Boulders on Stony Brook Campus May Reveal Geology of Long Island Sound Basement

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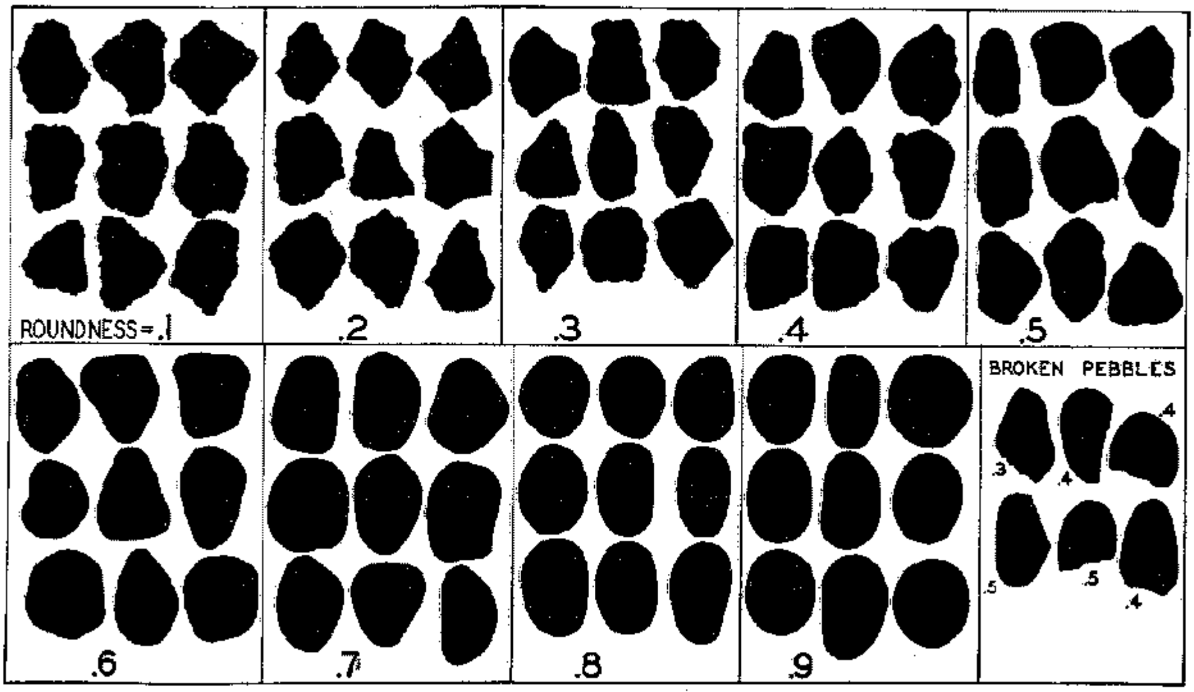
Hundreds of boulders from 30 to 300 cm in diameter are scattered about the campus of the State University of New York at Stony Brook. They were excavated from the underlying glacial sediments on campus during construction of roads, buildings, etc. The Stony Brook campus is on the Stony Brook Moraine which was formed near the end of the Wisconsinan some 20,000 years ago (Sirkin, 1986). Based on observations at construction sites and from a few bore holes the glacial sediments consist of an upper layer of loess up to one meter thick which overlies a layer of till about one meter thick. Below the till are sands, gravels and varved fine sand and clay which have been glaciotectonically disturbed. While the overlying till where exposed has a relatively high concentration of boulders, it is not clear that all of the boulders were derived from this till. In any case the boulders were brought by glaciers to the campus area. The dominant direction of travel of the glaciers was from the north across what is now Long Island Sound. The nearest presently exposed outcrops are in southern Connecticut some 15 to 20 miles to the north. However, when the last Wisconsinan glacier advanced toward present day Long Island the bottom of much of the present Long Island Sound was basement rock (Lewis and Stone, 1991). The sources of the boulders on campus could be anywhere to the north along the path of the glacier. If we can estimate the distance that the boulders have traveled, we may even be able to evaluate the types of basement rocks underlying Long Island Sound. The assumptions used for this study are that the most numerous and least rounded boulders are derived from the nearest basement. The least numerous and most rounded boulders are from basement at greater distances.

Three hundred seventy three boulders, from a 0.3 square mile area of the SUNY Stony Brook campus, have been classified according to size, shape, roundness, breakage, sphericity, combined mean size and rock type (Pacholik, 1999). These results have been used to estimate possible distances to the basement sources of the boulders. Petrographic descriptions of twenty-four thin sections for the most common boulders have been used to compare the boulders on campus to possible source rocks in southern Connecticut and to evaluate the rock types that may underlie Long Island Sound.

The boulders were derived by plucking or quarrying at the base of the glacier. Once plucked these boulders stay at the base of the glacier unless there is an obstruction along the path of the glacier in which case the boulder may be thrust above the glacier base. This was a temperate glacier with a wet bottom so that most of the forward motion (transport) of the glacier was associated with basal sliding and shearing of the sediment (till) at the base of the glacier. The basal transport zone (shear zone) within the till is usually only a few cm to tens of cm thick and rises or lowers within the till layer with changes in the amount of melting or regelation (freezing) (Boulton, 1978). As a result of these changes in the position of the basal transport zone, particles in the till will at various times be in or below the basal transport zone. In a temperate glacier with a wet base there is continuous melting at the base of the glacier. As a result sedimentary particles tend to stay at the base. However, at the front of temperate glaciers in the marginal zone of compression where there may be permafrost or freezing during the winter the base of the glacier may be frozen to the substrate and basal sediments may travel up into the glacier along englacial thrust faults (Boulton, 1978; Benn and Evans, 1998, p. 538).

There are numerous examples of boulders (erratics) traveling many hundreds of kilometers. However, this is not the norm for boulders. For example, Salonen (1986, 1987) found that after 5 kilometers of travel from their source, till contained only one-half of the proportion of the initial particles. Humlum (1981) found for cobbles derived from a rhyolite plug, that their size, shape and roundness reached an equilibrium state after transport of only 500 meters. This is in part because the larger clasts became lodged in the till while the smaller clasts continued to stay in basal transport. Goldthwait (1968) found that less than 0.1% of any rock type is found beyond 21 miles of it source. Due to the large number of advances and retreats of glaciers during the Pleistocene, boulders may have a complicated history of being removed from the bedrock, transported, deposited and then reincorporated in the basal transport zones of later glaciers allowing much longer distances and dispersed paths of transport.



PEBBLE IMAGES FOR VISUAL ROUNDNESS

Figure 1. Images for evaluating visual roundness of pebbles (Krumbein, 1941)

An essential factor in considering the distance that a boulder may travel is the establishment of dynamic equilibrium between roundness and breakage. Fig. 1 is the visual roundness of pebbles by Krumbein (1941). Roundness is not the sphericity. Spericity is a measure of the shape, which is how similar the three axes of a body are. Roundness is a measure of how smooth or angular the edges are. An object with very sharp edges has a roundness of 0.1. An object with extremely smooth edges has a roundness of 0.9. If an object of a given roundness breaks, the roundness becomes one-half of the origin al roundness. See broken pebbles in Fig. 1. For pebbles this balance develops after 1 mile of transportation and sustains to the end of the existence of the rock type in the basal transport zone of the glacier, which is 21 miles (Drake, 1972). For pebbles, the early development of the equilibrium, around 0.5 class of roundness is possible because of the small surface area of abrasion and the fact that the population of pebbles is continually replenished by the crushing of larger boulders. When boulders are crushed into smaller pieces, there is no replacement and the population of boulders constantly decreases. That is why the equilibrium between roundness and breaking, around 5 (0.5) roundness, develops after 9 miles of transportation and most boulders in the basal transport zone should survive only up to 18 miles (Fig. 2). The rate this balance is achieved depends on the hardness of rock, the extent of foliation or joints and whether the boulder moves upward into the glacier or remains at the base of the glacier during transport of the boulder.

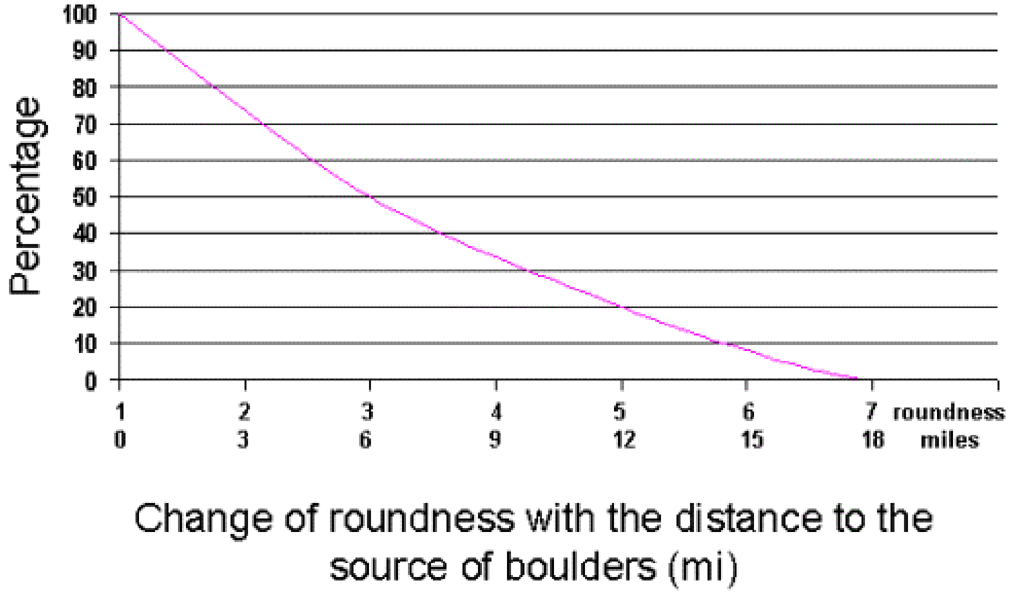


Figure 2. Change of roundness with the distance to the source of boulders assuming that the boulder was transported dominantly in the basal transport zone.

1. Newark (Rift Valley) Terrane
   a. Hartford Basin
   b. Pomperaug Basin
2. Proto-North American Terrane
   a. Carbonate shelf
   b. Grenville Massifs
3. Iapetos Terranes
   a. Connecticut Valley Synclinorium
   b. Bronson Hill Anticlinorium
   c. Merrimack Synclinorium
   d. Taconic Allochthons
4. Avalonian Terrane
5a. Fordham Terrane
5b. Coastal Plain

SB = SUNY Stony Brook Campus

Figure 3 Geologic Terranes of Eastern New York and Connecticut (Rodgers, 1985)

The terranes exposed in southern Connecticut (Rodgers, 1985) going from west to east include:

- Grenville gneisses about 1.1 Ga in age which formed the basement to Laurentia (proto-North America)
- Overlying Cambro-Ordovician metasedimentary rocks which were deformed and metamorphosed during the Taconian Orogeny (440 to 455 Ma),
- Schists and gneisses of the Connecticut Valley Synclinorium which were metamorphosed during the Acadian Orogeny (360 to 420 Ma),
- Triassic and Jurassic clastic sediments, basalt and diabase of the Hartford Basin, a rift basin, Seismic studies suggest that rift valley may underlie Long Island Sound to the south-southwest of the Hartford Basin between the two dotted lines(Lewis and Stone, 1991).
- Schists and gneisses of the Bronson Hill anticlinorium metamorphosed during the Acadian Orogeny,
- Schists and gneisses of the Merrimack synclinorium metamorphosed during the Acadian Orogeny.
- Schists and gneisses of the Avalonian terrane. The older gneisses are 600 to 700 Ma, the younger gneisses and plutons are about 300 Ma. Rocks deformed or metamorphosed at about 300 Ma are also found in windows (fenster) surrounded by schists and gneisses metamorphosed during the Acadian Orogeny in the Willimantic Dome in Connecticut and in the Pelham Dome in northwestern Massachusetts (*e.g.,* Robinson et al, 1998). It would seem that the Avalonian Terrane which was not affected by the Acadian orogeny underlies the terranes metamorphosed and deformed by the Acadian orogeny. That is a crustal slice associated with the Avalonian Terrane may have been thrust into crustal slices associated with Laurentia at about 300 Ma. The boundary between the Avalonian Terrane and the other terranes in Connecticut can be seen to extend to the west, south of the Bronson Hill Anticlinorium and may well extend further to the west in the basement under Long Island Sound. In which case much of eastern Long Island may be underlain by Avalonian Terrane.
- Holocene to Cretaceous mainly unconsolidated sediments make up the Coastal Plain that dips gently to the southeast. The dashed line through Long Island Sound is the approximate boundary between the Coastal Plain sediments and the basement rocks in Long Island Sound.

Branford – Stony Creek Type of Avalonian Terrane

The boulders on campus have been compared to the rocks in the Avalonian, Iapetos and Rift Valley Terranes in Connecticut (Fig. 3) The boulders whose compositions are similar to those of the Branford-Stony Creek Massive in the Avalon Terrane of southern Connecticut constitute 85% of the boulder population of Stony Brook suggesting that they may have been derived from a close source. The Branford - Stony Creek Massive consists of granite and foliated quartz monzonite or augen quartz monzonite of Lighthouse formation. The rocks of this massive also form a variety of gneiss and migmatite on the boundary with the rocks of the Iapetos Terrane. The modal quartz, potassium feldspar and plagioclase proportion for boulders on campus are compared to the fields for the rock types in Connecticut in Figure 4. There is a very good correlation.

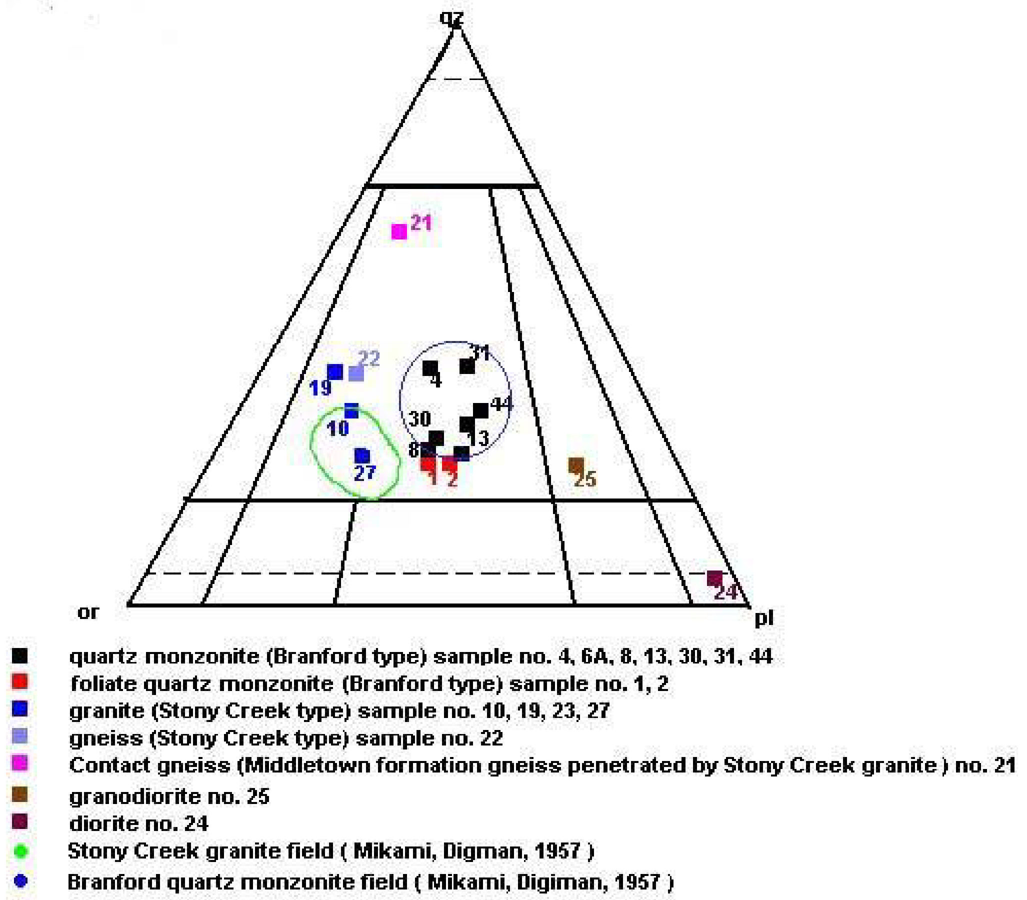


Figure 4 Ternary diagram showing the modal proportions of Quartz (qz), potassium feldspar (or) plagioclase (pl) for boulders of the Branford-Stony Creek types with a comparison to the fields for these rock types in Connecticut.

Table 1 shows the percentage of boulders in each of the roundness classes from least rounded 0.1 to most rounded 0.9. According to the maxima for the percentage distribution of roundness, the boulders could be divided into:

Near source with a roundness maximum of less than 0.5
Intermediate source with roundness maximum of 0.5
Distant source with roundness maximum greater than 0.5

Boulder types from a near source are represented by:

1. Stony Creek type of granite with the maximum at 0.3
2. Boulders of foliated quartz monzonite with the maximum at 0.2
3. Boulders of massive quartz monzonite with the maximum at 0.3.
4. Boulders of quartz, with the maximum at 0.3.
5. Boulders of pegmatite without garnet (this type of pegmatite is generally associated with the Stony Creek type of granite) with the maximum at 0.3

Boulder types from an intermediate source are represented by:

1. Basalt
2. Boulders of foliated quartz monzonite
3. Boulders of massive quartz monzonite
4. Boulders of quartz

Boulder types from a distant source are represented by

1. Stony Creek type of granite with maximum at 0.6
2. Boulders of pegmatite without garnet with maximum at 0.6
3. Boulders of quartz with maximum at 0.7 class

Some of the rock types have a bimodal distribution of roundness and others have only a single maximum. The Stony Creek type granite has two maxima of roundness at 0.3 and 0.6 suggesting it comes from sources. The Branford type foliated quartz monzonite also has two maxima, at 0.2, and 0.5. The massive quartz monzonite also has two maxima of roundness at 0.3 and 0.5. This suggests that these rock types may be derived from two separate sources along the path of the glacier. Basalt most likely derived from the possible rift basin under the present Long Island Sound has a single maximum of roundness at 0.5.

If the change in roundness curve in Figure 2 is reliable, the roundness data would suggest that the Branford type of rocks are exposed on either side of the rift basin in Long Island Sound. The basalt is derived from the rift basin.

The quartz boulders some of which may be quartzite but many of which are quartz vein material, have a wide range of roundness classes. This is consistent with their occurrence over a range of distances. Also, their durability should allow them to exist for a longer distance in the basal transport zone.

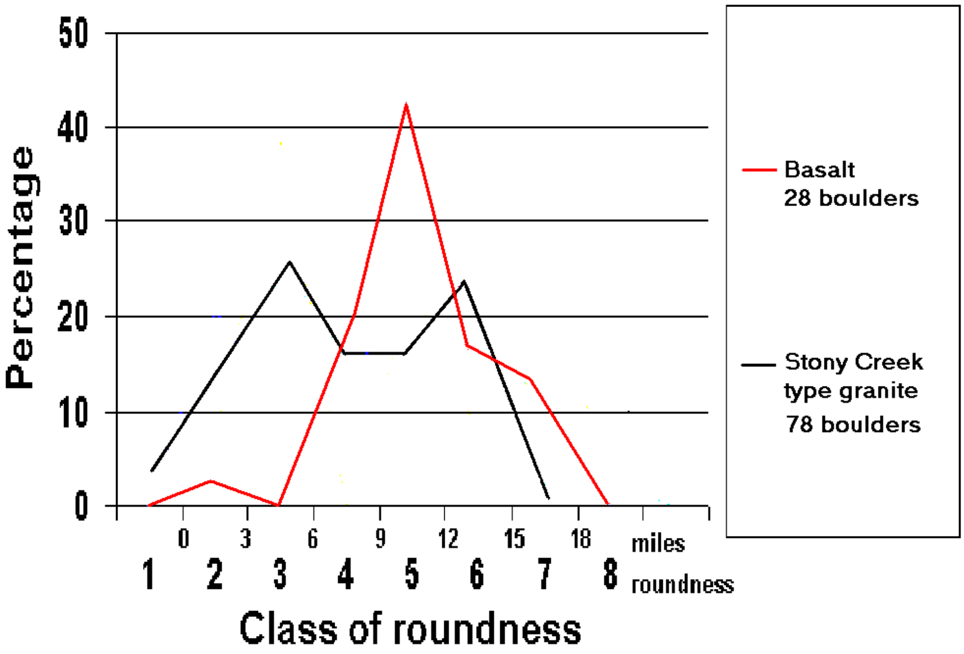


Fig. 5 Percentage of boulders from the Stony Creek type granite and basalt with a given class of roundness.

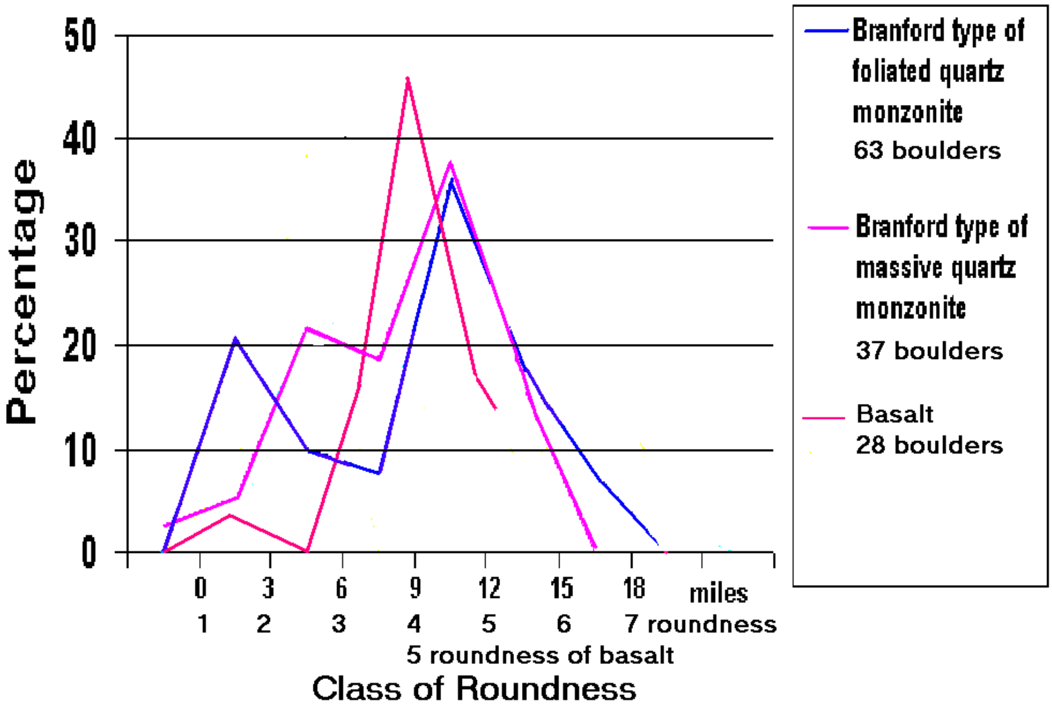


Fig. 6 Percentage of boulders from the Branford type of foliated quartz monzonite and massive quartz monzonite versus class of roundness.

Middletown Formation and Harrison Gneiss of Iapetos Terranes

The main characteristic of the Middletown formation of the Bronson Hill Anticlinorium is the widespread presence of hornblende in the rocks. The rock types include amphibole mafic gneiss, sialic gneiss and granulite, and biotite gneiss and schist (Crowley, 1968). The Harrison Gneiss of the Connecticut Valley Synclinorium is also hornblende rich. The Beardsley member of the Harrison gneiss in the Connecticut Valley Synclinorium is a biotite-hornblende gneiss. It as well as the associated Pumpkin Ground Gneiss may contain microcline megacrystals or augen which can vary widely in size and abundance. It commonly contains hornblende-rich schlieren which are parallel to the rock's foliation. The Pumpkin Ground member of the Harrison Gneiss in the Connecticut Valley Synclinorium is typified by the abundant large euhedral megacrysts of Carlsbad-twinned microcline averaging 3 cm by 1.5 cm (Crowley, 1968)

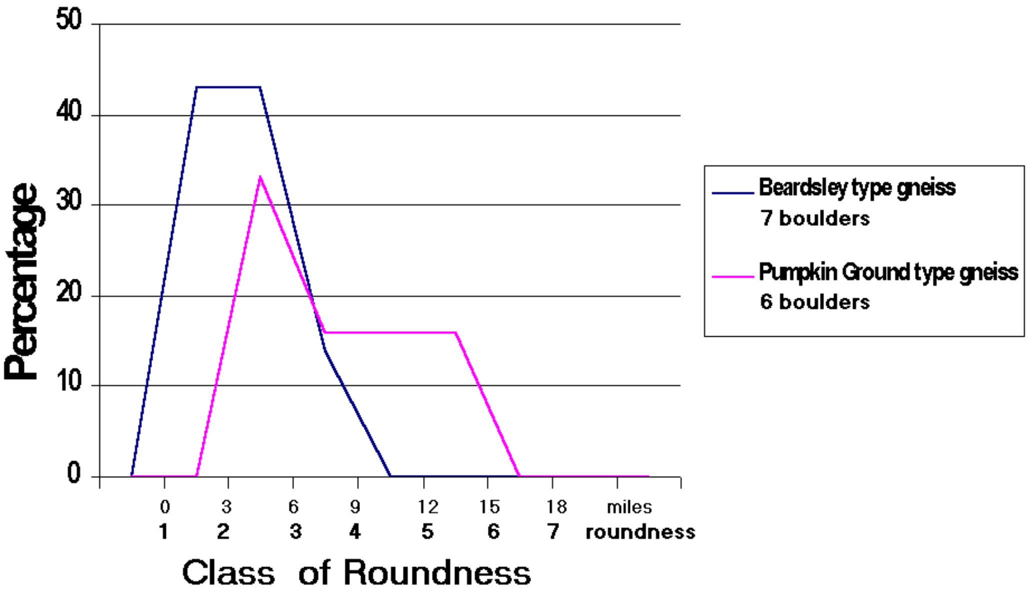


Fig. 7 Percentage of boulders from the Beardsley and Pumpkin Ground type of Harrison Gneiss versus class of roundness.

The boulder types similar to the Middletown formation and the Harrison gneiss (Table 1 and Fig. 7) have low classes of roundness and represent only 5.3% of the boulder population. This suggests that the sources for this lithology are very small and nearby.

The sources for these boulders may be small areas of scattered outcrops of Iapetos Terrane rocks on the Avalonian Branford-Stony Creek massive in Long Island Sound. This percentage agrees with the observation that less than 5% of the surface of the Branford-Stony Creek massive in Connecticut is covered by scattered outcrops of rocks from the Middletown formation (Mikami and Digman, 1957).

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