

The Provenance of Erratics on the Stony Brook Campus Based on Ar-Ar ages of mica and hornblende

Waldemar Pacholik¹, Sidney Hemming² and Gilbert N. Hanson³

¹ Central Islip High School

² Columbia University, Lamont Doherty Earth Observatory, Palisades, NY 10964

³ Department of Geosciences, SUNY, Stony Brook, NY 11794-2100

Single grain Ar-Ar ages for biotite, muscovite and hornblende have been obtained on representative erratic boulders on the Stony Brook Campus to test the hypothesis that most of the boulders are from the basement of Long Island Sound (Pacholik and Hanson, 2001). The basis for this hypothesis is that the boulders, which were brought to the Stony Brook campus by the late Wisconsinan glacier, traveled in an essentially north-south trend. If the boulders were sourced in Connecticut, there should be a large proportion of biotite- and hornblende-rich rocks of the Harrison Gneiss suite, typical of the rocks immediately to the north in Connecticut. However, most of the boulders on campus are typically leucocratic and are more similar to those found in the Avalonian Terrane east of New Haven. This would suggest that another source, such as the basement of Long Island Sound, is the source of many of these boulders.

Geologic Background

Three hundred seventy three boulders, from a 0.3 square mile area of the SUNY Stony Brook campus, were classified according to size, shape, roundness, breakage, sphericity, combined mean size and rock type (Pacholik, 1999 & 2000, and Pacholik and Hanson, 2001). Using hand specimen descriptions and petrography the rocks on campus have been compared to similar rocks in Connecticut. The assumptions used for evaluating the distance traveled by the boulders are that:

- The most numerous and least rounded populations of boulders are derived from the nearest basement.
- The least numerous and most rounded populations of boulders are derived from basement at greater distances.

These results have been used to estimate relative distances to the basement sources of the boulders.

The general information about bedrock of the Long Island Sound basin is derived from geophysical studies; but specific data about the types of basement rocks are not known. Sanders (1960, 1963) proposed that Triassic-Jurassic rocks similar to those found in the Hartford Basin extended into Long Island Sound. A driller reported encountering several hundred feet of sandstone near Northport, Long Island (de Laguna and Brashears, 1948). A magnetic map of Long Island Sound shows a change in character of the magnetic anomalies where the basin is proposed to be (Grim et al. 1970). Seismic studies are consistent with this interpretation. Lewis and Stone (1991) report a deep bedrock anomaly in the same area. This is important because if the boulders are derived from a northerly direction there should be few or no boulders of Hartford Basin sedimentary rocks or basalts found on campus, because the Hartford Basin is to the east of the area. If there is a rift basin in the Long Island Sound north of Stony Brook we should expect to find a relatively large number of basaltic boulders on campus. The likelihood of numerous large sedimentary boulders is small because of the size of the beds, the close spacing of the joints and the friable nature of the sedimentary rocks in these basins.

The results of the study by Pacholik and Hanson, 2001 show that 85% of the boulders are similar to those in the Avalon Terrane. Also the Avalonian boulders have a bimodal distribution when their percentage is plotted against roundness. Of the 373 boulders studied 28 are basalts. The basalts are unimodal when their percentage is plotted against roundness. The mode for basalts is between the two modes for the Avalonian terrane boulders suggesting that the rift basin is cutting rocks of the Avalonian terrane in Long Island Sound.

The coarse grained boulders on campus have been broadly separated into Avalonian, Acadian and others. The Avalonian boulders have been subdivided into Middletown, Branford and Stony Creek types. The Acadian boulders have been subdivided into Beardsley and Pumpkin Ground types of the Harrison Gneiss (Pacholik and Hanson, 2001). While the Avalonian boulders make up 85% of the boulder population on campus, the Acadian boulders make up only 3%.

Ar-Ar ages

Muscovite, biotite and hornblende grains were co-irradiated with hornblende monitor standard Mmhb (age = 525 Ma, Samson and Alexander, 1987) in the Cd-lined, in core facility (CLICIT) at the Oregon State reactor. Analyses were made in the Ar geochronology laboratory at Lamont-Doherty Earth Observatory. Individual grains were fused with a CO₂ laser, and ages were calculated from Ar isotope ratios corrected for mass discrimination, interfering nuclear reactions, procedural blanks and atmospheric Ar contamination. The analytical uncertainty for the single grain micas for all but one of the samples is 1.5 million years or less. One biotite sample has an analytical uncertainty of 6 Ma.

Rocks associated with or affected by the Taconian are found in the western Hudson Highlands and the Taconic Mountains of eastern New York and western New England. The Taconian Orogeny began about 455 million years ago and lasted for some tens of millions of years (Lanzirotti). Much of the area affected by the Taconian Orogeny was later affected by the Acadian Orogeny as a result biotite and muscovite K-Ar ages for the Taconian terrane rocks were reset to between 400 to 350 Ma (Long, 1962). The rocks affected by the Acadian orogeny in western Connecticut have biotite and muscovite ages between 350 to 320 Ma (Scott et al., 1980, Seidemann, 1980). The mica ages of Acadian terrane rocks in the southern part of western Connecticut were reset by Alleghanian events (Clark and Kulp, 1968, Cosca *et al*, 1997). In Connecticut the rocks affected by the Alleghanian Orogeny have mica ages between 220 to 300 Ma (Zartman et al, 1970, Scott et al., 1980, Dallmeyer, 1982 Cosca *et al*, 1997), with older ages in the west and younger in the east.

Avalonian Boulders

Thirteen biotite and muscovite grains from four Branford type boulders (no. 4, 30, 31 and 44 Pacholik, 1999) give an average age of 237 Ma with a standard deviation of 11 Ma. Ten muscovite and biotite grains from three Stony Creek type boulders (no. 19, 22, and 27, Pacholik, 1999) give an average age of 234 Ma with a standard deviation of 5 Ma. These ages are consistent with these boulders being derived from an Avalonian terrane.

Six biotite grains from two Middletown type boulders give an average Ar-Ar age of 234 Ma with a standard deviation of 5Ma. Three biotite grains from one boulder (no. 27a, Pacholik, 1999) give an average age of 280 Ma with a range of 279-283 Ma. These ages are also consistent with these boulders being derived from an Avalonian terrane. It is not clear why biotite from boulder 27a gives a significantly older age.

Acadian Boulders

Four biotite grains from one Beardsley type boulder (no. 37, Pacholik, 1999) give an average age of 284 Ma with a range of 280 to 291 Ma. Five biotite grains from a Pumpkin Ground type boulder (no. 20, Pacholik, 1999) give an average Ar-Ar age of 268 Ma with a range of 263 to 274 Ma. These mica ages are young compared to the more typically 320 to 350 m.y. ages for the Acadian micas. They are consistent with the finding of Clark and Kulp, 1968, and Cosca *et al*, 1997 that some mica ages for basement rocks in southern Connecticut and under Long Island Sound have been reset by the Alleghenian Orogeny.

Other Boulders

Two biotite grains from a diorite boulder (no. 24, Pacholik, 1999) give Ar-Ar ages of 417 and 423 ma. These ages are too old to have been affected by Acadian events and are more typical of rocks affected by the Taconian Orogeny in western New England and eastern New York (Long, 1962). Thus, this boulder has traveled a long distance from the northwest.

Three chloritized biotite grains from a granodiorite boulder (no. 25, Pacholik, 1991) give an average age of 386 Ma with a range of 364 to 399 Ma. This rock shares a mineral composition with the Beardsley Gneiss, a member of the Harrison gneiss which was intruded during the Taconian Orogeny at 430 to 455 Ma (Sevigny and Hanson, 1995). These ages are older than most of the Acadian mica ages. Also, the range in ages suggests that the micas are Taconian and were partially reset by the Acadian orogeny. Again, this boulder has traveled a long distance from the northwest.

One hornblende grain from a hornblendite boulder (HOR, Pacholik, 1999) gives an Ar-Ar age of 369 Ma. This is an Acadian age and suggests that this boulder was probably derived from Connecticut essentially directly north of the campus.

One biotite grain from a biotite hornblende granite boulder (no. 29, Pacholik, 1999) gives an age of 187 ± 6 Ma. This age is young even for a rock affected by the Alleghenian orogeny and most probably has undergone alteration or weathering.

Conclusion

The single grain Ar-Ar ages for mica and hornblende support the hypothesis that the boulders on the Stony Brook Campus were derived from the basement in Long Island Sound and that the basement is dominated by Avalonian terrane granites and gneisses. A small proportion of boulders typical of the Harrison Gneiss in Connecticut have Alleghenian metamorphic ages suggesting that they either they are from southern Connecticut or from Acadian terrane underlying Long Island Sound. Diorite and granodiorite boulders have mica ages that are more typical of the Taconian terrane. This suggests that these boulders were derived from near the New York – New England border area to the northwest and traveled a significant distance, many tens of miles, to reach Stony Brook. One hornblendite boulder has a typical Acadian terrane age and was probably derived from basement rock directly to the north in Connecticut. Thus, while most of the boulders most likely have the basement underlying Long Island Sound as their source, a small proportion of the boulders have traveled much further.

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