

**Field Book for the
Geological Society of New Hampshire
2010 Summer Field Trip**

Saturday, August 7, 2010

0900am - Meet at the Madison Town Hall for sign-in and coffee and doughnuts; depart for the Madison Boulder by bus

1000am - **A** - Madison Boulder cooperative agreement ceremony and Boulder site tour at the end of Boulder Road, off NH Rte. 113, Madison, NH.

1200 noon - Catered GSNH cookout luncheon at the Tin Mountain Conservation Center, 1245 Bald Hill Road, Albany, NH

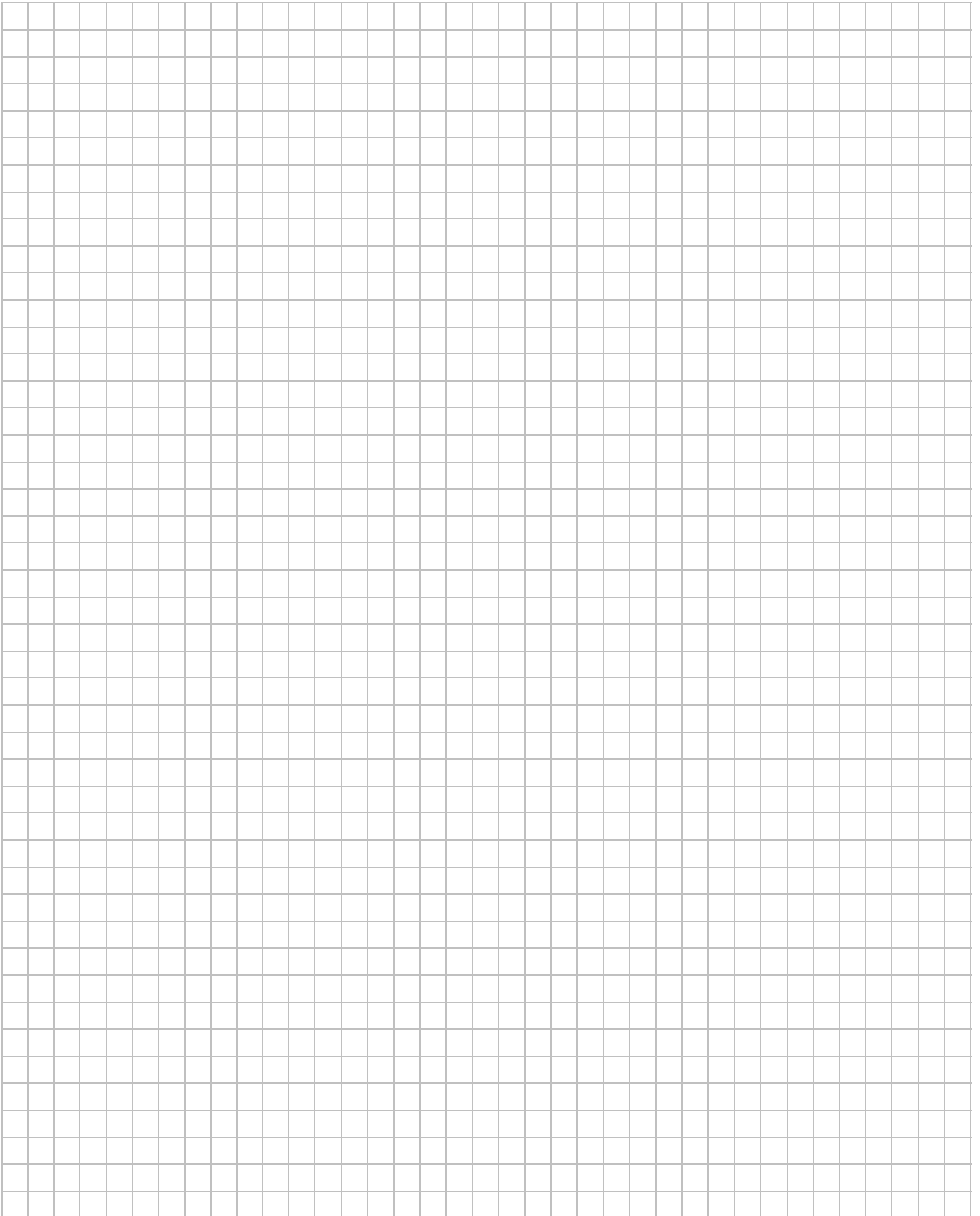
1300pm - **B** - Tour of the Redstone Quarry and famous Conway Geothermal Borehole, off US 302, southeast of Conway, NH. Trip concludes at Redstone Quarry parking site.



Glenn W. Stewart, (center) NH State Geologist, (1963-1979), oversaw the drilling project and core recovery.

Harry Mason, (right) a former Redstone quarryman, was caretaker of the inactive Redstone quarry.

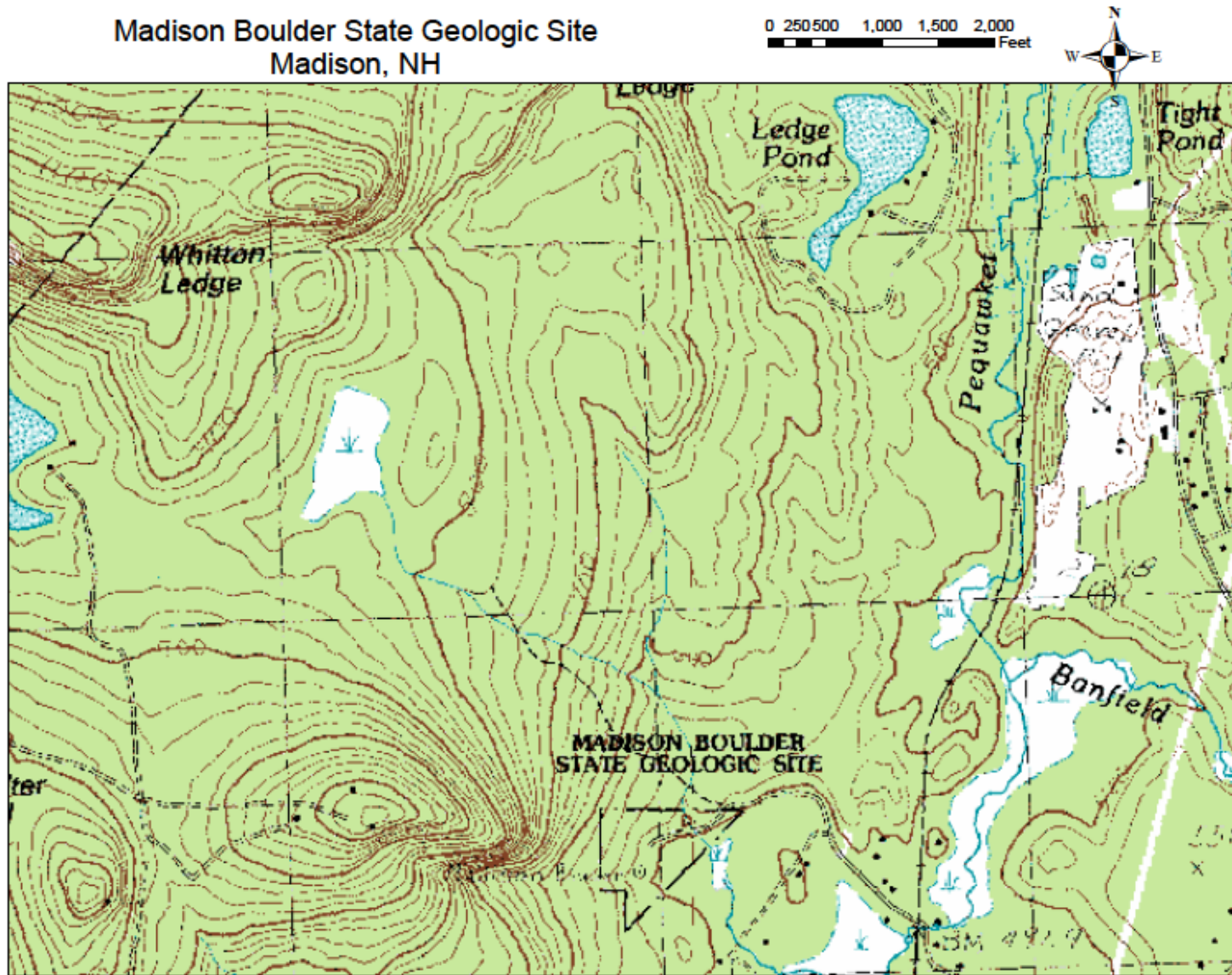
NOTES:



A – [From - New Hampshire Geological Survey's Madison Boulder brochure -

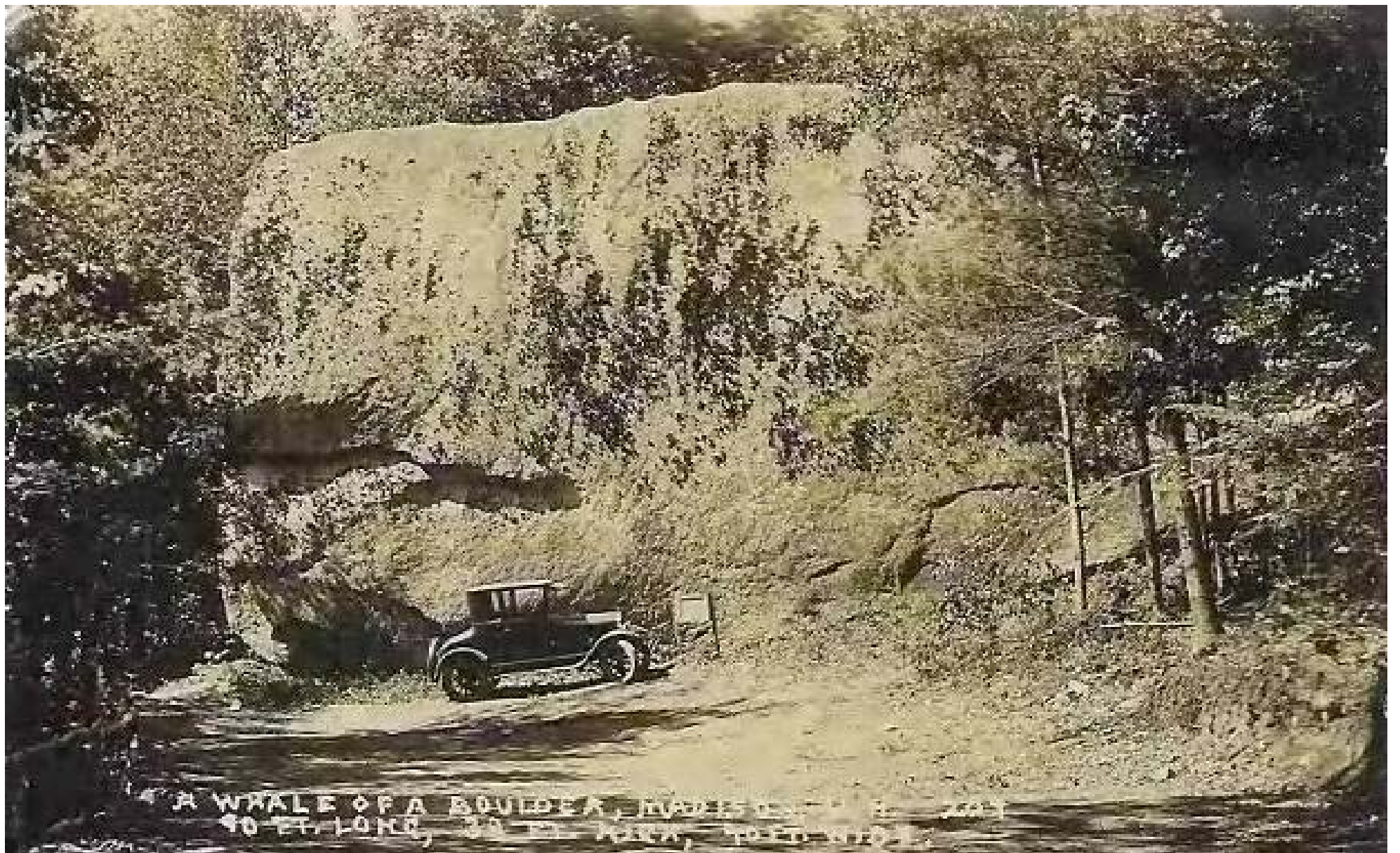
<http://des.nh.gov/organization/commissioner/pip/publications/geologic/documents/madison-boulder-brochure.pdf>]

Madison Boulder located off NH Route 113 in Madison, NH is the largest known glacial erratic in North America and a National Natural Landmark. Its base is buried up to 10' deep. The exposed portion of the Madison Boulder measures 23' (7m) in height, 37' (11m) from front to back and 85' (28m) long. The Madison Boulder was probably plucked from Whitten Ledge, which is made of Conway Granite less than two miles to the northwest and deposited on Concord Granite. Estimated weight 11,926,000 lbs. based on granite weighing 164.86 lbs per cubic foot.



"Most authorities trace Madison Boulder to the Whitten or White ledges 1.25 and 4 miles respectively, to the northwest. However, a few maintain that the boulder so closely resembles one of the four types of rock that form Mount Willard in Crawford Notch, twenty-four miles to the northwest, that the ice sheet must have brought it from there. Madison Boulder lies on "glacial drift," unsorted sediments left by the retreating ice sheet."

<http://www.newhampshire.com/state-parks/madison-boulder-natural-area.aspx>



B – Redstone Quarry, Conway, NH

Why was the 3002-foot deep Redstone Quarry hole drilled?

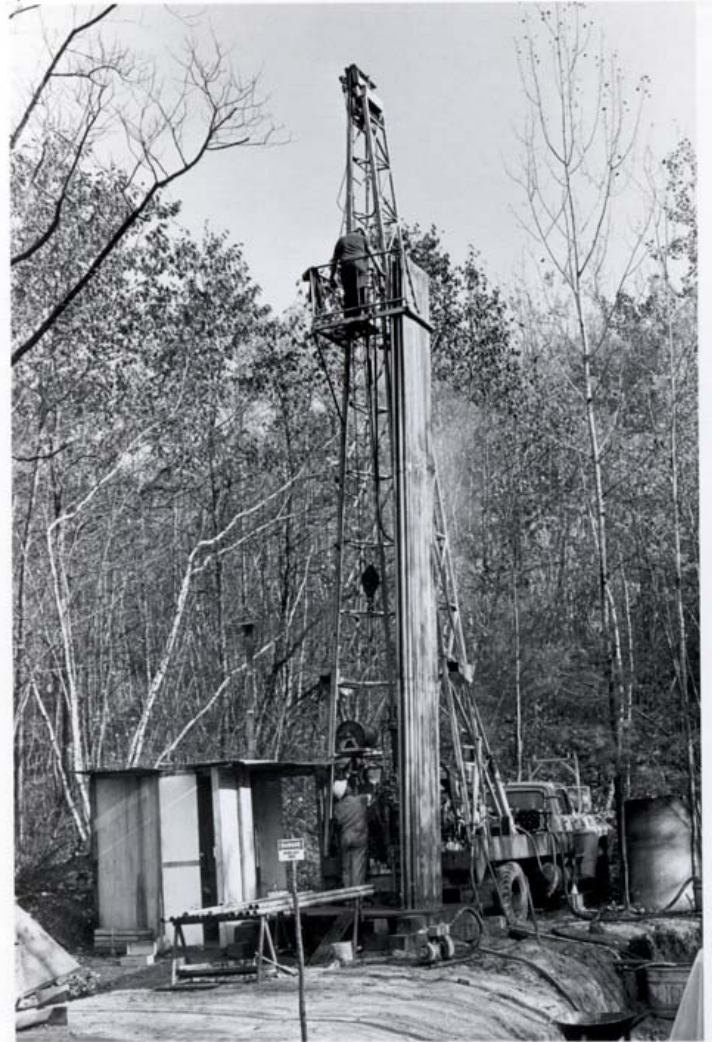
The purpose of the Redstone drill hole was primarily to evaluate the heat flow and the geothermal potential of the Conway Granite. Secondly to evaluate the Conway Granite not only as a source of energy but as a potential source of uranium and thorium and assess the possibility that vein-type uranium and thorium deposits might be associated with the Conway Granite. (Hoag and Stewart 1977)

History

Steve Swenson's ancestors were among those who operated the quarry, which saw activity from about 1883 into the 1940's. The remarkable pink and green granite from Redstone made the quarry famous, and its stone was valued for building projects throughout the region and at least as distant as Washington, D.C. The community which supported the quarry was once a very busy one, including, in its hey-day in the 1920's and 1930's, such features as a store, school, church, railroad station, and boarding house. (From <http://horsefeathers.com/wordpress/?p=196>)

This quarry is located in the Redstone district of Conway, NH, northeast of US 302, and east of its junction with NH 16. [From Lee Wilder's story titled Conway Granite Geothermal Drilling Project in Granite State Geologist: The Newsletter of the Geological Society of New Hampshire, Summer 2003, Issue No. 41.] In 1975, the Longyear Drilling Co., of Minneapolis, MN, was contracted by the Resource and Reservoir Assessment B ranch, Division of Geothermal Energy, US Energy Research and Development Administration (Hoag and Stewart, 1977). The Longyear Company drilled a 2-7/8" diameter hole, 3002' deep, (producing a 1-7/8" diameter core) in the Conway Granite at the Redstone Quarry, in North Conway, NH. At the time, the quarry was jointly owned by the Fletcher Brothers Granite Company of Milford, NH and the John Swenson Granite Company of Concord, NH.

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. Roy, Blackwell and Birch 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. (Hoag and Stewart, 1977) The Conway Granite is typically a coarse grained, pink, biotite granite (the red phase). In reality, it occurs in at least five different phases: the coarse pink (the red phase), which is typical of the Redstone Quarry; a porphyritic phase, having large feldspar (5-20 mm in diameter) and quartz crystals (2-5



The Longyear Drilling Company
Rig drilling the Conway
Borehole at the Redstone
Quarry 8/12 - 11/28/75.

mm in diameter); a medium grained and a fine grained phase; and a green phase (related to the Mt. Osceola Granite) - the green probably being kaolinite altered from green micro-perthite (Hoag and Stewart, 1977 as cited in Wilder, 2003).

Hoag and Stewart (1977) report that work by Wetterauer and Bothner (1977) suggested that the Conway Granite may extend to 2.4 km near the Redstone Quarry and may be even deeper toward the center of the pluton. But by 1000 m (~3000'), Pat (Everett) Hughes, the driller for the Longyear Drilling Company, was bringing up cores, that were not like the Conway Granite found near the surface, and on which the original heat flow assumptions were made (Roy et al (1968) and Eggers (1976).) Without the quantity of radioactive minerals for decay from the red phase of the Conway Granite, there was not the heat energy necessary to produce a good geothermal source. It was estimated that at 1000 m (1 km) the temperature should have been 44.5 degrees C. and at 6 km the temperature should be some 260° C. With a downhole temperature of only 33° C. at 3002' (1 km) (Hoag and Stewart 1977), the drilling stopped. (Wilder, 2003)

Pat (Everett) Hughes, the driller for the Longyear Drilling Company, at the Conway Granite borehole



TinMountain

CONSERVATION CENTER

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The mission of the Tin Mountain Conservation Center is “to promote an appreciation of the environment among children, families, and the community through hands-on programs in the schools, at camp, and in the community.”

Descriptions of the Conway Granite

The rocks of the White Mountain plutonic-volcanic series vary in age from 240 million year to about 90million 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. (Hoag and Stewart, 1977)

Conway Granite - Middle - Late? Jurassic White Mountain Plutonic-Volcanic Suite: Typically pink, coarse-grained mesoperthitic biotite (amphibole-free) granite; locally fine-grained or porphyritic. Includes Cretaceous alkalic syenite to granitic to gabbroic plutons, minor volcanic rocks, and lamprophyre dikes of the New England-Quebec igneous province; also includes Jurassic granite and syenite and less abundant quartz syenite, diorite, gabbro, nepheline syenite, and volcanic rocks of the White Mountain igneous province. [From USGS at <http://tin.er.usgs.gov/geology/state/sgmc-unit.php?unit=NHJc1b:0>]

Figure 1 Location of the Redstone Quarry Drill Hole - From Hoag and Stewart, 1977.

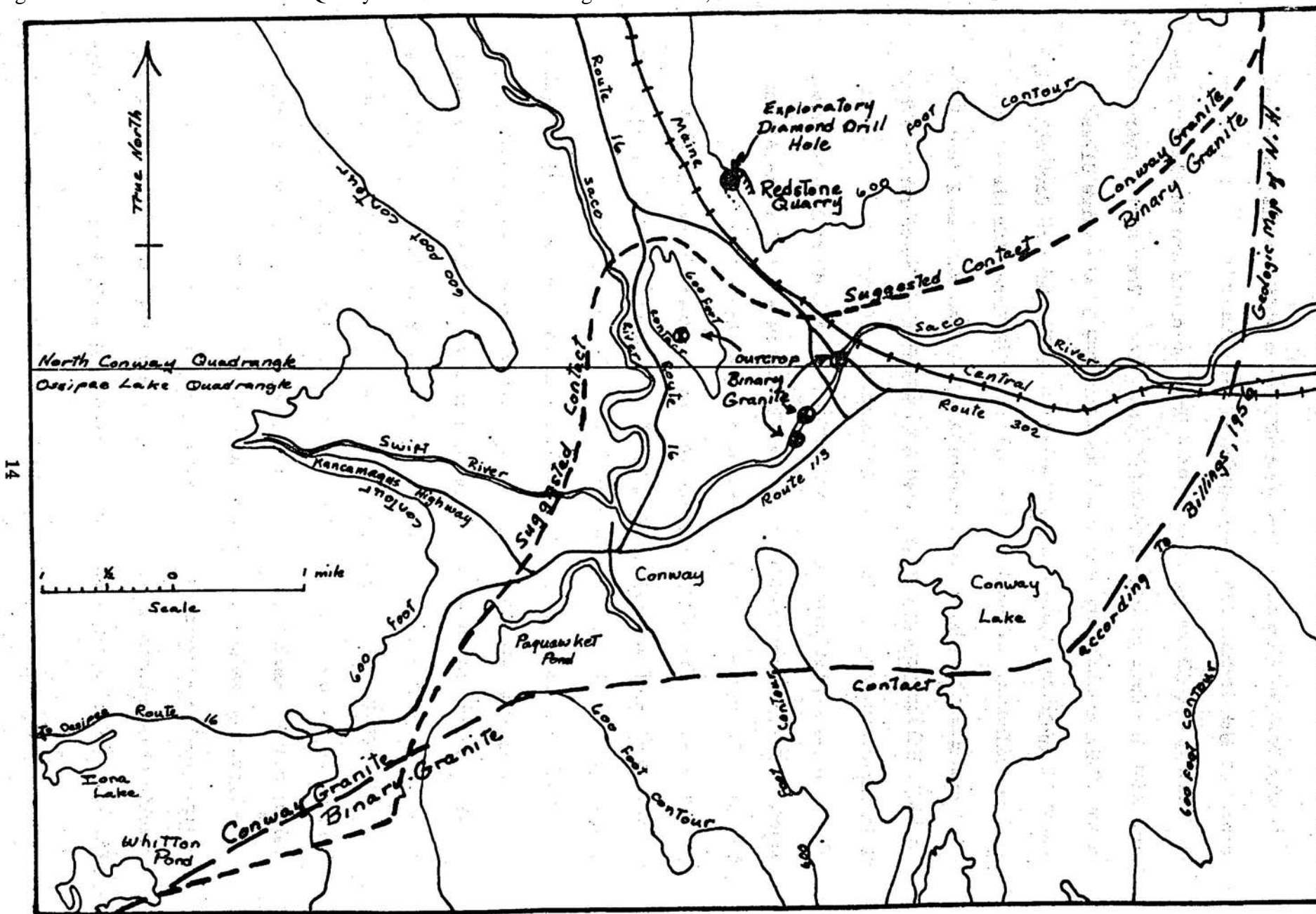
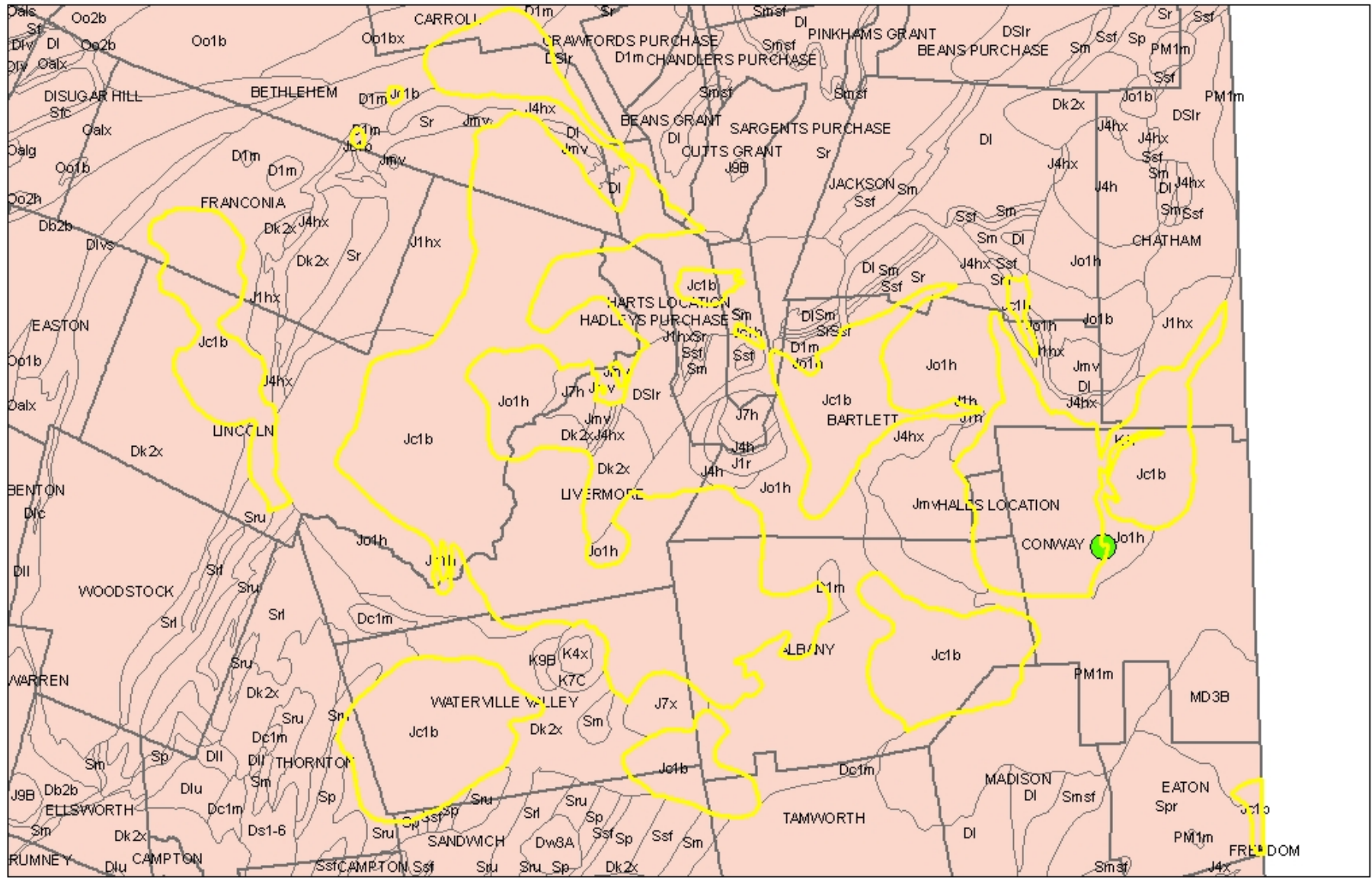
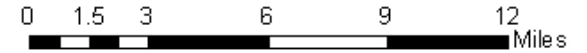


Figure 1 Location map showing proposed contact revisions

Automated from "A New Bedrock Geologic Map of New Hampshire" by Lyons et al., 1991, Geological Society of America Abstracts with Programs. 1:250,000-scale Available from GRANIT.
 Jc1b - Conway granite contacts highlighted
 Redstone Quarry in Conway marked with dot



DESCRIPTIONS OF THE CONWAY GRANITE (continued)

[From – Creasy and Fitzgerald] This pink sub-aluminous biotite granite is the most extensive unit in the North Conway quadrangle. Billings (1928) showed the Conway Granite as a single irregularly shaped pluton and as the youngest of the White Mountain magma series. More detailed mapping (Osberg and others, 1978) has recognized several distinct plutons of biotite granite on the basis of texture and outcrop geometry (Figure 3). Absolute ages for plutons in the North Conway quadrangle are within the range of 183-155 Ma (Eby and others, 1992). Field relations suggest that emplacement of these plutons was not synchronous across the quadrangle but related to individual magmatic centers. The Birch Hill pluton (Osberg and others, 1978) is the largest pluton. The Conway Granite of this pluton becomes finer grained, porphyritic, and miarolitic where it intrudes the Moat Volcanics. The Gardiner Brook pluton (Osberg and others, 1978) intrudes Moat Volcanics on Mount Kearsarge and is associated with the magmatic center defined by ring IV (Figure 3). The Conway Granite of this pluton shatters Silurian metasedimentary rocks (Hatch and others, 1984) along the East Branch of the Saco River. A third pluton underlies most the Green Hills, the prominent north-south oriented ridge forming the east side of Mt. Washington Valley; this pluton is well exposed on Black Cap Mountain.

The Conway Granite is a medium- to coarse-grained pink biotite two-feldspar granite. Values of microperthite: oligoclase range from 2:1 to 10:1 and average 4-5:1 (Creasy, 1974). Annite (Ann90) forms anhedral interstitial grains up to 5 mm in size. In contrast with other members of the White Mountain magma series, fayalite and ferropedenbergite are absent. Subordinate amphibole is present in some samples. Zircon, allanite, apatite, sphene, and fluorite are common accessories. Near intrusive contacts, the Conway Granite shows a variety of textures that may grade into each other on the outcrop scale: porphyritic, aplitic, miarolitic, and pegmatitic. Miarolitic cavities are typically of mm-scale and bounded by euhedral crystals of quartz and feldspar. A zone of miarolitic cavities ranging up to several meters is present within the Conway Granite adjacent to the Moat volcanics on the east side of the Moat Range.

This and similar occurrences of miarolitic cavities in the eastern batholith have produced many beautiful smokey quartz crystals. Weakly developed banding on the cm- to dm-scale resulting from variations in grain size and/or mineral concentrations is developed near some contacts. Lithic fragments of any type are sparse in the Conway Granite.

Black Cap Granite. The Black Cap Granite (Billings, 1928) is a fine-grained pink aplitic biotite granite that outcrops in two small areas in the North Conway quadrangle. It is composed of quartz, microperthite, subordinate oligoclase, and chloritized biotite. Accessories include zircon, magnetite, apatite, and fluorite. The Black Cap Granite is shattered and intruded by the Conway Granite (Green Hills pluton) on the flanks of Black Cap. Billings considered this rock an early lithologically distinct 'phase' of the Conway Granite. Osberg and others (1978) suggest that the Black Cap granite to be coeval with and a roof facies of the Conway Granite.

What were the geothermal expectations?

[From Virginia Minerals, 1982]

Birch and others (1968), Lachenbruch (1968), and Roy and others (1968) showed that the local heat flow in the eastern United States has a well-defined relationship to the concentration of uranium and thorium in fresh, unweathered samples of crystalline rock (mostly granite) collected from the surface of the earth. The generation of heat by the radioactive decay of naturally occurring isotopes is a process that converts mass to energy according to Einstein's equation $E = mc^2$. Isotopes of only three elements occur in sufficient abundance and have half-lives sufficiently long relative to the age of the earth to be important for heat generation from radioactivity in rocks (Birch, 1954). These are isotopes of uranium (U), thorium (Th), and potassium (K). Radioactive isotopes of these elements have half-lives of the order of 1 billion years or more. The heat contribution, H, in calories per gram of rock per year is given by the equation:

$$H = 0.72 U + 0.20 Th + 0.27 K$$

where U is uranium content of rock in parts per million, Th is thorium content of rock in parts per million, and K is potassium content of rock in weight percent. From the above equation, it is apparent that decay of a uranium atom produces about four times as much heat as the decay of thorium atom.

Hot Dry Rock in the Eastern United States

Rocks hot enough to be a potentially useful energy source exist everywhere, but it must be possible to reach the depths of these rocks economically. Hot dry rock is rock of extremely low permeability. The resource is utilized by fracturing the rock, injecting water into the fracture system, and then extracting the heated water. Regional heat flow data indicate that almost 250,000 km² in the western U.S. is underlain by hot dry rock at temperatures above 290°C at a depth of 5 km (Pettit, 1979). Los Alamos Scientific Laboratory, a leader in the development of hot-dry-rock resources, predicts that there are large such resources in the East, and that the most likely heat source is radioactive granite (Pettit, 1979). At any given depth, temperatures in hot dry rock in the East will be lower than those in the West because of the high level of tectonic activity and vulcanism in the West. The range of temperatures to be expected in the East can be estimated from Figure 3. A recent report (Schubert and Johnson, 1980) evaluates the hot -dry- rock potential near Wallops Island, Virginia.

The increased concentrations of uranium, thorium, and potassium in granitic rocks are the primary cause of elevated heat flow in the eastern U.S. Not all granites are similarly enriched, and characterization of the granites is necessary to identify those with the highest potential.

DESCRIPTION OF THE DRILL CORE

(Following descriptions are from Hoag and Stewart, 1977) 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, a mottled greenish rock, lamprophyre dikes and aplite and fine-grained pink granite dikes at numerous locations

Rock Types Encountered

Conway Granite – red phase - The red phase of the Conway Granite is a coarse-grained hypidiomorphic rock composed of microperthite, smoky quartz, biotite, minor plagioclase and amphibole. Accessory minerals include hastingsite, apatite, zircon, fluorite, allanite, monazite and thorianite.

Conway Granite – green phase (Mt. Osceola Granite)

The green phase of the Conway Granite is a medium-grained hypidiomorphic rock composed of altered green' micro-perthite, smoky quartz, hastingsite, biotite, and minor plagioclase. The micro-perthite crystals 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. Common accessory minerals include zircon, fluorite and monazite.

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. It also has a substantial amount of apatite and other accessory minerals as inclusions. Also contains microperthite, smoky quartz crystals, and hastingsite with magnetite and apatite as common inclusions and sometimes replacing biotite. The main accessory minerals are fluorite, apatite, magnetite and abundant zircon.

Hastingsite-biotite granite

The bottom 200 feet of the drill hole consists of a hastingsite biotite granite. The main feldspar is microperthite. The plagioclase is less abundant than the microperthite.

Quartz exists as large irregular crystals 2 mm in diameter and small rounded crystals 0.1 mm in diameter. Amphibole is brown to-dark green and probably is hastingsite. Magnetite is frequently found as inclusions. Biotite is less abundant than amphibole but is conspicuous in places. The accessory minerals are magnetite, zircon, apatite and very minor fluorite.

Less common rock types include coarse-grained mottled syenite, fine-grained foliated granite (dark greenish-gray), lamprophyre dikes (exclusively between depths of 1638 and 2547 feet and all but one thin dike are found in the red phase of the Conway Granite), and eight significant alteration zones (ranging in size from 150 feet to 3 feet in thickness).

RADIOACTIVITY

The average radioactivity of the different rock types is: the red phase, 700 pulses/second; the green phase, 350 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 – (averages 650 to 750 pulses/second) The background radioactivity of the red phase is exceedingly variable. High values are thought to represent normal levels with the low values thought to represent a loss of radioactive elements. As a general rule perhaps 80% of the time, zones of lower radioactivity are related to fine grained rocks, mushy areas and zones of alteration. (The "mushy zones in the red phase were probably formed by movement in the partially crystallized magma.

The .Green Phase – (350 pulses/second) Have constant radioactivity levels with peaks coinciding with fine-grained granites or aplite dikes with sharp contacts, mushy, fine-grained shearing or zones of minor rock alteration. There are no lows below the base level indicating that the sources of the high radioactive zones are a different magma source than the green phase in the dikes or deposition from radioactive solutions in the alteration zones.

Albany Quartz Syenite – (200 pulses/second) – Irregularity of the radioactive response is due to the heterogeneity of the core which is mixed with red phase or zones of pegmatites and miarolitic cavities. Aplite, fine-grained granite dikes and a few areas of minor alteration are the zones high in radioactivity and minor alteration zones and mafic segregations are significant lows.

Hastingsite-Biotite Granite – (260 pulses/second) The radioactive signature is very stable. Monazite [(Ce,La,Nd,Th)PO₄] or thorianite [ThO₂] were not observed but zircon was conspicuous. Probably the radioelements are contained in this mineral.

Coarse-Grained, Mottled Quartz Syenite - 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 [(Ca, Ce, La, Y)₂(Al, Fe)₃(SiO₄)₃(OH)] or thorianite.

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. [HFU (heat flow units), HGU (heat generation units)]

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. (Hoag and Stewart, 1977)

(Following is the abstract from Caruso and Simmons, 1985 demonstrating the presence of radioactive elements in veins in the Redstone Quarry core.)

The spatial distribution and mineralogical association of uranium in 30 samples of a 1,000 meter core from the Redstone (NH) Quarry were examined with fission track techniques, backscattered electron imaging, and energy dispersive X-ray spectrometry with the following results for the Conway and Mount Osceola granites: (1) Uranium occurs in microcracks sealed with siderite and/or with Ca+ RE [radio elements] fluorocarbonate minerals; the uranium contents of siderite and the RE fluorocarbonates are 1 to 30 ppm and 500–1,500 ppm, respectively. (2) Siderite and to a lesser extent RE fluorocarbonate minerals occur as replacement minerals of amphibole and biotite; the RE fluorocarbonates are the main alteration minerals of allanite. (3) The degree of alteration and the extent of uranium redistribution are greater in samples with major uraniferous microcracks. (4) The contents of Ca and Mn are approximately constant for siderite in sealed cracks throughout the Conway and Mount Osceola granites for the entire section penetrated by the corehole, approximately 700 meters. — From these observations, we conclude that an extensive set of fractures throughout a significant volume of the Mount Osceola and Conway granites were the conduits through which hydrothermal fluids containing CO₂, uranium, and REs circulated. Microcracks facilitated fluid-rock interactions resulting in alteration and uranium redistribution. Certain primary uraniferous accessory minerals, i.e., allanite and ilmenorutile may have been the source for at least part of the uranium and REs that now occur in secondary minerals in these granites.

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