts with the host rocks show a fine-grained chilled margin with a very steep angle of greater than 70°.

Petrography of the Alteration Zones

Eight significant alteration zones exist in the drill core and these range in size from 150 feet to 3 feet in thickness. Four of these occur in the green phase, two in the red phase and two in the bottom hornblende-biotite granite. No major alteration zones occur in the Albany quartz syenite.

One alteration zone from the green phase and one from the red phase will be described in detail. The other alteration zones have similar characteristics and will not be described. Assumptions on the chemistry and temperature of the hydrothermal fluids responsible for this alteration can be made by examining the petrography.

Alteration zone in the green phase

At a depth of 471 feet the first alteration zone was intersected. It consists of complete kaolinization of plagioclase (albite) with almost no alteration of the other minerals. The onset of this zone is very sudden and extends only 6 inches, from 471 feet to 471'6". The potash is highly altered to a dusty clay mineral, probably illite and kaolinite with some hematite. The dark minerals, hastingsite and biotite, are altered to what appears to be montmorillonite and hematite. The content of sericite increases downwards and becomes very abundant at a depth of 473 feet. At 478 feet albite appears again, replacing the potash feldspar to a minor degree. The other alteration effects remain about the same. A near vertical fracture extends from 480 to 481 feet below which the potash feldspar crystals are more highly altered, replaced by more sericite. Quartz is less abundant and considerable amounts of a dark green, opaque, fine-grained mineral occur (probably montmorillonite). The dark green mineral disappears and the feldspars become salmon colored from 484 to 488 feet. Quartz is almost lacking and secondary plagioclase and sericite are more abundant in this section. The potash feldspar is highly altered and replaced by sericite. From 488 feet to 494'10" the dark green mineral, montmorillonite, appears again similar to the alteration from 481 to 484 feet. The montmorillonite disappears at 494'10" and the feldspars become very white and albitized. Only a few quartz grains are visible. Minor sulfides are very conspicuous at this depth. This zone continues to 522'8" where the green montmorillonite appears again, however it alternates with the previously mentioned white zones. At 532 feet the feldspars become salmon colored and alteration decreases with the disappearance of the

montmorillonite. Quartz increases with much less alteration from 535 to 539 feet. At 539 feet the albite is again the only mineral altered. Its alteration to white kaolinite marks the end of the alteration zone, however alteration begins again at 539'6" in a similar repetitive manner up to 609'10", at which point the alteration ends completely.

Two main channel ways appear to have existed in which the hydrothermal solutions passed, or the channel split, leaving an island of unaltered rock at 539 feet. The temperature of the fluids was probably between 150°-250° because the alteration zone shows typical epithermal mineral relationships. The conspicuous occurrence of albitization suggests that the hydrothermal fluids were probably rich in soda.

Alteration zone in the red phase

At 1753 feet to 1754'6" fractures are sealed with a dark mineral, chlorite or montmorillonite, with very red feldspars. From 1754'6" to a depth of 1759 feet coarse-grained red granite occurs with some fractures but less dark material is found. Biotite is altered to chlorite and magnetite, and abundant chlorite occurs throughout the potash feldspar from 1759 to 1761 feet. Abundant sericite appears at 1761 feet and quartz disappears and gradually becomes less abundant up to 1765 feet. Quartz increases and sericite decreases from 1765 to 1766 feet. From 1766 feet to 1767'4" a fine-grained dark green zone is present, and looks like an altered xenolith or segregation which was high in mafic minerals. As the quartz decreases the number of cavities increases and sericite increases from 1767'4" to 1768'6". Some of the quartz crystals which remain appear to be better crystallized, whereas other crystals are quite ragged. Another altered xenolith

or segregation exists from 1768'6" to 1768'8". From 1768'8" to 1773' feet the potash feldspar becomes whiter, with fine green veins occurring in the crystals producing a green appearance. Quartz is fairly abundant with considerable sericite, montmorillonite, and in places many small cavities. Quartz decreases from 1772 feet to 1773 feet. Feldspars become cream colored with considerable sericite, less montmorillonite and a loss of most of the quartz produced many cavities down to 1775 feet. From 1775 feet to 1776'6" the cavities are filled with calcite, with amounts of sericite and montmorillonite similar to that as noted from 1772 feet to 1773 feet. At 1776'6" a sharp contact occurs with the red granite. The prominent minerals are quartz, red potash feldspar and altered biotite. This rock is much less altered than the previous section and it is in contact with a zone of micro-graphic granite at 1778 feet, ending the alteration zone.

Contact Relationships

Green and red Conway Granite contacts

The green phase of the Conway Granite is in contact only with the red phase of the Conway Granite at depths of 985'9", 1012'6" and 1019 feet. The contact at 985'9" is not very sharp and extends over a distance of 3 or 4 inches. In fact, large phenocrysts of the red phase are found 6 or 7 inches into the green phase and crystals of the green phase are found 6 or 7 inches into the red phase. The contact angle cannot be determined accurately but it appears to be about 40° . Another section of the green phase occurs from 1012'6" to 1019 feet; these contacts are not very sharp. The change of the dark mineral from hornblende in the

green phase to biotite in the red phase may be observed in the thin sections before the grain size and color can be distinguished.

No age relationships between the two rock phases can be determined. Apparently both rock types were crystallized with a lower volatile content, because the feldspars are less altered. In addition, the green phase has less fluorite and contains amphibole rather than biotite. According to the gamma log and analysis made elsewhere (Frye, 1965) the radioactivity of the green phase is one-half of the red phase, another indication that the red phase is a more differentiated rock.

Red phase and Albany quartz syenite contact

The first contact between the red phase and the Albany quartz syenite occurs at a depth of 1020'6". The contact is distinct but is not sharp. It dips at an angle of about 45° . The red phase appears to have a slightly finer margin at its boundary, but it certainly is not a chilled contact, and the existence of the finer material is subjective and perhaps somewhat questionable.

The above features of this contact indicate that both rocks were molten or at least were a crystal mush during emplacement. This condition implies that the rocks are of similar age.

The quartz syenite is in contact with the red phase again at 1128 feet. It is a distinct but not a sharp contact. In thin section the contact is found by identifying the dark minerals because the red phase contains mostly biotite and the Albany quartz syenite contains only hastingsite.

Another contact between the red phase and the Albany quartz syenite

occurs at 2295 feet. This contact is distinct but no chill zone or shearing is found. The contact dips at approximately 30° . Many zones of the red phase are found in the Albany quartz syenite and appear to be mostly assimilated. Similarly, the red phase contains many zones of assimilated syenite near the contact. It is concluded that both rocks were a crystal mush during intrusion and mixing occurred near the contacts. However, the syenite in the mixed zone appears to be highly crushed and assimilated, indicating that the red phase may be slightly younger and the Albany was in a stage of semi-solidification.

Albany quartz syenite and hornblende-biotite granite contact

The Albany quartz syenite is found in contact with the hornblende-biotite granite at a depth of 2800 feet. The contact is sharp at an angle of 45° and shows no evidence of resorption of either the syenite or granite. The syenite looks unaffected whereas the granite appears slightly finer-grained and sheared at the contact. Apparently the granite is younger and intruded into the syenite.

Mottled quartz syenite and red phase contacts

The upper contact of the mottled quartz syenite in each of its three occurrences is preceded by a fine-grained zone which appears to be a crystal mush of red phase. The contact of the fine-grained zone and the mottled rock is sharp but not chilled at an angle of approximately 45° . The bottom contact is represented by a mixed zone of mottled syenite and red phase.

A zone of assimilation appears to be present below the mottled rock but the upper contact may be a zone of movement with partial crushing of the red phase when it was a crystal mush. The mottled zone

found from a depth of 1849 feet to 1861 feet is different in that the bottom contact zone contains a mixture of the mottled rock and red phase which, in turn, is separated from the main red phase by a fine-grained "mushy" zone of the red phase.

The origin of this mottled quartz syenite is not known but it may represent a partially assimilated xenolith or it may represent a separate magma which intruded into the red phase.

The syenite composition of the mottled rock suggests that if it is a xenolith it may represent a piece of the Albany quartz syenite which moved upward during intrusion of the red phase. However if it were a xenolith of the Albany, one would expect to find a similar rock type at the Albany and red phase contact. No such rock is found at this contact.

The existence of another magma with the composition of the mottled phase is difficult to prove because this rock has not been recognized in other field and subsurface studies of the White Mountain plutonic-volcanic series. The abundance of fluorite indicates the parent magma was high in fluorine and probably high in other volatiles.

Fine-grained foliated granite and red phase contacts

The fine-grained, foliated granite from 1253 feet to 1267'6" lies within the red phase of the Conway granite. These upper and lower contacts are very sharp at about 20° . A few large crystals of the red phase are found in the finer-grained granite and thin section of the contact shows some replacement of the red phase by the fine-grained rock, indicating that the fine-grained, foliated rock is younger than the red phase.

The sequence of events as displayed by the core is probably the

following. Intrusion of the Albany quartz syenite, and partial solidification, followed by intrusion of the red and green phases almost simultaneously. Soon after, while the red phase was semi-solidified, the mottled quartz syenite intruded. A period of cooling and probable uplift occurred, after which the amphibole-biotite granite and the fine-grained foliated granite intruded. Soon after aplite, fine-grained granite, and a few pegmatite dikes intruded; then hydrothermal fluids were generated and formed alteration zones in the different rocks. The last event, intrusion of the lamprophyre dikes, occurred after the previous rocks were solidified.

The contact angle relationships are shown by the two histograms displayed in Figure 3. The major and minor rock types are separated from the dike rocks for this display. Even though a 2 inch core is probably not representative of the contact angle, certain relationships are indicated. The major and minor rock types all have contact angles less than 50° , whereas all but one of the dike rocks have contact angles greater than 40° . Intrusion of White Mountain series rocks has thought to have been by forceful injection at steep angles. From the contact angle measurements made in this study it appears that the main lithologies intruded at rather low angles. The drill hole is located near the edge of the batholith, and this may account for the low angles. The dike rocks, however, intruded at steeper angles, perhaps due to expansion of crystallizing magmas, creating steep tension fractures into which these dikes intruded.

Figure 3 Histogram of the contact angles of the major rock types and dike rock

RELATIONSHIP OF RADIOACTIVITY TO PETROGRAPHY

This section summarizes comparisons made between visual observations of both hand specimens and thin sections, and the natural gamma log of the drill hole conducted by the U.S. Geological Survey (Appendix VI). This type of comparison is useful for identifying possible uraniferous rocks in the field and for lending support to assumptions made in regard to the cause of uranium mobility. The different types of rocks are subdivided and discussed separately. A detailed description of the rock at each point of high and low radioactivity is given in Appendix VII.

The Green Phase

The background radioactivity is remarkably constant at a value of approximately 350 pulses/second. A total of 16 peaks in radioactivity is found varying from 280 to 645 pulses/second. Each radioactive peak coincides with fine-grained granites or aplite dikes with sharp contacts, mushy, fine-grained shearing or zones of minor rock alteration.

These observations indicate that the radioactive elements were higher in the dike rocks and the source magma of these rocks is different from that of the green phase. In the case of the altered and mushy zones, solutions may have passed through the rock adding radioactive elements from an exterior source. Of significance is the fact that no valleys are found below background radioactivity associated with the peaks, indicating that the peaks in radioactivity must be due to radio-element input from an exterior source rather than to redistribution from the surrounding rock.

The Red Phase

The background radioactivity of the red phase is exceedingly variable

with many peaks and valleys, and averages between 650-750 pulses/second. Most of the valleys, with the exception of the valleys caused by the lamprophyre dikes, are higher than the peaks found in the green phase. In contrast to the green phase it appears that the peaks in the red phase are normal, and the valleys may represent a loss of radioactive elements. As a general rule perhaps 80% of the time, zones of relatively lower radioactivity are related to finer-grained rocks, mushy areas and zones of alteration. In contrast to the green phase this decrease in radioactivity indicates that fluids passed through or were generated in these zones with the radio elements being mobilized. More detailed analytical work needs to be done before these assumptions can be verified.

The fact that the valleys in the red phase are as high as the peaks in the green phase lends support to the fact that the red phase may be the source of the fine-grained rocks in the green phase, or perhaps all fine-grained rocks have a similar source.

Albany Quartz Syenite

The background activity of the Albany quartz syenite is more irregular than the green phase, but not as irregular as the red phase. The background is approximately 200 pulses/second. This irregularity is due to the heterogeneity of the rock in this part of the core. For example, from 2410 to 2440 feet the rock consists of syenite intimately mixed with the red phase. From 2456 to 2493 feet the core consists of syenite with numerous zones of pegmatites andmiarolitic cavities. Brecciation with minor alteration is found from 2600 to 2650 feet.

Aplite, fine-grained granite dikes and a few areas of minor alteration are the zones high in radioactivity. Significant valleys exist at

depths of 2644 and 2746 feet which are correlated with minor alteration zones and mafic segregations, respectively.

In thin section the radioelements appear to be associated with zircon and those opaque minerals occurring as inclusions in quartz and feldspar.

Hastingsite-Biotite Granite

The hastingsite-biotite granite has a background radioactivity of about 260 pulses/second, which is higher than the syenite but lower than the red and green phases. The background is remarkably stable, with the only peak being near the contact with the Albany quartz syenite. The higher radioactivity at this point is due to the presence of an aplite dike.

In thin section crystals of monazite or thorianite were not observed but zircon was conspicuous. Probably the radioelements are contained in this mineral.

Coarse-Grained, Mottled Quartz Syenite

The mottled quartz syenite from 1409'3" to 1430'6" is high in radioactivity in its upper part and is apparently due to small rectangular opaque minerals which have radiating fractures around them. These minerals are probably allanite or thorianite. The lower part of this mottled zone is much less radioactive (300 pulses/second) than the red phase. At the lower contact with the red phase the radioactivity rises again due to the normal levels of that phase.

The mottled quartz syenite from a depth of 1594 to 1598 feet, although a relatively narrow zone, is reflected in the gamma log as a valley, 250 pulses/second lower than the red phase abutting this zone.

A valley, 300 pulses/second lower than the adjacent red phase, is found from a depth of 1849 to 1863 feet, coinciding with the third zone of mottled quartz syenite. Although this rock is of syenitic composition and the radioactivity is much lower than the red phase, it is higher than the Albany quartz syenite by 100 to 200 pulses/second.

Fine-Grained Foliated Biotite-Amphibole Granite

The radioactivity of the pink phase above the upper contact (1253 feet) shows a remarkable dip of 300 pulses/second which continues to the contact. The radioactivity increases in the fine-grained granite in a rather irregular manner to a radioactive level from 150 to 100 pulses/second below the red phase. At the lower contact (1267'6") the radioactivity of the pink phase again takes a dip to about the same value as the upper contact and remains low for 10 feet before again reaching normal levels.

The mineral probably responsible for the high radioactivity is an elongated lath-like dark brown mineral which has very slight pleochroism. The minerals are nearly isotropic and have a very low birefringence. These minerals might be a radioactive apatite, which is quite different from the radioactive minerals in the other rock types.

Lamprophyre Dikes

Wherever the gamma probe crossed a lamprophyre dike the log showed a very low radioactive level of about 100 pulses/second. These dikes are the most consistent rock type with respect to radioactivity, showing very little variance. The radioactivity of the smallest dikes is not reflected as such a low value apparently due to the lack of sensitivity of the probe.

Fine-Grained Granites, Aplites and Mushy Zones

In the green phase the radioactive peaks are either due to fine-grained granite, aplite dikes or small fracture zones. Wherever the fine-grained dike rock is encountered there is a peak in radioactivity. These peaks go up to 650 pulses/second, but average between 400 and 500 pulses/second.

The radioactivity of the red phase is much more complicated than the other rock types. Probably most of the peaks indicate the normal granite and the valleys coincide with abnormal zones. Peaks which are above the normal background can almost always be correlated with miarolitic cavities, whereas valleys in radioactivity are usually correlated with either mushy zones or fine-grained granite dikes. Nevertheless, these valleys in radioactivity in the red phase are generally a similar height as the peaks in the green phase. Thus the fine-grained dike rocks found in both phases probably have a similar origin. The mushy zones are found mainly in the red phase. They appear to be zones where movement occurred when the granite was partially solidified thereby losing radioactive elements. Similar to the behavior of the dike rocks in the green phase, the dike rocks in the syenite and hornblende-biotite granite follow a similar pattern and are represented by peaks in the gamma log.

The minerals responsible for the higher radioactivity in these fine-grained rocks appear to be monazite and thorianite, although identification is difficult because many minerals have an extensive alteration halo.

Relationship of Radioactivity to the Alteration Zone

The gamma log of the alteration zone at 471 to 620 feet shows a large variation in radioactivity. A large peak, 150 pulses/second above background is found in the beginning of the alteration zone down to 492 feet. A slight valley occurs at 527 feet. Beyond this point a series of peaks continue to the end of the alteration zone. It appears as if this alteration zone has gained radioactivity. The mineral locale of this radioactivity is not evident, however the radioactive elements might be related to the various opaque clay minerals.

The alteration zone from 1753 to 1779 feet shows a similar relationship to the above alteration zone. The background radioactivity of the red phase is very irregular, and the distinction between a peak and a valley with background is very difficult. But in relative terms the peaks occur at the beginning and end of the alteration zone with a valley in the center of the zone, similar to the alteration zone between 471 and 620 feet.

Whether the radioactive elements increase or decrease through the alteration zone cannot be answered without extensive sampling and chemical analysis. If these alteration zones represent channel ways in which mineralizing solutions flowed, then these solutions could have extracted significant uranium, thorium and other minerals. These metals might have been reconcentrated in favorable areas to form an economic mineral deposit.

FRACTURE PATTERNS WITHIN THE REDSTONE DRILL HOLE

The fracture pattern in the core is displayed by the histograms in Appendix VIII. Low-dipping fractures ($0-5^{\circ}$) are abundant in the upper part of the core, but are relatively scarce, or missing, below 600 feet. These low angle fractures (known as sheeting) are probably release fractures caused by glacial unloading or bedrock erosion. A similar hypothesis is that these fractures are caused by progressive lowering of the surface of the earth due to erosion and consequent decrease in the confining pressure, causing the rock to expand in all directions. The vertical expansion is unimpeded whereas the horizontal expansion is hindered by rock. Compressional forces parallel to the surface of the earth develop and cause rupture (Billings, 1972).

The steeper fractures, which appear to be developed in clusters in the core (Appendices IV and VIII) are caused by a different mechanism. Some may be caused by vertical compressional forces which developed in response to intrusion of magma, others may be caused by horizontal tensional forces due to crystallization of magma, and possibly to plate tectonic movement, which provided the channels for the original intrusion of magma, and whose movement continued after emplacement.

Figure 4 is a plot of the number of fractures in 50 foot intervals versus depth. Superimposed on this plot are the major lithologies and alteration zones. The peak from 0 to 200 feet is due to the abundance of near horizontal fractures, whereas the other peaks are due to numerous steep fractures (see Appendix VIII). Many of these fracture zones are accompanied by alteration zones, indicating these fracture

Figure 4 Frequency of fractures in 50 foot intervals versus depth

zones acted as channel ways for solutions. This implies that the fractures formed soon after or during a magmatic event, thus are probably not recent fractures. There does not appear to be any relationship between the distribution of fractures and the occurrence of different rock types.

The abundance of fractures throughout the core indicates that hydrofracturing of the rock for production of geothermal heat would be very successful. The fracture pattern found in the Redstone hole probably would be similar in other areas within the Conway Granite and hydrofracturing would likely be successful.

THE PROBABILITY OF VEIN-TYPE URANIUM DEPOSITS ASSOCIATED WITH THE CONWAY GRANITE

The following discussion will compare the physical and chemical characteristics of the Conway Granite to granites which have known vein-type uranium deposits associated with them. Evidence for uranium mobility within the Conway Granite also will be presented.

Rich et al. (1975) summarized the physical and chemical characteristics of granitic rocks that contain associated vein-type uranium deposits.

These characteristics are the following:

- (1) The parent granitic rock has a high uranium content compared to the average granite.
- (2) The parent granitic rocks are usually of Precambrian, late Mesozoic or Tertiary age.
- (3) Open space fractures are related to intrusion of the granite, and mineralization in these fractures is usually of a simple nature.

The Conway Granite has 2 to 4 times the uranium content of "average" granites (Billings and Keevil, 1946). It has an age ranging from 194 to 110 million years (Foland and Faul, submitted for publication). Cox (1970) found that the lead and silver veins in New Hampshire and Maine related to the White Mountain plutonic-volcanic series were formed as open space fillings in tension fractures produced by the magmatic activity.

The prerequisites for the formation of a vein-type uranium deposit, as determined by Rich et al. (1975) are:

- (1) A source of leachable uranium.
- (2) A reducing agent.
- (3) A hydrologic setting in which large amounts of fluids can pass through a sufficiently small volume of rock favorable to pitchblende deposition.
- (4) A source of highly oxidized solutions.

The Conway Granite is a good source of uranium because most uranium-bearing minerals are contained in easily altered biotite (Frye, 1965). Several lines of evidence indicate this uranium is mobile. The "mushy" zones in the red phase were probably formed by movement in the partially crystallized magma. The lower radioactivity of these zones indicates that uranium was mobilized and removed by magmatic fluids passing through these "mushy" zones. Another indication of magmatic movement of uranium is the emplacement of aplite and fine-grained granite dikes which have a lower radioactivity than the red phase but a higher radioactivity than the green phase of the Conway Granite. The source of these rocks is not known, but their mineralogical compositions indicate a closer association to the red phase and they

may have originated from the same magma. If this is true then some uranium was lost from the dike magma before emplacement. However, if the dike rocks are related to one of the lower radioactive lithologies, then uranium was mobilized and concentrated in the dikes.

More interestingly, perhaps, is the presence of alteration zones which indicate low temperature (100° - 250° C) hydrothermal activity. The zones found in the Redstone core contain minor sulfides and hematite, and show both peaks and valleys in radioactivity. The occurrence of many areas in the White Mountain batholith of "Rottenstone" may be due to the weathering of alteration zones and not fresh bedrock. A different kind of alteration was found by Brimhall and Adams (1969) in Core "A". It consisted of a quartz stringer type alteration which is higher in uranium content than the surrounding bedrock. It has low temperature characteristics and is associated with small amounts of metal sulfides.

Reducing agents necessary for deposition of uranium are found as sulfides in known base metal vein deposits, and mafic minerals associated with the surrounding metasedimentary rocks (Littleton formation). In fact, the Littleton formation contains on the average 5% to 6% FeO (Billings and Wilson, 1964).

Tension fractures probably produced by the intrusion of White Mountain plutonic-volcanic series rocks have created porous channel ways in which occasionally base metals are already found. The association of fracture zones with alteration zones in the Redstone core indicates large amounts of fluids passed through the granitic rocks and possibly into the surrounding metasedimentary bedrock.

The source of oxygenated solutions depends on the origin of these waters. The potential ore solutions may be descending or deeply circulating surface waters which have reached equilibrium with atmospheric oxygen. They may also be deep ascending waters of non-surface origin which have equilibrated with an oxidizing substance such as hematite. The red color of the microperthite in the red phase is probably due to fine grains of hematite. The red color is more abundant in zones near fractures where minor alteration has occurred, indicating oxidizing solutions had passed through these zones. Several hematite vein deposits which may be associated with the White Mountain plutonic-volcanic series are known. Examples are the Iron Mountain and Franconia Iron Mines. These mines and the red feldspars indicate that oxidizing solutions, which could mobilize uranium, were present.

No known vein-type deposits occur in or near the Conway Granite, however, recent radiometric surveys show many unexplained anomalies, generally along the margin of White Mountain plutonic-volcanic plutons. Additional exploration evidence may be available in 1978 if the results of the stream sediment and ground water NURE program are put on open file. A comparison of these results with the radiometric data should indicate good exploration targets.

Uranium vein-type deposits may not have been found to date for two reasons.

- (1) The less competent fracture zones have been eroded deeply and subsequently have been covered with extensive glacial overburden.
- (2) No systematic searches have been made.

In summary, the ingredients for the formation of vein-type uranium

deposits are present in the area containing the White Mountain plutonic-volcanic series and it remains for the exploration geologist to find them.

SUMMARY AND CONCLUSIONS

Heat Flow Potential

An estimate of the heat flow potential of the Redstone drill hole gives a value of heat production of 14.5 HGU and a heat flow of 1.9 HFU. It is estimated that if the hole had intersected only the red phase and this phase continued to a depth of 7.2 km that the heat production would have been 25 HGU and the heat flow would have been 2.7 HFU, producing a temperature of 260°C at 6 km. Even higher temperatures would be found in areas where the red phase of the Conway Granite is overlain by a metasedimentary cover. The apparent low angle contact relationships found in the drill hole indicate areas might be found where this condition exists. Detailed geophysical, geological and geochemical studies need to be made before the optimum location for geothermal potential can be found.

Description of the Drill Hole

The Redstone drill core intersected four lithologies; the green and red phase of the Conway Granite, the Albany quartz syenite and a medium-grained hastingsite-biotite granite. Minor rock types included a foliated fine-grained granite, a mottled quartz syenite, many lamprophyre dikes and numerous aplite and fine-grained granite dikes.

The average radioactivity of the different rock types is: the green phase, 350 pulses/second; the red phase, 700 pulses/second; Albany quartz syenite, 200 pulses/second; and the hastingsite-biotite

granite, 260 pulses/second. All the rock types except the red phase have fairly uniform radioactivity. The red phase's irregularity in radioactivity is due to numerous "mushy" zones and aplite and fine-grained granite dikes, suggesting that the radioelements have been mobilized.

The distribution of fractures shows an abundance of low dipping fractures near the surface and steeply dipping fractures throughout most of the core at depth. The abundance of fractures throughout the core indicates that hydrofracturing would be successful.

The drill core intersected several alteration zones up to a thickness of 150 feet. These alteration zones have mineral assemblages which indicate a low to medium temperature, and may indicate passage of mineralized solutions.

Uranium Potential

The Conway Granite has the physical and chemical characteristics necessary for the formation of vein-type uranium deposits. Unexplained radiometric anomalies indicate possible vein deposits.

This investigation has shown that the Conway granite has many possibilities for the production of energy. Geothermal power, although not expected to produce large quantities of energy, might produce significant amounts for local use. The possible occurrence of vein-type uranium deposits associated with the Conway Granite makes areas around the Conway Granite prime areas for mineral exploration. These facts indicate that a comprehensive investigation of the Conway Granite and surrounding areas is necessary.

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APPENDIX I TECHNICAL MEMORANDUM NO. 40

Preliminary Analysis of Gamma Spectra of the Redstone Core Hole,
North Conway, New Hampshire by Dwight E. Eggers of the U.S.G.S.,
Water Resources Branch, Denver, Colorado.

Technical Memorandum No. 40 -- Preliminary analysis of gamma spectra
spectra of the Redstone core hole, North Conway, New Hampshire

The following are the results of the analysis of gamma spectra made during logging of the Redstone core hole, March 12-13, 1976. Spectra were recorded digitally using the 1 7/8" gamma probe on the Water Resources Division research logging truck no. 1.

Table I
Analysis of Gamma Spectra

Depth	K(%)	eU(ppm)	Th(ppm)	Heat Production (HGU)
260	4.65	8.4	29.3	11.6
313	3.70	22.8	60.3	26.2
483	6.85	9.0	32.7	13.1
520	0.56	7.6	27.6	9.8
565	0.43	7.4	30.1	10.1
597	6.90	10.5	33.4	14.2
960	4.58	7.0	20.6	9.2
992	3.74	19.5	66.4	25.0
1120	4.45	6.7	36.7	11.7
1129	3.65	23.6	75.0	29.2
1150	3.62	18.3	62.9	23.6
1200	3.81	20.4	72.7	26.7
1321	3.79	16.7	56.8	21.5
1372	5.64	27.9	138.7	43.3
1445	4.19	22.0	71.3	27.6
1491	3.95	12.0	44.3	16.4
1525	4.13	22.2	70.0	27.5
1591	2.59	12.8	39.7	15.8
1800	4.17	20.8	69.6	26.5
1858	3.25	9.5	23.7	11.0
2000	1.78	2.1	7.5	3.1
2145	3.79	16.4	53.8	20.8
2192	4.47	26.5	72.9	30.9
2278	4.84	18.3	69.8	25.1
2320	4.39	5.7	14.9	7.3
2348	4.42	12.1	48.2	17.2
2390	4.24	12.6	35.9	15.4
2420	4.74	6.0	20.4	8.5
2482	5.30	1.1	3.4	2.5
2640	3.40	2.7	7.8	3.9
2720	3.88	2.9	12.2	4.9
2811	4.74	25.3	44.2	25.3
2970	4.81	4.6	16.9	7.0

Uranium concentrations are for the radium equivalent uranium and thus do not indicate disequilibrium conditions which may be present.

This analysis is based on a least-squares fitting of the observed spectra over the energy range 0.3-3.0 Mev with reference spectra for K-40 and the U-238 and Th-232 decay series. The reference spectra were obtained by a boot-strap procedure of adding and subtracting portions of select spectra which appeared enhanced or deficient in one of the components to obtain spectra which appeared to be characteristic of individual components.

There is no calibration of these reference spectra so the fitting technique gave only relative concentrations with regard to the reference spectra. These results were then scaled to physical units, as they appear above, such that the spectrum at 260 feet had the same concentrations as the average of Frye's analysis of five surface samples from the Redstone Green Quarry: $4.65 \pm .12\%$; $8.4 \pm .7$ ppm U; 29.3 ± 2.6 ppm Th. (Frye, John K., 1965, Composition and crystallization history of the Conway Granite of New Hampshire, Ph.D. Thesis, Pennsylvania State University). This appears to be a reasonable assumption from the gross gamma log. At present it is the only calibration data which we have; the analyses will be modified when laboratory results are completed.

The potassium concentration is fairly uniform over the entire hole with the exception of the lamprophyre dike at 2000 feet and the alteration interval 470-610 feet. Excluding these depths the average potassium concentration for these data points is 4.22 ± 0.66 percent. The extreme range of values in the altered interval, about 7 percent near the edges to about 0.5 percent near the middle, while the eU and Th concentrations show little variation, is one of the most fascinating features of these results. This suggests migration of potassium from the center toward the contacts of the altered zone; the nature of this interval is complex and the data points too sparse to make this conclusion with much assuredness.

The equivalent uranium and thorium concentrations of the upper 1120 feet of the hole are fairly uniform. Excluding the points at 313 and 992 feet, which represent the two major anomalies on the gross gamma log, the average concentrations for this portion of the hole are 8.1 ± 1.2 ppm and 30.0 ± 4.8 for eU and Th, respectively. This is in good agreement with the results of Frye, cited above. The distinct and fairly uniform nature of this upper portion of the hole, excluding the altered interval, is readily apparent in the gross gamma log, Glenn Stewart's core log, and Jim Scott's magnetic susceptibility measurements of the core. The altered interval is also apparent on the other logs, including the neutron, gamma-gamma, and acoustic velocity logs, but these do not indicate the distinct nature of this upper portion of the hole.

Over the depth interval 1129 to about 2300 feet the eU and Th concentrations average 18.4 ± 4.7 ppm and 60.2 ± 15.2 ppm, excluding the anomaly at 1372 feet and the lamprophyre dike at 2000 feet. According to Stewart's core log this interval is typical of the Conway granite. These results are in good agreement with those of other authors for laboratory radio-metric analysis of core from the Conway Granite of about 16 and 56 ppm for eU and Th concentration, respectively (Roy, R.F., D.D. Blackwell,

and F. Birch, Heat generation of plutonic rocks and continental heat flow provinces, Earth and Planetary Science Letters, 5, 1-12, 1968; and Richardson, K.A., thorium, uranium, and potassium in the Conway Granite, New Hampshire, U.S.A., in The Natural Radiation Environment, J.A.S. Adams and W.M. Lowder, ed., University of Chicago Press, Chicago, 39-50, 1964).

Figure 1* is a plot of the uranium vs. thorium concentrations for these data. A linear regression fit of these points, excluding 1372 and 2811 feet which are anomalously high in Th and eU respectively, is shown by the solid line. The correlation coefficient for this fit is 0.969. The dashed line is taken from Robinson, cited earlier. It represents data over a much smaller range of concentrations.

The radiogenic heat production can be determined from these concentration data. Using conversion factors from Roy and others, the results of these calculations are also shown in Table I in heat generation units (HGU), 10^{-13} cal/cm³sec. These can be used to determine the average radiogenic heat production over the depth interval of this hole. The average of these is 17.3 HGU. A simple average from spectra results however, incorporate bias which may have occurred in the selection of depths for observing spectra. Another approach is to use the simple model that the potassium concentration is 4.22 percent and the Th:eU ratio is 3.24 constant over the entire hole, as determined by the regression fit in Figure 1*. Then the eU and Th concentration, and consequently the radiogenic heat production, can be determined directly from the gamma log. The method used to perform this kind of analysis is shown in Figure 2* where the gamma log count rate versus the Th-content by the spectral analysis is plotted. The line shows the linear regression fit to the data which do not indicate an anomalous distribution. The correlation coefficient for this fit is 0.996. The zero-intercept indicates which portion of the gamma log results from the 4.22 percent potassium and the slope gives a scale factor to convert the gamma log count rate to Th and eU content. Using this approach gives a weighted mean radiogenic heat production of 14.5 HGU over the entire depth of the hole. Though this model does not take into consideration intervals of anomalous distribution it does account for large, apparently uniform, sections of the hole which are represented by a relatively small number of spectra.

Roy, Blackwell and Birch, cited earlier, have obtained good correlation between radiogenic heat production and heat flow for seven core holes in New England. Three of these are located in the Conway Granite. They compute a mean thickness of the radiogenic heat layer of 7.2 km and a reduced heat flow, the heat flow originating from below this layer, of 0.84 HFU (heat flow unit; 10^{-6} cal/cm² sec). The three core holes in the Conway Granite, none of which exceed 1000 feet in depth have an average radiogenic heat production of about 19 HGU and heat flow about 2.1 HFU. Thus in the Conway Granite 60 percent of the heat flow results from radiogenic heat in the upper crust.

As thermal conductivity measurements are made for this core hole and the heat flow is computed it will be of considerable interest, from the standpoint of geothermal studies, whether these data are consistent

with Roy's model. Assuming the 14.5 HGU value is representative of the heat production of the upper 7.2 km of crust the heat flow for this hole should be about 1.9 HFU. This hole is not sufficiently deep to draw conclusions about the distribution of radiogenic heat in the upper crust.

There are admittedly some weaknesses in the techniques used to arrive at this analysis. The only calibration available is extrapolated from near-surface data. The method used to obtain the reference spectra is subjective in nature. This approach was necessary since there are presently no reference borehole spectra. It was not possible to use the reference spectra used in laboratory radiometric analysis because the geometry of the borehole environment results in much greater Compton continuum. These results may include significant systematic error, but I am confident that the general relationships are valid. I would judge these results to be good at least within 10 percent plus one unit. As laboratory analysis of the core becomes available we will be able to improve on these results.

* Figures not included in this report.

[illegible]

DATE _____ TIME _____

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Persuant out phone conversation of May 4, the laboratory radiometric analyses on Redstone core made by Carl Bunker which have been completed thus far are as follows:

<u>Depth (feet)</u>	<u>Ra eU (ppm)</u>	<u>Th (ppm)</u>	<u>K (%)</u>
266.0	8.79	36.7	4.78
1323.5	40.3	160.	3.99
1445.5	23.3	99.5	3.85
2000.2	2.51	10.1	1.63
2813.5	36.2	36.9	3.06

There was considerable delay in obtaining these results. Radiometric analyses of the samples which you sent to Los Alamos should be conducted more expeditiously.

Feel free to include these results in your project report, but please consult us before including them in any publications.

APPENDIX III

Detailed Written Lithologic Log of the Redstone Core. Core
was Logged in the Field and Checked in the Laboratory.

<u>Depth</u>	<u>Rock Type</u>	<u>Description</u>
11'7"-12'	Green phase	Weathered, buff colored spars with some red feldspars and much iron staining.
12'-12'5.5"		Fragments
12'5.5"-28'1"		Weathered, red color, with much iron staining.
28'1"-53'8"		Less iron stain and less weathering.
53'8"-55'7"		Altered amphiboles changing to chlorite, some spars altered.
55'7"-55'10"		Broken core, molybdenum flakes and hydrothermal alteration.
55'10"-63'		Fractures filled with clay material (61-62) altered mafics, reddish spars, dark green.
63'-65'7"		Tan granite with slight alteration of amphiboles.
65'7"-66'6½"		Altered core, spars and amphiboles altered.
66'6½"-66'7¼"		Spars of dark tan, coarse textured.
66'7¼"-67'9 3/4"		Altered amphiboles and some spars.
67'9 3/4"-71'3 3/4"		Very coarse pink spar, amphibole altered.
71'3 3/4"-71'8"		White alteration (kaolinite).
71'8"-72'1"		Moderate alteration of amphibole to green products.
72'1"-73'1	Fine-grained granite dike	Pink, fine-grained rock looks to be associated with a fracture.
73'1"-85'5"	Green phase	Red spars fairly coarse-grained.
85'5"-87'	Mixed zone of green phase and aplite pegmatite	Fine-grained band at 85'9" (1½") dips 20-30° - red spar increases in size from 86'-87' - pegmatite?
87'-88'1"		Patchy red spar as above with zones of fine-grained granite. Red spars fade out at 88'1".
88'1"-89'9"	Green phase	Buff. to pink medium-grained granite.
89'9"-94'6"		Spars becoming greener, losing pink color, more buff spars at 91'.

94'6"-95'6 $\frac{1}{2}$ "	Green phase	More buff colored spars.
95'6 $\frac{1}{2}$ "-98'11 $\frac{1}{2}$ "		Pink spars becoming predominant.
98'11 $\frac{1}{2}$ "-113'		Buff to a greenish granite.
113'-114'6"		Spars becoming pinkish near a fracture.
114'6"-117'2 $\frac{1}{2}$ "		Grey to buff granite.
117'2 $\frac{1}{2}$ "-117'9"	Dike	Fine-grained granite or aplite.
117'9"-123'2"	Green phase	Veins of pink fine-grained and pegmatitic granite.
123'2"-123'9"		Green granite.
123'9"-124'9"		Spars of red associated with a fracture zone.
124'9"-125'2"		Buff spars.
125'2"-125'6"		Red spars.
125'6"-126'3"		Buff spars.
126'3"-128'		Red spars.
128'-129'6"		Buff spars.
129'6"-129'9"		Red spars.
129'9"-133'4"		Buff spars.
133'4"-137'5"		Granite becomes orange-red and loses most mafics (altered) with a brecciated zone with quartz and very large spar crystals at 136'3", fine-grained aplite at 136'5" for 2" then red zone again to 137'5".
137'5"-143'		Spars becoming buff again and gradually green then buff.
143'-148'		Green-grey granite.
148'-149'		Vein of finer-grained mushy zone at a dip of 70°-80°.
149'-199'5"		Green-grey granite with slight variations in color.
199'5"-199'10"	Dike	Fine-grained red dike rock.
199'10"-211'	Green phase	Green granite.
211'-212'4"		Pinker granite, amphibole altered.
212'4"-214'11"		Green granite becoming pinker by 214'11".
214'11"-218'		Fine-grained red granite.
218'-223'10"		Green granite.
223'10"-225'		Spars becoming pinker.
225'-228'		Green granite.
228'-230'10"		Slightly pinker.

230'10"-232'4"	Green phase	Red granite with a miarolitic cavity until 232'4".
232'4"-273'		Green granite.
273'273'8"		Buff colored granite.
273'8"-274'3"		Red granite.
274'3"-300'11"		Grey, buff to pink granite.
300'11"-301'6"		Very red granite.
301'6"-305'9"		Buff spars.
305'9"-311'6"		Spars become porphyritic with reddish rims. Amphiboles decrease in size.
311'6"-312'10"		Buff spars.
312'10"-318'7"		Mixture of fine-grained granite with porphyritic granite and buff colored granite. Contacts sharp, amphibole highly altered in places.
318'7"-332'2"		Buff spars.
332'2"-333'9"		Broken fine-grained (porphyritic) red granite.
333'9"-334'9"		Gradation at contact into buff colored granite.
334'9"-350'		Grey-greenish granite.
350'-361'10"		Granite becoming buff.
361'10"-367'		Pink granite becoming very red at 367'.
367'-368'		Red becoming pink then buff.
368'-388'5"		Pink to buff granite.
388'5"-389'1"		Alteration of amphibole to maroon. Spars kaolinized.
389'1"-390'7"		Dark red color at 390'7". Amphibole altered to dark red color.
390'7"-393'		Red granite but amphibole changed to a green color again. K-spars fractured.
393'-394'10"		Bleached zone with sulfides.
394'10"-397'		Red granite amphibole changed to a green color.
397'-398'		Amphiboles altered to a dark (mahogany) red color like 389-390'.
398-398'8"		Kaolinized spars.
398'8"-406'		Buff granite.
406'-423'4"		Alteration, bleached zone with sulfides.

423'4"-426'	Green phase	Pink granite.
426'-427'7"		Dark red granite-amphiboles altered to a light green.
427'7"-429'10"		Red to pink (some miarolitic cavities loss of amphiboles).
429'10"-436'		Red granite going to buff.
436'-453'11"		Buff-pink granite.
453'11"-454'4"	Dike	Fine-grained pink granite.
454'4"-471'	Green phase	Pink granite (very hard drilling).
471'-473'		Kaolinized spars.
473'-493'	Green phase-alteration	Highly altered and kaolinized very porous rock.
493'-533'		Bleached, white, highly altered kaolinized rock. Sulfides-pyrite.
533'-535'4"		Altered changing to red -altered granite, lots of kaolinite and pyrite.
535'4"-539'		Increase in quartz, much less alteration.
539'-560'5"		Severe alteration and kaolinization.
560'5"-571'4"		"Sharp" blue-green or grey-green alteration boundary at 560'5" - gets lighter toward end of section.
571'4"-573'		Pink alteration spars and amphibole kaolinized.
573'-575'		Dark green with pink-red spar conspicuous.
575'-600'		Pink-red granite with a few dark green lenses and cavities-very porous-highly altered.
600'-609'8"		Spars less altered, rock becoming less altered, pure clay at 602'9".
609'8"-642'6"		Pink granite at beginning, changing to buff later on.
642'6"-644'10"		Pink granite.
644'10"-646'		Red zone by a fracture.
646'-762'	Green phase	Buff granite.
762'-765'6"		Fine fractures and alteration, pink spars.
765'6"-832'10"		Buff granite with many fractures with minor alteration near fractures.
832'10"-833'3"	Dike	Fine-grained granite dike dips at 50°.
833'3"-838'3"	Green phase	Fractured and slightly altered rock maybe even brecciated.

838'3"-848'6"	Green phase	Buff granite.
848'6"-851'3"		Fracturing and minor alteration abundant at 851'2". A 60° fracture occurs with subordinate vertical fractures.
851'3"-859'		Pink-buff granite.
859'		Contact with darker fine-grained rock. Less spar, more amphibole, very fine-grains mixed with a few larger grains.
859'860'3"	Fine-grained rock	Fine-grained dark rock.
860'3"-925'	Green phase	Buff granite, pink near some of the numerous fractures.
925'-980'		Grey-green granite.
980'-985'10"		Pink-buff granite with local zones of finer-grained mushy zones.
985'10'	Red phase	Distinct contact with coarse-grained granite.
985'10"-1003'		Coarse-grained granite with zones of finer-grained material and some amphibole phenocrysts.
1003'-1014'9"		Similar to above with local variations in texture and percentage of mineral grains. Quartz higher.
1014'9"	Syenite	Distinct boundary between coarse-grained and medium-grained syenite.
1014'9"-1043'6"		Syenite, finer-grained mixture.
1043'6"-1044'		Zone of darker fine-grained syenite.
1044'-1058'7"		Coarse-grained syenite.
1058'7"-1061'6"	Red phase	Band of coarser-grained pink granite.
1061'6"-1097'3"	Syenite	Dark grey syenite.
1097'3"-1103'10"		Finer-grained, pinker, lower biotite.
1103'10"-1128'2"		Dark, medium-grained rock with segregations of biotite becoming finer-grained and pinker at base.
1128'2"-1135'	Red phase	Distinct contact with coarse-grained granite.
1135'-1137'		Local segregations of dark and light material, zone of sheared spars and silicification.
1137'-1143'		Coarse-grained granite.
1143-1145'		Micro-shearing and silicification.

1145'-1167'	Red phase	Coarse-grained granite.
1167'-1168'		Zone of finer-grained mushy granite.
1168'-1189'8"		Coarse-grained granite.
1189'8"-1190'6"		Miarolitic cavities.
1190'6"-1194'5"		Coarse-grained granite.
1194'5"-1196'9"		Miarolitic cavities.
1196'9"-1229'		Coarse-grained pink granite.
1229'-1235'11"		Red, coarse-grained granite.
1235'11"-1253'1"		Pink granite.
1253'1"-1267'6"		Grey foliated fine-grained granite.
1267'6"-1284'5"		Typical pink granite.
1284'5"-1284'8"	Dike (xenolith?)	Foliated fine-grained granite.
1284'8"-1286'9"	Red phase	Pink granite.
1286'9"-1287'1"		Salt and pepper appearance.
1287'1"-1299'5"		Pink granite.
1299'5"-1301'3"		Pink granite, shear zone, crystals broken.
1301'3"-1310'		Pink granite.
1310'-1313'6"		Red granite.
1313'6"-1315'10"		Graphic granite.
1315'10"-1325'		Pink granite.
1325'-1327'		Minor alteration and kaolinization and alteration of amphibole-biotite-fine-grained graphic granite.
1327'-1331'6"		Pink granite.
1331'6"-1332'3"		Fine-grained graphic granite, vague foliation at base-60°.
1332'3"-1335'8"		Coarse, light pink granite.
1335'8"-1336'9"		Fine-grained rock - mushy zone.
1336'9"-1338'4"		Light pink granite.
1338'4"-1345'		Minor alteration and fracture zone, redder color.
1345'-1368'		Pink granite.
1368'		Midpoint of red spar and quartz "vein" and (5") zone of foliated granite dip of 50° for both.
1369'-1373'3"		Pink granite.

1373'3"-1375'7"	Red phase	Miarolitic cavity with high radio-activity.
1375'7"-1406'9"		Typical pink granite.
1406'9"-1409'3"		Fine-grained granite-shear.
1409'3"-1428'5"	Mottled quartz syenite.	Coarse rock with clusters of amphibole.
1428'5"-1430'6"	Red phase	Mixed area of pink granite and mottled syenite.
1430'6"-1480'		Pink coarse-grained granite at 1462' $\frac{1}{4}$ "- $\frac{1}{2}$ " thick zone of fine-grained material with graphic granite. Similar zone at 1463'6 $\frac{1}{2}$ " for $\frac{1}{2}$ " and at 1467'8 $\frac{1}{2}$ " for $\frac{1}{2}$ "-1".
1480'-1480'6"		Dike or lens of dark material-60° dip.
1480'6"-1506'1"		Typical pink granite.
1506'1"		Mushy zone, quartz and spar $\frac{1}{4}$ " wide, 50° dip.
1506'1"-1507'3"		Typical pink granite.
1507'3"-1510'8"		Mushy zone, dip 40°.
1510'8"-1516'		Grey to pink, coarse-grained granite.
1516'-1516'4"		Miarolitic cavity, dip 50°-60°.
1516'4"-1530'1"		Grey to pink granite with some small cavities and pegmatite texture.
1530'1"-1530'2"		Graphic granite and miarolitic cavity.
1530'2"-1532'6"		Grey to pink coarse-grained granite.
1532'6"-1535'7 $\frac{1}{2}$ "		Texture change to fine-grained quartz and K-spar - "mushy" zone.
1535'7 $\frac{1}{2}$ "-1535'8"		Quartz-spar zone, $\frac{1}{4}$ ", dips 60°.
1535'8"-1538'9"		Pink, coarse-grained granite.
1538'9"-1538'10"		Lens or dike, $\frac{1}{2}$ " fine-grained quartz, biotite core, white spars on outer edge.
1538'10"-1548'9"		Buff variable textured granite.
1548'9"-1549'3"		Zone of miarolitic cavities.
1549'3"-1561'		Buff variable textured granite.
1561'-1561'5"		Quartz-rich zone, fine-grained lens containing spar.
1561'5"-1567'8"		Buff coarse-grained.
1567'8"-1569'7"		Medium to fine-grained pink textured zone. Biotite concentrated at contact.
1569'7"-1590'8"		Buff coarse-grained granite.
1590'8"-1590'9"		Mushy zone, healed fracture.
1590'9"-1591'3"		Finer-grained granite.

1591'3"-1592'

Red phase

Nearly horizontal foliation of dark quartz and biotite. Another band of biotite then dips down core at 80°. Buff coarse-grained granite surrounds dark zones.

1592'-1592'6"

Zone of clear crystals at an 80° dip.

1592'6"-1594'

Buff coarse-grained granite.

1594'-1598'

Mottled quartz
syenite

Mottled rock with abundant fluorite.

1598'-1607'10"

Red phase

Pink coarse-grained granite.

1607'10"-1608'4"

Zone of miarolitic cavities and pegmatites.

1608'4"-1610'10"

Coarse-grained, pink granite.

1610'10"-1610'11"

Miarolitic cavity.

1610'11"-1613'2"

Pink coarse-grained granite.

1613'2"-1614'7"

Granular mass of pink spar and quartz - dike like.

1614'7"-1624'8"

Pink coarse-grained granite.

1624'8"-1630'8"

Zone of variable texture, medium to coarse-grained granite.

1630'8"-1639'1"

Pink, coarse-grained granite.

1639'1"-1664'8"

Lamprophyre dike.

1664'8"-1678'6"

Pink coarse-grained granite with many zones of finer material.

1678'6"-1678'8"

Graphic granite.

1678'8"-1691'6"

Coarse-grained red granite.

1691'6"-1691'8"

Graphic granite.

1691'8"-1694'1"

Red coarse-grained granite.

1694'1"-1694'3"

Miarolitic cavities.

1694'3"-1711'

Red to pink coarse-grained granite becoming red again.

1711'-1715'

Dark red fine-grained granite with a core of coarse-grained rock.

1715'-1721'2"

Coarse-grained pink granite.

1721'2"-1729'6"

Lamprophyre dike, irregular contact.

1729'6"-1744'8"

Red coarse-grained granite.

1744'8"-1745'11"

Shear zone with quartz filling.

1745'11"-1752'6"

Red coarse-grained granite.

1752'6"-1758'

Vertical fracture filled with calcite and much alteration. Amphiboles are altered as are feldspars.

1758'-1778'	Red phase	Alteration zone where at the center quartz is gone and cavities are filled with calcite.
1778'-1792'4"		Red coarse-grained granite.
1792'4"-1793'		Fine-grained reddish granite.
1793'-1839'		Red to pink coarse-grained granite with many zones of mushy areas and biotite segregations.
1839'1847'2"		Pink coarse-grained granite.
1847'2"-1848'8"		Fine-grained granite.
1848'8"-1861'	Mottled quartz syenite	Mottled quartz syenite with black clumps of amphibole, abundant fluorite.
1861'-1863'8"	Red phase	Mixed zone of coarse-grained buff granite and fine-grained granite with zones of mottled quartz syenite.
1863'8"-1879'8"		Coarse-grained buff granite with many zones of finer-grained mushy areas.
1879'8"-1880'4"		Fine-grained "salt and pepper" rock - may be inclusion or a dike.
1880'4"-1886'9"		Pink coarse-grained granite with some fine-grained areas.
1886'9"-1887'9"	Dike	Fine-grained granite, pink gradational contact with a steep dip (70°-80°).
1887'9"-1892'	Red phase	Pink coarse-grained granite with some finer-grained mushy zones.
1892'-1894'6"	Dike	Fine-grained granite, gradational contact.
1894'6"-1917'9"	Red phase	Pink to red coarse-grained granite.
1917'9"-1921'11"		Pink to red coarse-grained with many zones of finer minerals.
1921'11"-1940'4"		Pink to red coarse grained granite.
1940'4"-1942'		Graphic granite and mixed zones of coarse-grained granite.
1942'-1949'6"		Red coarse-grained granite.
1949'6"-1949'8"	Lamprophyre dike	Very small dark semi-porphyrific dike.
1949'8"-1963'3"	Red phase	Pink coarse-grained granite.
1963'3"-1964'1"		Fine to medium-grained granite with an increase in biotite.
1964'1"-1990'		Pink-red coarse-grained granite with many zones of fractures and alteration of biotite. Some mushy areas.
1990'-2018'3"	Lamprophyre dike	Black semi-porphyrific lamprophyritic dike.

2018'3"-2030'	Red phase	Pink coarse-grained granite with some mushy zones and zones of graphic granite.
2030'-2041'		Fine mixed zone of pink granite with almost a foliation.
2041'-2042'8"		Coarse pink granite.
2042'8"-2043'4"	Dike	Fine-grained granite.
2043'4"-2059'1"	Red phase	Coarse-grained pink granite.
2059'1"-2059'2"		Graphic granite lens or dike.
2059'2"-2072'6"		Coarse to medium-grained pink to grey granite with some finer zones.
2072'6"-2072'7"		Two miarolitic cavities.
2072'7"-2115'11"		Coarse pink to grey granite with many finer-grained zones and zones of graphic granite and a few miarolitic cavities.
2115'11"-2118'9"		Fine-grained biotite-rich zones, may be assimilated xenolith.
2118'9"-2140'5"		Coarse grey granite.
2140'5"-2142'8"		Biotite-rich foliated fine-grained zone.
2142'8"-2167'9"		Grey coarse-grained granite.
2167'9"-2173'		Mixed zone of grey coarse and fine-grained granite.
2173'-2201'9"		Grey coarse-grained granite.
2201'9"-2202'7"	Albany quartz syenite	Dark coarse-grained dike of Albany quartz syenite.
2202'7"-2222'8"	Red phase	Grey coarse-grained granite with some pink.
2222'8"-2240'		Grey, pink to greenish coarse-grained granite, very variable in color.
2240'-2247'		Mixed area of buff coarse granite with dark segregations, probably assimilated Albany.
2247'-2261'6"		Buff to pink coarse-grained granite.
2261'6"-2268'9"		Fine-grained granite with abundant dark material.
2268'9"-2297'		Buff to grey coarse-grained granite.
2297'-2328'	Albany quartz syenite	Albany quartz syenite.
2328'-2343'		Mixed zone of granite and syenite.
2343'-2363'	Red phase	Pink coarse-grained granite with some segregations of dark minerals.

2363'-2363'3"	Lamprophyre dike	Lamprophyre dike.
2363'3"-2380'6"	Red phase	Coarse-grained granite with segregations of dark minerals.
2380'6"-2381'2"	Syenite	Greenish grey feldspars.
2381'2"-2409'	Red phase	Pink to buff coarse-grained granite.
2409'-2410'		Fine-grained foliated granite.
2410'-2410'8"		Coarse-grained pink granite.
2410'8"-2411'6"		Mixed zone of syenite and granite.
2411'6"-2413'	Syenite	Albany quartz syenite.
2413'-2434'		Mixed zone of syenite and granite.
2434'-2456'6"		Syenite
2456'6"-2493'		Zone of pegmatites and miarolitic cavities. Rock fractured and brecciated-syenite.
2493'-2502'		Grey syenite with a few pink spars.
2502'-2510'		Streaky fine to medium-grained pinker syenite with a few zones of pegmatite material and dark grey zones at 2505'-2505'6" and at 2507' - 2508'4".
2510'-2522'8"		Grey syenite with a few pink spars.
2522'8"-2523'10"		Sharp contact with very dark grey syenite without pink spars.
2523'10"-2527'1"		Pink-grey syenite.
2527'1"-2527'4"		Fine granite dike with no mafics.
2527'4"-2532'10"		Pink-grey syenite.
2532'10"-2533'6"		Dark grey syenite, gradual contact with abundant mafics.
2533'6"-2533'7"		Pegmatite, graphic granite and miarolitic cavities.
2533'7"-2533'8"		Dark grey syenite as before.
2533'8"-2546'6"		Pink-grey syenite.
2546'6"-2546'8"		Small, highly altered lamprophyre dike.
2546'8"-2591'6"		Pink-grey syenite.
2591'6"-2596'		Considerable alteration with low quartz, chlorite and red spars.
2596'-2596'8"		Slight alteration.
2596'8"-2597'3"		Moderate alteration.
2597'3"-2598'3"		Slight alteration.
2598'3"-2600'		Considerable alteration.

2600'-2610'6"	Syenite	Slight alteration with many near vertical fractures filled with calcite and quartz.
2610'6"-2654'4"		Highly fractured core with much mineral filling.
2654'4"-2654'8"		Pink-red aplite dike.
2654'8"-2658'10"		Highly fractured syenite.
2658'10"-2660'9"		Red aplite dike.
2660'9"-2662'10"		Highly fractured syenite.
2662'10"-2673'3"		Unfractured grey syenite.
2673'3"-2676'		Pink aplite dike.
2676'-2696'9"		Grey syenite.
2696'8"-2696'10"		Aplite dike.
2696'10"-2733'		Grey to pink syenite with many fractures with fillings and alteration of spars near fractures.
2733'-2783'4"		Grey syenite.
2783'4"-2783'9"		Dark biotite-rich band or dike (inclusion?).
2783'9"-2785'		Grey syenite.
2785'-2785'2"		Gneissic or granitic band.
2785'2"-2791'7"		Pink syenite.
2791'7"-2792'5"		Pegmatite and cavity.
2792'5"-2793'10"		Pink syenite.
2793'10"-2809'	Biotite-amphibole granite	Medium-grained, less granular biotite-amphibole granite.
2809'-2809'2"	Dike	Aplite and pegmatite zone.
2809'2"-2812'	Biotite-amphibole granite	Biotite amphibole pink granite.
2812'-2814'8"	Dike	Aplite or mushy zone.
2814'8"-2816'7"	Biotite-amphibole granite	Granite
2816'7"-2816'9"	Dike	Pegmatite, aplite zone.
2816'9"-2817'7"	Biotite-amphibole granite	Granite.
2817'7"-2817'9"	Dike	Pegmatite and aplite dike.
2817'9"-2819'10"	Biotite-amphibole granite	Biotite-rich granite.
2819'10"-2829'		Granite with amphibole and biotite.

2829'-2829'1"	Dike	Small pegmatite vein.
2829'1"-2889'5"	Biotite-amphibole granite	Granite with variable mafic content and color of spars are pink to grey.
2889'5"-2890'3"	Dike	Aplite and pegmatite dike, red-pink to orange spars.
2890'3"-2900'3"	Biotite-amphibole granite	Shear zone. Spars are red at the contact with aplite becoming greyer below. Green color prominent in fractures.
2900'3"-2927'		Light grey granite.
2927'-2949'10"		Granite with abundant fractures and spars becoming red near fractures.
2949'10"-2952'3"		Shear zone with numerous fractures and considerable alteration in the shear zone.
2952'3"-2962'2"		Buff to pink medium-grained granite, less alteration but with considerable fracturing.
2962'2"-2998'9"		Light grey becoming buff granite.
2998'9"-3003'		Highly altered and porous granite, sharp contact.

APPENDIX IV

Detailed Graphical, Lithologic and Fracture Log.

1750
Biotite zone
ALTERATION
beginning in biotite
quartz decreasing
increasing in
quartz
also grained
quartz - biotite
highly altered
quartz with some
green veins 1750
quartz abundant as
sieve-like mass
small cavities
cream colored
quartz
short, very heavy
quartz
with small
dark gray
and quartz
granite
Red
1780
Coarse
grained
granite
1790
fine grained
red granite
Red
To
1800
Pink
Coarse
1810
grained
granite
with
1820
many
mushy
zones
and
1830
biotite
Segregations
1840
Pink
Coarse
grained
granite
fine grained
granite
1850
MOTTLED
QUARTZ
SYENITE
1860
mixed coarse
quartz and mottled
syenite
Coarse grained
buff granite
with many
mushy zones
RED PHASE
1870

1870
Buff
To
Red
granite
1880
Pink granite
with some
finer grained
zones
1890
fine grained
pink granite
with
mushy zones
1900
fine grained
granite
gradational
contact
Pink
To
1900
Red
Coarse
grained
granite
1910
Pink to Red
granite with
1920
some finer
material
Pink
To
Red
Coarse
1930
grained
granite
1940
mixed area
of biotite
quartz and coarse
red
Coarse
grained
granite
1950
Pink
Coarse
grained
granite
1960
Pink to
Red
Coarse
grained
granite
with
alteration
1970
1980

1980
near
Fractures
1990
Lamprophyre
2000
Dike
2010
Pink
Coarse
grained
granite
with mushy
zones and
some graphic
granite
2020
fine
grained
zones of
pink granite
with a
crude
foliation
2030
Pink
granite
fine grained
zone
Coarse
grained
2040
Pink
granite
2050
Coarse
grained
2060
Pink
granite
2070
Coarse
grained
Pink to gray
granite with
some finer
grained zones
2080
microscopic
Coarse pink
to gray granite
with many
finer grained
2090
zones and
zones of
graphic granite
with a few
microscopic
cavities
2100

2090
Coarse Pink
to gray
granite
with
2100
many
finer
grained
zones
2110
white rich
zones
2120
Coarse
grained
2130
gray
granite
2140
white rich
foliated zone
gray
Coarse
2150
grained
2160
granite
Mixed zone
of pink
2170
grained and
coarse gray
granite
gray
2180
Coarse
grained
2190
granite
2200

APPENDIX V

General Lithologic Log at the Same Scale as the Geophysical
Logs, 1" = 100'.

APPENDIX VI

Geophysical Logs of the Redstone Drill Hole.

- A. Caliper Log
- B. Resistance Logs
- C. Temperature Log
- D. Epithermal Neutron Log
- E. Gamma Log
- F. Gamma-Gamma Log

[illegible]

500.

500.

1000.

1000.

1500.

1500.

2000.

2000.

0. LONG NORMAL 20.
MILLI - VOLTS

-10. SHORT NORMAL 30.
MILLI - VOLTS

500.

500.

1000.

1000.

1500.

1500.

2000.

2000.

1500. TEMPERATURE 3500.
3500. PULSES/SEC 5500.

500.

+ + + + + + + +

500.

1000.

+ + + + + + + +

1000.

1500.

1500.

2000.

2000.

0. EPITHERMAL NEUTRON 4000.
MILLI - VOLTS

1500.

1500.

2000.

2000.

2500.

2500.

3000.

PROJECT: CONWAY, N.H.
HOLE(S): REDSTONE
DATE(S): 1/24-29/76

0. GAMMA 1000.
1000. PULSES/SEC 2000.

500.

1000.

1500.

2000.

400. 0. GAMMA-GAMMA
0. PULSES/SEC -400.

600. 100. GAMMA-GAMMA
100. PULSES/SEC -400.

1500.

1500.

2000.

2000.

APPENDIX VII

Description of the Core at Sites of High and Low Radioactivity.

<u>Depth</u>	<u>Gamma Pulses/sec.</u>	<u>Rock Description</u>
118'	380	Fine-grained granite dike.
148'	420	Zone of fine-grained mushy or shear zone.
163'	410	Minor alteration near fractures.
200'	380	Fine-grained granite dike.
211'	470	Minor alteration near fractures.
217'	460	Fine-grained granite dike.
226'	410	Minor alteration near fractures.
Note: Mirolitic cavity and very red granite at 231', but no radioactive response.		
Note: Very red altered green phase with a fracture at the center of the red zone, but no radioactive response at 274'.		
307'	590	Porphyritic red granite may be the red phase.
315'	645	Mixture of fine-grained sheared granite and porphyritic granite - red phase?
332'	580	Fine-grained porphyritic pink granite - same as at 315'.
Note: Alteration zone from 388'5" to 433'. Average radioactivity with a low zone at 412'. This low zone coincides with a bleached core with sulfide mineralization.		
Note: Alteration zone from 471' to 613' has many peaks of higher radioactivity which usually coincide with salmon-colored "quartz absent" zones.		
478'-491'	470	Broad double peak highly altered rock salmon or green in color, very little quartz.
Note: At 493'-533' bleached zone with sulfides and/or hematite. Radioactivity is less than average.		
533'	400	Salmon-colored, spars very little quartz.
550'-558	370	Salmon to pink-colored spars, very little quartz.
573'	410	Salmon and green-colored spars, very little quartz.
589'	450	Salmon-colored spars, almost no quartz.
596'	450	Salmon-colored spars, almost no quartz.
Note: After 600' there are no more peaks encountered until the coarse-grained contact is reached at about 986'.		
983'-1008'	740	Contact between medium-grained green phase and and coarse-grained red phase at 985'10". Red phase continues to 1012'8" with zones of finer-grained rock. No explanation for valley at 1005'.
1059'	510	1058'7"-1061'6" - band of pink coarse-grained red phase.

<u>Depth</u>	<u>Gamma Pulses/sec.</u>	<u>Rock Description</u>
1131'	810	Distinct contact with very coarse-grained red phase.
1136'	Valley (530)	Zone of sheared spars with "silicification" and decrease in radioactivity.
1160'	755	Typical buff to pink coarse-grained red phase.
1166'-1172'	Valley (550)	1167'-1168' - red zone of finer-grained "mushy" red phase.
1186'-1193'	850	Double peak, associated with miarolitic cavities.
1251'	Valley (420)	Light pink to buff coarse-grained Conway granite. No explanation for the decrease.
Note: 1253'11"-1267'6", grey fine-grained granite with apparent constant radioactivity of about 580 pulses/sec. It has abundant fractures and filling. A peak near bottom contact in grey phase equals 680 pul/sec.		
1270'	Valley (450)	Typical buff red phase becoming pinker away from grey rock. No reason for decrease in radioactivity.
1282'	675	Typical light pink red phase.
Note: At 1284'5" to 1284'8" there is a mushy shear zone. An assimilated xenolith exists at 1286'9" to 1287'1". An apparent broad irregular radioactive valley (550-610) is associated with this.		
1295'	695	Typical red phase
Note: Valley (510) at 1298' to 1306' coincides with "mushy" zone.		
1308'-1317'	670-690	Double peak, granite red at 1310', zones of graphic granite at 1313'6" and 1315'10".
1326'	Valley (460)	Alteration of biotite at 1325' and kaolinization of plagioclase.
1335'	680	Typical Conway granite.
1339'	Valley (570)	Alteration of biotite near fracture zone at 1339'-1343'.
1353'	790	Light pink-red phase.
1373'	1500	At 1368' to 1357'7" zone of quartz vein and miarolitic cavities.
1406'	Valley (550)	At 1406'9" a fine-grained "mushy" zone.
1410'	760	A large (5x3 mm) allanite (?) crystal at 1409', upper contact of the mottled quartz syenite.
1422'	620	Small peak in radioactivity coincides with a zone of red phase at 1418'9" to 1428'7".
Note: Double valley (540, 480) coincides with the mottled quartz syenite.		
1445'	770	Typical red phase.

<u>Depth</u>	<u>Gamma Pulses/sec.</u>	<u>Rock Description</u>
1470'-1496'	Valley (470)	Typical red phase, no reason for remarkable decrease in radioactivity.
1498'	700	Typical red phase which gets redder between 1493' -1503'.
1508'	700	"Mushy" zone.
1516'	830	4"miarolitic cavity.
Note: From 1516'-1550' higher overall radioactivity at about 800 pul/sec.		
1551'-1558'	900	Typical red phase, very variable texture.
1595'	Valley (450)	Mottled quartz syenite.
1628'	820	Pink to red, red phase with many broken crystals.
1635'-1670'	Valley (100)	Lamprophyre dike.
1670'-1710'	600-750	Typical red phase.
1720'-1730'	Valley (100)	Lamprophyre dike.
1740'	780	Red phase with very red spars.
1755'	Valley (580)	Altered biotite in coarse-grained granite with vertical fractures filled with calcite.
1760'	780	Minor alteration, some spars are altered.
1765'-1770'	Valley (650-580)	Highly altered and kaolinized rock.
1781'	770	Red coarse-grained granite with a fracture at 1782'.
1790'	Valley (450)	Red granite with many fractures and a "mushy" zone at 1790'.
1838'	Valley (470)	"Mushy" zones of finer-grained granite.
1848'-1862'	Valley (320)	Mottled quartz syenite.
1868'	655	Typical red phase
1880'	Valley (485)	"Mushy" zone.
1887'	645	Typical red phase.
1892'	Valley (490)	Fine-grained granite dike, gradational contact.
1919'	Valley (550)	"Mushy" zone.
1928'-1942'	Valley (490)	"Mushy" zone and graphic granite.
1950'	Valley (470)	Small 2" lamprophyre dike.
1950'-1968'	Valley (400-520)	Irregular valley caused by minor alteration near fractures and "mushy" zones.
1970'-1990'	600	Red to pink granite with many fractures and alteration of biotite.

<u>Depth</u>	<u>Gamma Pulses/sec.</u>	<u>Rock Description</u>
1990'-2018'	Valley (100)	Lamprophyre dike.
2020'	630	Pink-red phase with minor alteration and some mushy zones and zones of graphic granite.
2037'	Valley (300)	Crystal "mush" shear zone.
2042'	680	Typical red phase.
2058-2062'	Valley (380)	Grey to buff red phase, graphic granite and cavity at 2059'.
2085'	770	Grey pink phase with zones of finer material.
2170'	780	Mixed area with fine-grained zones.
Note: Several small peaks and valleys are found between 2085'-2170' which probably can be related to the heterogeneity of the rock.		
2173'-2184'	Valley (550)	Grey coarse-grained red phase, no reason for decrease in radioactivity.
2188'-2200'	760	Grey red phase, no reason for increase in radioactivity.
2202'-2240'	Valley (400-500)	Broad irregular valley caused by Albany syenite xenolith from 2201'10" to 2202'8". Then very variable texture and color red phase. Perhaps represents assimilation of syenite.
2248'	620	Pink coarse red phase.
2262'	Valley (300)	Fine-grained granite, streaky with abundant dark zones.
2270'	600	Buff colored red phase.
2273'	Valley (420)	Buff granite with some streaks of greener spars.
2283'	700	Buff colored red phase.
2295'-2340'	Valley (250)	2297'-2328' Albany quartz syenite. 2328'-2343' mixed zone of red phase and syenite.
2344'	600	Typical red phase.
Note: Zone from 2344' to 2411' consists of red phase with segregation of syenite in a mixed zone. Variable radioactivity with peaks coinciding with red phase and valleys coinciding with syenite.		
Note: At 2363' a very small 3" lamprophyre dike barely detectable on the gamma log.		
Note: At 2450' the radioactivity drops to a lower background of about 200 pulses/sec, coinciding with the Albany quartz syenite.		
2510'	280	Pegmatitic material.
2527'	300	Fine-grained granitic dike.

<u>Depth</u>	<u>Gamma Pulses/sec.</u>	<u>Rock Description</u>
2532'	290	Pegmatitic graphic granite.
2590'	290	Alteration zone.
2660'	420	Aplite dike.
2675'	335	Aplite zone.
2812'	560	Aplite zone.

Note: Background level increases at the contact with granite at 2794' to about 250 gamma/sec. Very uniform, no peaks or valleys from 2812' to the end of the core.

APPENDIX VIII

Histograms at 50 Foot Intervals Showing the Frequency of Fracture Angles with Depth.

**F
R
E
Q
U
E
N
C
Y**

ANGLE