TRIP C

THE SQUANTUM FORMATION: PALEOZOIC TILLITE OR TILLOID ?

Dabney W. Caldwell, Wellesley College

The origin of the Squantum formation has long been a controversial subject in the geology of the Boston Basin area, Massachusetts. Two points of view have been expressed: (1) the Squantum formation is a Paleozoic tillite and, (2) the Squantum formation is not a Paleozoic tillite. The purpose of the present field trip is to examine the field evidence on which these views are based. Following a description of the geologic setting of the Squantum formation and a brief review of some of the previous work dealing with the Squantum formation, the results of some recent studies of the texture will be presented. Finally, a log of the field trip stops will be included.

Geologic Setting and Stratigraphic Position of the Squantum Formation

The traditional view of the Boston Bay group of sediments, to which the Squantum formation belongs, is that it comprises, in stratigraphic order, the Roxbury conglomerate, the Squantum tillite and the Cambridge argillite. These rocks overlie the Mattapan volcanics and the Dedham granodiorite and are exposed in the Central Anticline and repeated several times by faulting (Billings, 1929. LaForge, 1932). More recently Dott (1961) and Rahm (1962) have suggested that these units are more intimately related and are characterized by interfingering and facies changes. Billings (1929) considered the Squantum formation to be a separate, mappable rock unit and explained the various repetitions in terms of faulting, whereas Dott (1961) suggested, in effect, that there may exist more than one Squantum "tillite" bed within the Roxbury and Cambridge lithologies.

The age of the Squantum formation and the associated Boston Bay group has not been settled and yet is very pertinent to any discussion of a glacial or non-glacial origin of the formation. Those workers who have proposed or accepted a glacial origin have tended to place the Squantum formation within the Pennsylvanian or Permian (Sayles 1914, Emerson 1917, Billings 1929, Billings et al., 1939), whereas Dott (1961), who proposed a non-glacial origin, believed the Squantum to be Mississippian or Devonian in age. Analogy with the Permian Gondwana formations of India and the southern hemisphere and the apparent similarity between the Boston Bay Group and Carboniferous and Permian strata in Rhode Island has led to the designation of the Squantum as being of Permian or Permo-Carboniferous age, according to Dott (1961).

Origin of the Squantum Formation

There are characteristic features common to some exposures of the Squantum formation and many Pleistocene tills, such as poor sorting, lack of stratification, and relative abundance of clay matrix compared with the gravel and larger sizes. Sayles (1914) found striated pebbles in the Squantum formation but apparently is, along with Lahee (1914), the only worker to do so. Because of similarity between Pleistocene till and the Squantum formation and because a late Paleozoic glaciation had been established in the southern hemisphere and India, Sayles (1914), after extensive field work and consultation with other workers, proposed a glacial origin for the Squantum formation, which became established in the literature as the Squantum tillite. Earlier, Dodge (in Mansfield, 1906) had suggested that parts of the Roxbury formation were of glacial origin.

Later Sayles (1916, 1919) proposed that the overlying Cambridge argillite was also of glacial origin and pointed to the similarity between the rhythmical banding found in the Cambridge argillite and in Pleistocene varved sediments. Sayles apparently became the authority upon which later workers based their acceptance of a glacial hypothesis.

Dott (1959, 1961) has been a leading proponent of a non-glacial origin of the Squantum formation and has disagreed with many of the accepted views dealing with the formation. As has been mentioned, he does not accept a late Paleozoic age for these rocks and also finds many features which he feels are more reminiscent of subaqueous, partly volcanic mud flows or slides than of glacial till. Dott (1961, p. 1300) has compared the compositions of the larger fragments of the Squantum and Roxbury and finds them to be essentially the same and believes the Squantum to be reworked Roxbury sediment with some mud added during the reworking. As the clasts in both the Squantum and Roxbury formations are similar in composition and of local origin, a glacial origin for the Squantum is not only unnecessary but improbable. Dott also points out that the lack of any striated pavement beneath the Squantum and its apparently unique position in North America make a glacial hypothesis more untenable.

Many of the exposures of the Squantum mentioned by Sayles (1914) are gone but the most important are still preserved and will be visited on the field trip as will most of those mentioned by Dott (1961).

Shape of Clasts in the Squantum and Roxbury Formations

Regardless of the opinion held by previous workers concerning the origin of the Squantum formation, most have compared the Squantum formation with the Roxbury: those who have believed in a glacial origin have stressed the greater

angularity of the pebbles and cobbles in the Squantum as compared with those in the Roxbury conglomerate, whereas Dott (1961, p. 1300) believes ..."that Squantum fragments are not greatly different in shape from those of the Roxbury...". In order to come to some objective conclusion in the matter, the writer has measured the shape of several hundred cobbles and pebbles from both the Squantum and the Roxbury formations and the results of the measurements are presented below.

Smoothed surfaces have been produced by Pleistocene glaciation or by jointing on many outcrops of the Squantum and the Roxbury formations and it is possible to measure the roundness of clasts directly from the outcrop, following the method described by Krumbein and Pettijohn (1938, p. 295). Roundness is expressed as

$$\text{Roundness} = \frac{\text{Average radius of corners and edges}}{\text{Radius of maximum inscribed circle}}$$

The average radius of sharp corners and edges is small compared with the size of the fragment as a whole, and the roundness is low. With increasing rounding of the edges, the average edge and corner radius approaches the radius of the fragment and the value of the roundness approaches 1.0. According to Pettijohn (1957, p. 59), the common terms used to describe roundness have the roundness values shown in Table 1.

TABLE 1 - Roundness values of common roundness terms

Angular	=	0	- 0.15
Sub Angular	=	0.15	- 0.25
Sub Rounded	=	0.25	- 0.40
Rounded	=	0.40	- 0.60
Well Rounded	=	0.60	- 1.0

At each locality, the roundness of 100 fragments was measured and the median roundness, the mean roundness and the standard deviation were determined. These data are presented in Table 2.

TABLE 2 - Roundness and standard deviation of clasts in the Squantum and Roxbury formations

	LOCALITY	Roundness MEDIAN	Roundness MEAN	Standard Deviation
ROXBURY	Chestnut Hill	.49	.54	.16
	Franklin	.46	.52	.14
	Atlantic	.47	.53	.15
SQUANTUM	Weld Street	.45	.53	.23
	Arboretum	.45	.54	.23
	Atlantic	.44	.52	.24

This analysis indicates that, as expressed by "average" roundness, median or mean, there is little significant difference between the Squantum and Roxbury clasts but a significant difference in the dispersions of roundness values about the mean roundness values. Stated in words, it may be said that in the Squantum, there are a greater number of both angular and well-rounded fragments than in the Roxbury. It is interesting to note that as far as average roundness is concerned both formations may be characterized as having clasts which are rounded (roundness 0.4 to 0.6).

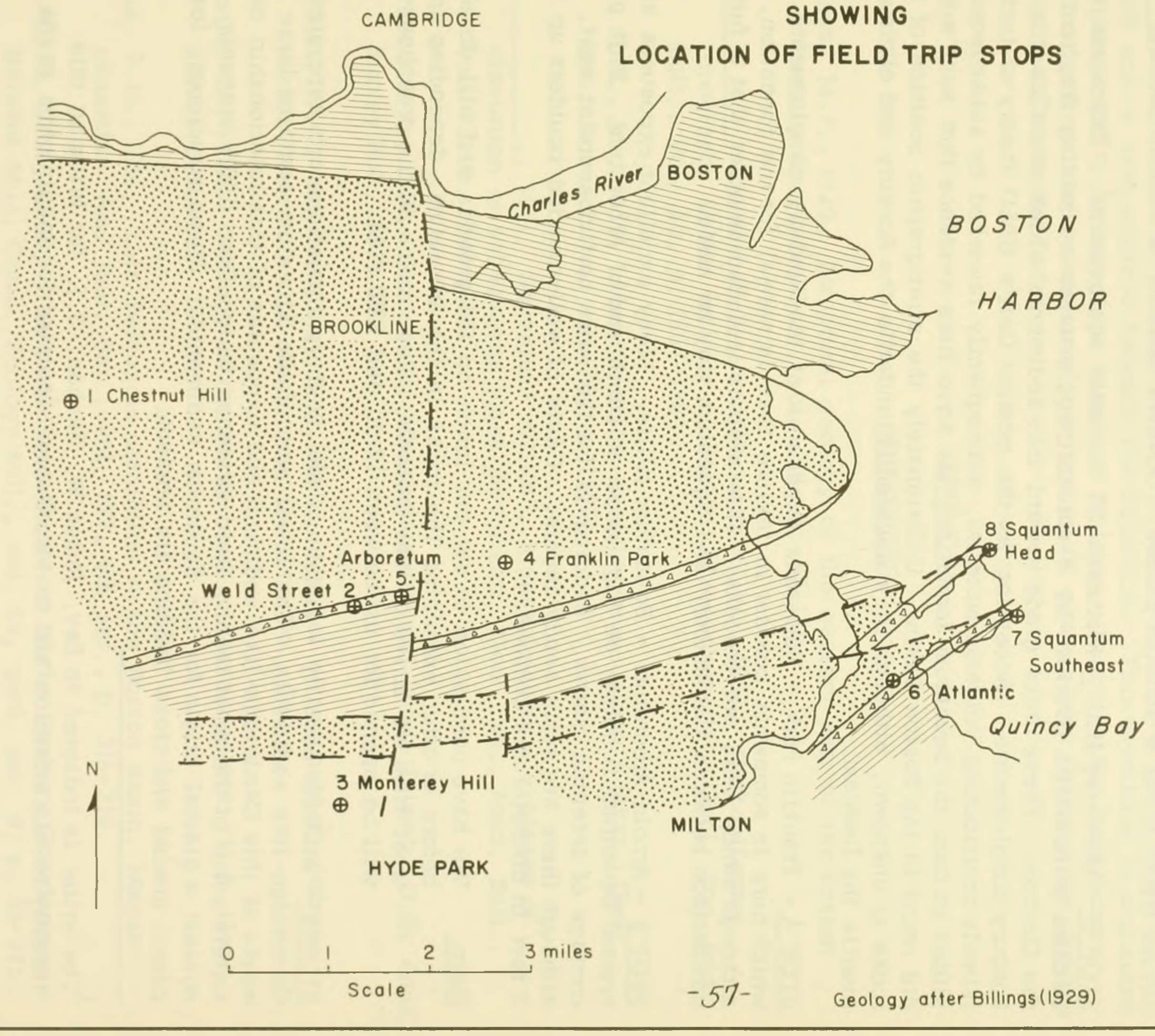
The results of these roundness measurements, as they may pertain to the origin of the Squantum, appear to be ambiguous: on the one hand, the similarity in average roundness measured in the Squantum and Roxbury formations suggests a similar abrasion history and by implication supports a non-glacial origin. On the other hand, the consistent difference in the range of roundness values, as measured by the standard deviation (see Table 2), implies that the units in question have different origins. Although this difference in roundness does not, of course, necessarily support a glacial origin for the Squantum, neither does it necessarily support an origin by subaqueous mass movement, as suggested by Dott (1959, 1961). Studies by Wentworth (1936) of the shape of glacial cobbles showed that 82% were well-rounded or moderately rounded but only 18% were angular or sub-angular. This suggests that angularity is not characteristic of glacially abraded fragments in the first palce and that the foregoing discussion may be beside the point, after all.

Log of Field Trip Stops. The approximate location of these stops is shown on the accompanying map.

Figure 1. MAP OF THE BOSTON AREA

SHOWING

LOCATION OF FIELD TRIP STOPS



Geology after Billings (1929)

STOP 1 - Chestnut Hill - This stop was chosen as a typical and convenient exposure of the Roxbury conglomerate. On hill summit east of road, the Roxbury consists of cobblestone and pebble conglomerate with obscure bedding. In road cut, the formation is more variable with several sandy beds and shale partings. Obscure ripple marks, current bedding and graded bedding are visible.

STOP 2 - Weld Street, Squantum tillite - Typical Squantum lithology is exposed in an old quarry. Note relative abundance of fine matrix as compared with Roxbury. Boulders up to 2 feet in diameter occur here. In these exposures, Sayles (1914) found a striated pebble. Obscure bedding is locally present.

STOP 3 - Monterey Hill _ Mattapan (?) volcanic agglomerate[1]. Exposures of Dedham granodiorite overlain by a volcanic agglomerate containing fragments of the Dedham. These rocks grade upward into sediments which resemble the Roxbury conglomerate. Accepting for the moment Dott's (1961) theory of tectonic islands contributing volcanic material, subsequently reworked by subaqueous slides to form the Squantum formation, we have here evidence that such activity did occur in the Boston Basin. Unfortunately the stratigraphic position of these rocks is unknown, although they apparently underlie the Roxbury and obviously overlie the Dedham.

STOP 4 - Franklin Park - Numerous exposures of the Roxbury conglomerate, which here is somewhat coarser in texture than is normal for the formation, although sandy beds are present. This stop is included in order that a further comparison between the Roxbury and Squantum may be made.

STOP 5 - Arnold Arboretum - Squantum tillite. Many excellent exposures showing typical Squantum lithology on high ridge at south end of Arboretum. High percentage of greenish matrix. Bedding is for the most part obscure at best, although there are some sandy layers. Casts of well-rounded boulders up to 3 feet in diameter are common.

Note: We have permission to eat our lunch on the grounds and will do so before or after examining the rocks in the Arboretum, depending upon what time we arrive on the grounds. Rest rooms at the greenhouses will be opened for us between 12:00 and 1:00 P.M.

STOP 6 - Atlantic Locality - Squantum and Roxbury formations are separated by Cambridge-like sediments. The lower part of the Squantum contains large fragments of this Cambridge-like sediment and exposures of this relationship constitute some of the most telling field evidence which Dott (1961) presents against a glacial origin for the Squantum sediments. Slump structures, load casts, graded and cross bedding are present.

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[1]The writer is indebted to Rev. James W. Skehan, S.J. for bringing this locality to his attention and to Mr. George Saulnier for guiding him in the area.

STOP 7 - Squantum Southeast - Recent construction has obscured many significant parts of this locality but Cambridge argillite overlying the Squantum is still exposed. Unfortunately, the fine exposures figured by Sayles (1919) of slump structures within the Cambridge have been covered.

STOP 8 - Squantum Head - Cambridge argillite here overlies the Squantum formation and is also exposed beneath the Squantum. This repetition is explained by Billings (1929) as being the result of faulting. Roxbury-like beds occur within the Squantum formation proper and small scale slump features are present within the Cambridge beds.

TRIP C

REFERENCES

Billings, M.P., 1929, Structural geology of the eastern part of the Boston Basin: Am. Jour. Sci., vol. 218, p. 97-139.

_____, Loomis, F.B., and Stewart, G.W., 1939, Carboniferous topography in the vicinity of Boston, Massachusetts: Geol. Soc. Amer. Bull., vol. 50, p. 1867-1884.

Dott, R.H., Jr., 1959, Ancient tillite or subaqueous slide ? (Abst.) Geol. Soc. Amer. Bull., vol. 70, p. 1592.

_____, 1961, Squantum "tillite", Massachusetts - evidence of glaciation or subaqueous mass movement: Geol. Soc. Amer. Bull., vol. 72, p. 1289-1306.

Emerson, B.K., 1917, Geology of Massachusetts and Rhode Island: U.S. Geol. Survey Bull. 597, 289 p.

Krumbein, W.C. and Pettijohn, F.J., 1938, Manual of sedimentary petrography: New York, D. Appleton - Century Co., 549 p.

LaForge, L., 1932, Geology of the Boston area, Massachusetts: U.S. Geol. Survey Bull. 839, 105 p.

Lahee, F.H., 1914, Late Paleozoic glaciation in the Boston Basin, Massachusetts: Am. Jour. Sci., vol. 187, 4th ser., p. 316-318.

Mansfield, G.R., 1906, The origin and structure of the Roxbury Conglomerate: Harvard Mus. Comp. Zoology Bull., vol. 49, geol. ser. 8, p. 91-271.

Pettijohn, F.J., 1957, Sedimentary rocks: New York, Harper and Bros., 718 p.

Rahm, D.A., 1962, Geology of the main drainage tunnel, Boston, Massachusetts: Jour. Boston Soc. Civil Engineers, vol. 49, p. 319-368.

Sayles, R.W., 1914, The Squantum tillite: Harvard Mus. Comp. Zoology Bull., vol. 66, p. 141-175.

_____, 1916, Banded glacial slates of Permo-Carboniferous age, showing possible seasonal variation in deposition: Nat. Acad. Sci. Proc., 2, p. 167-170.

_____, 1919, Seasonal deposition in aqueo-glacial sediments: Memoirs of Mus. Comp. Zoology, Harvard College, 47, 67 p.

Wentworth, C.K., 1936, An analysis of the shapes of glacial cobbles: Jour. Sed. Petrol., vol. 6, p. 85-96.