Provenance of Loess on Long Island using single grain $^{40}Ar/^{39}Ar$ ages of muscovite

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Loess is unconsolidated, wind deposited sediment composed largely of silt-sized particles with a modal diameter between 15-50 µm. Loess is very homogeneous and shows little or no stratification. It is ubiquitous over much of the North American mid-continent and forms some of the most productive agricultural soil. On Long Island, loess covers large areas and it is the basis of local agriculture (deLaguna, 1963; Newman, 1967; Nieter et al., 1975; Sirkin, 1967). It is generally thought that most of the loess in North America was deposited during times of continental ice sheets when glaciers produced significant amounts of silt by bedrock abrasion. Much of this silt was deposited in outwash plains and in braided stream flood plains where strong winds picked up and transported the silt. The provenance of resulting loess deposits holds information about the ice retreat, wind and stream patterns and other processes on the ice sheet margin.

In this provenance study we use single-step laser fusion $^{40}Ar/^{39}Ar$ ages of single grains of muscovite in loess and sand to evaluate the potential for distinguishing provenance sources. $^{40}Ar/^{39}Ar$ ages of single grains of muscovite are advantageous for this study because they are common in our loess samples and there is reasonable published coverage of $^{40}Ar/^{39}Ar$ and K/Ar ages of bedrock in the region. Furthermore, Long Island provides a good setting to evaluate this method for provenance because the cooling ages for mica in the basement rocks north of Long Island, the potential local sources of loess, change systematically from 200 Ma in eastern Massachusetts and Rhode Island, 300 and 400 Ma in western Connecticut and western Massachusetts, 800 Ma in New York, and older than 1,000 Ma further to the west in North America (Zartman et al., 1988) (Fig. 1). The cooling ages of mica in southern New England area, including southeastern New York, Connecticut, Massachusetts and Rhode Island, are a consequence of a complex history (Zartman et al., 1988). In general, four major orogenic events, the Grenville (~1000 Ma), Taconian (~450 Ma), Acadian (420-360), and Alleghenian (~300) formed this area. The oldest Grenville event developed in the west, and sequentially, the later ones developed toward the east (Fig. 1). Where a later metamorphism overlaps a previous one, the mineral ages may be completely reset. At the transition zone, later metamorphism may partially reset the previous ages, producing intermediate ages.

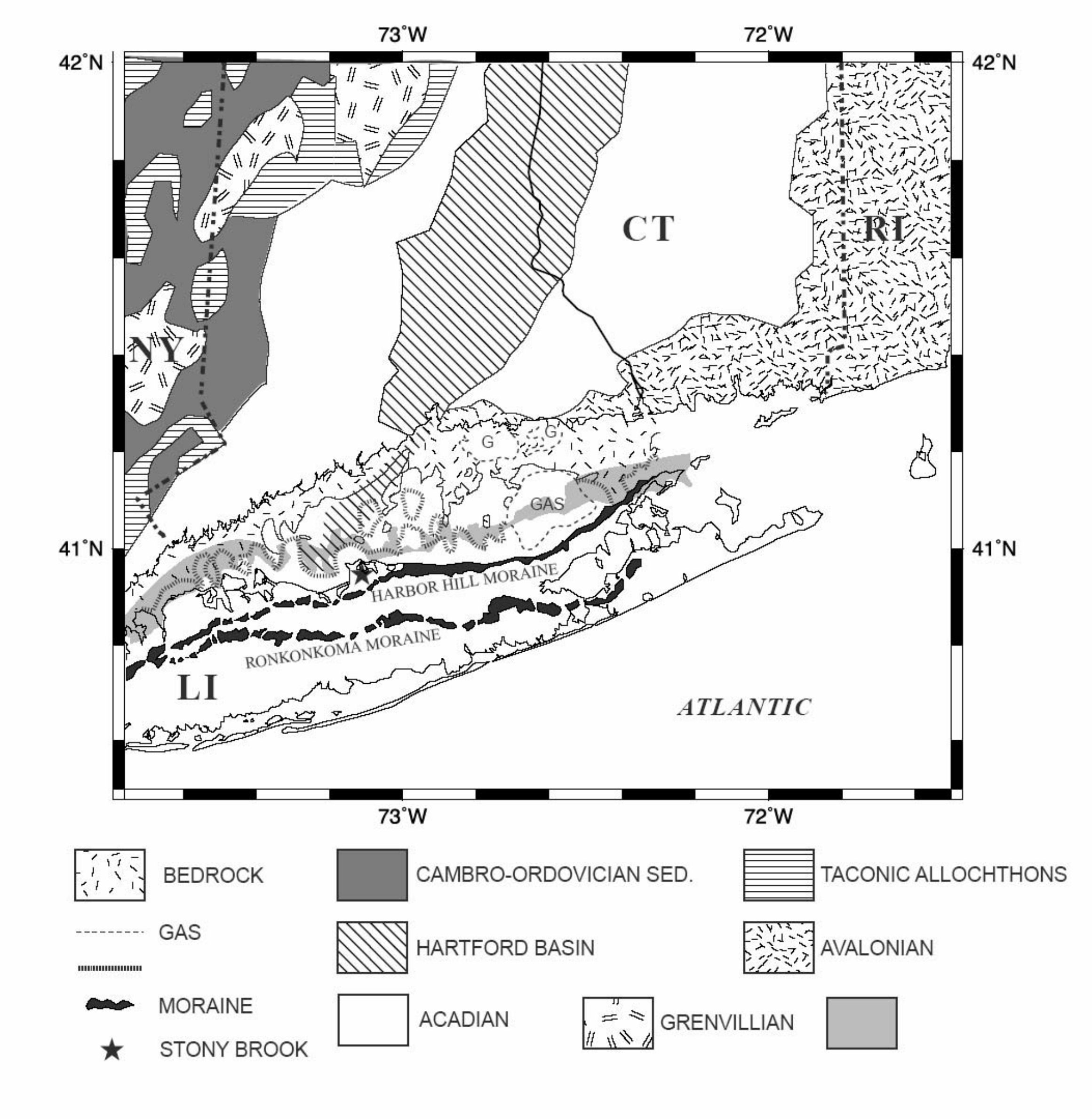
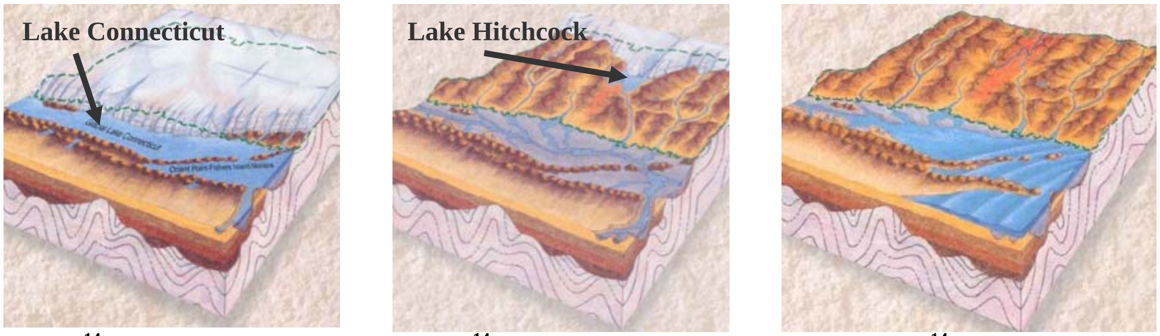


Figure 1. Regional Geology Map

Long Island topography is marked by two moraines southern, Ronkonkoma moraine and northern, Harbor Hill moraine. The Laurentian ice sheet reached the position on Harbor Hill moraine at 21,750±750 ^{14}C yr BP (Sirkin and Stuckenrath, 1980).

The deposition of loess on the north shore of Long Island probably started as soon as the ice sheet retreated. The most likely source of the sediment were exposed lake beds of the drained proglacial lakes to the north of Long Island. Proglacial Lake Connecticut was dammed by the Harbor Hill moraine on the south and by the ice sheet on the north and it has occupied the area of Long Island Sound Basin (Fig. 3) (Lewis and Digiacomo-Cohen, 2000). By ~15,500 ^{14}C yr BP the lake drained and its bed was completely exposed (Stone et al., 1998). Melt water streams from the ice sheet brought glacial silt and deposited it in the broad valley of Lake Connecticut's exposed bed. This freshly deposited silt could have been the first local source area for Long Island loess. By 12,400 ^{14}C yr BP the relative sea level in Long Island Sound was -40m (Lewis and Stone, 1991). At this level, the sea would have covered the eastern part of Long Island Sound Basin, reducing the source areas to river deposits in the northern and northwestern areas of the Long Island Sound Basin (Fig. 2). As the ice sheet continued to retreat new proglacial lake called Lake Hitchcock formed in front of it. Lake Hitchcock occupied much of the Connecticut River Valley and it might have drained as early as ~14,000 ^{14}C yr BP (Stone and Ashley, 1992) but it might have persisted in the upper Connecticut valley to as late as 10,400 ^{14}C yr BP (Ridge et al., 1999). Permafrost and cold conditions could have persisted in the area after the lake drained as indicated by possible pingo scars found in the area once occupied by Lake Hitchcock (Stone and Ashley, 1992). The stream deposits on the drained bed of this lake are a second plausible sediment source area for Long Island loess.



17,500 ^{14}C yr BP years ago **15,500 ^{14}C yr BP years ago** **15,000-5,000 ^{14}C yr BP years ago**

Figure 2. Long Island glacial history.

Loess on Long Island is commonly found on the surface above underlying glacial sediments. It is mostly about a meter thick. In Long Island Soil Survey loess is usually described as “silt loam” (Soil-Conservation-Service, 1975) and it is mostly found in agricultural areas since it generates a very fertile soil. It is easily distinguished from the immediately underlying till or outwash by its characteristic grain size distribution and appearance. Thick loess deposits can be found in topographic depressions such as kettle holes and valleys which acted as aeolian sediment traps during the loess deposition but also as cover deposits in the eastern part of Long Island. There is no overlying outwash or till, therefore, the loess had to be deposited after the last glacier retreated from Long Island.

Loess samples were collected at two sites on the north shore of Long Island, Stony Brook University Campus and Wildwood State Park and at Mahoney Farm on the south fork of Long Island (Fig. 3) as well as from the Lake Hitchcock bottom deposit.

Loess deposit at Stony Brook Campus is about 1 m thick, underlain by 30 cm of sand, which overlies the till. The freshly exposed loess has soil developed in the upper 50 cm. The lower 50 cm of loess is yellowish brown, composed of clay, silt and fine grain sand with no depositional features and homogeneous in all dimensions. Pebbles as large as 4 cm in diameter are found in the loess. We have collected 10 loess samples from 50 cm to 1 m below the ground surface at about 5 cm intervals. The top 50 cm of soil was not sampled because of the alteration by the soil processes.

A core was obtained from a 270 cm thick loess deposit in a kettle hole in Wildwood State Park. The kettle hole, which is 65 m wide, 230 m long and 10 m deep, is on the Harbor Hill moraine 20 km east of Stony Brook and about 1 km south from Long Island Sound shore. The core sampled 270 cm of loess but was only 216 cm long because of the sediment compression in the core. The samples were taken at 10 cm intervals. The top 63 cm of the core were not sampled due to alteration by soil development. A sample was collected from Mahoney farm in the town of East Hampton on the south fork of Long Island. The farm is placed less than 1 km south of Ronkonkoma moraine. The silt was cored up to 140 cm in depth with a hand auger. Muscovite grains were sampled from a depth of 100 cm. Additionally, a sample of sand was collected from the Lake Hitchcock bottom deposit.

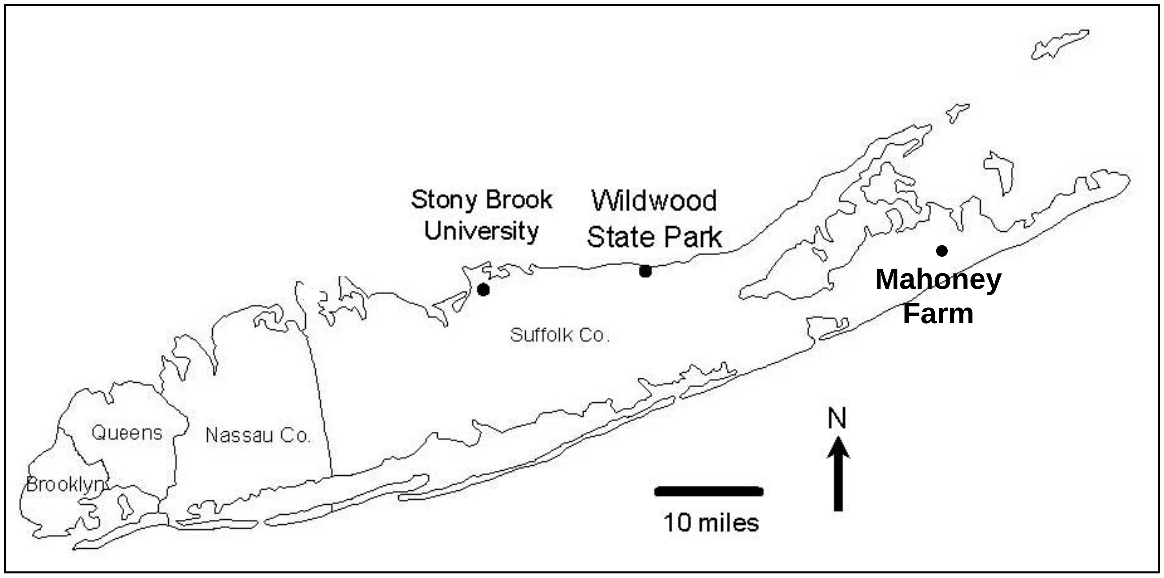


Figure 3. Sample sites location.

$^{40}Ar/^{39}Ar$ ages were obtained on 600 muscovite grains from Wildwood State Park loess and about 100 muscovite grains from other locations and 100 muscovite and biotite grains from Lake Hitchcock bottom sand sample. Most muscovite grains contain greater than 90% radiogenic argon and give ages with uncertainties of less than a few million years. The uncertainties for muscovite ages are mostly below 0.5%, with a few between 0.5% and 1%.

Figure 4. Muscovite ages in Stony Brook Campus loess.

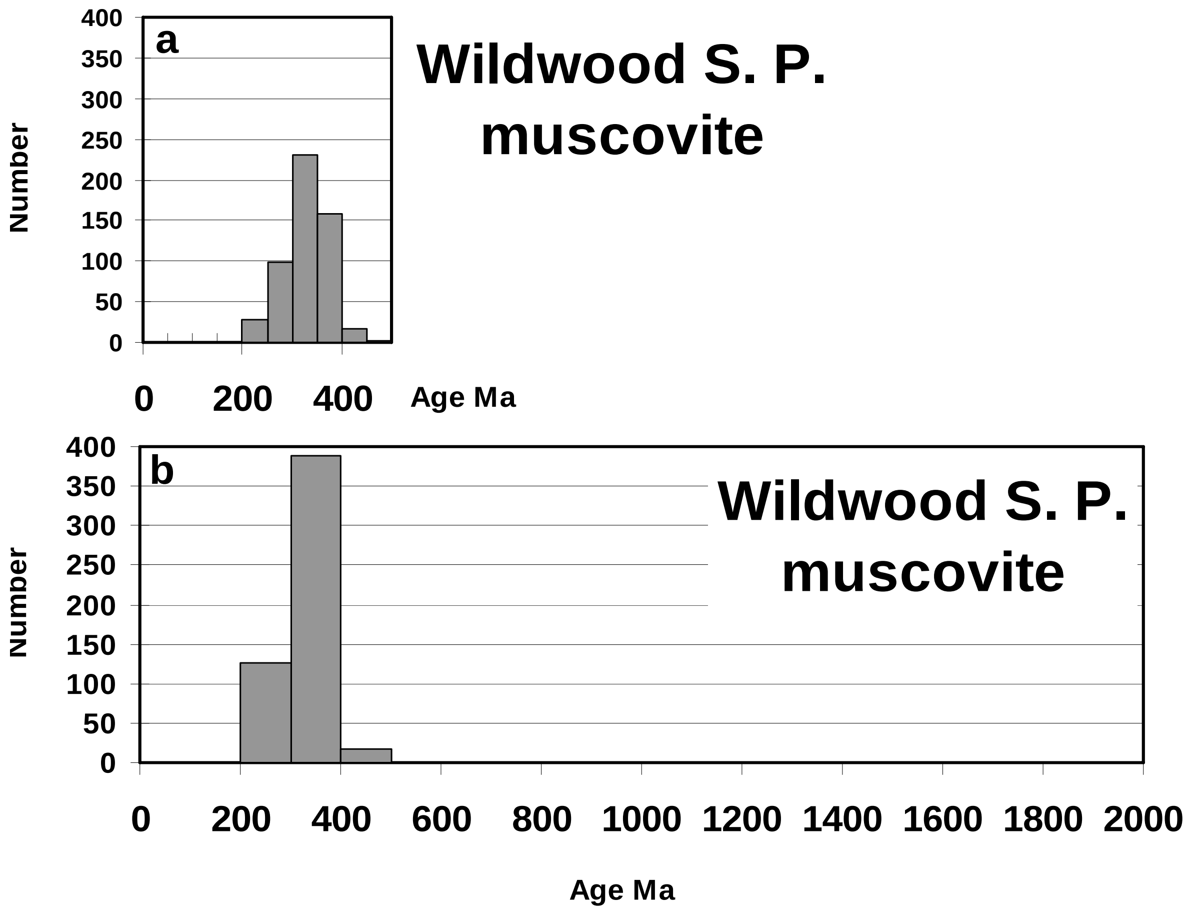


Figure 5. Muscovite ages in Wildwood State Park loess.

Muscovite from Stony Brook has mode between 300 to 400 Ma (Fig. 4) and this suggests local sources to the north in Connecticut (Fig. 1). Most of the muscovite ages from Wildwood State Park loess also fall in the 300-400 Ma age range which is consistent with muscovite ages from Stony Brook Campus (Fig. 5b). On the 50 Ma age range histogram most of the muscovite ages are between 300 and 350Ma (Fig 5a). Therefore, the source region for Wildwood State Park loess has to have a major component in the region with cooling ages between 300-350 Ma which is found to the north of Long Island in the Acadian terrane. This terrane occupies the central and western part of Connecticut and stretches northward through Massachusetts and New Hampshire (Fig. 1). Other two major age components in loess are 200-300 Ma and 350-400Ma and they are consistent with the $^{40}Ar/^{39}Ar$ and K/Ar ages of mica in the Avalonian and Taconian terranes respectively (Fig. 1). In contrast, muscovite from the South Fork of Long Island has a mode between 200 Ma and 300 Ma suggesting derivation from a more easterly source in eastern Massachusetts and Rhode Island (Fig. 6).

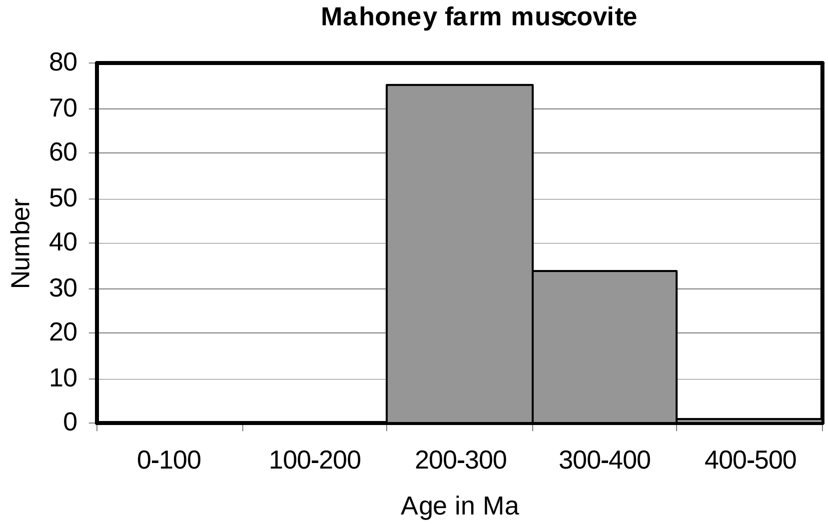
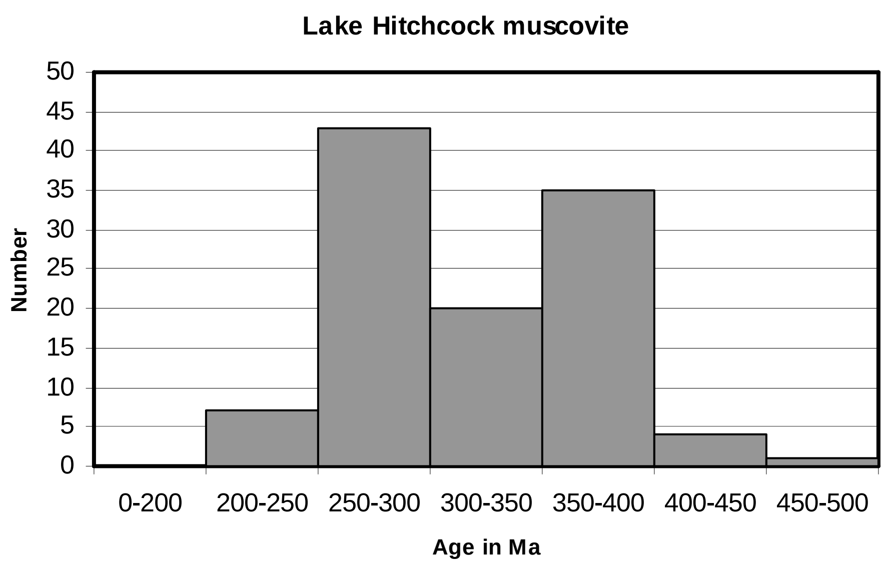


Figure 6. Muscovite ages in Mahoney farm loess

Muscovite from Lake Hitchcock bottom deposits has a bimodal distribution of $^{40}Ar/^{39}Ar$ ages with a mode younger than 300 Ma and a mode between 300 Ma and 400 Ma. Biotite $^{40}Ar/^{39}Ar$ ages from the same sample, however, are mostly younger than 320 Ma and lacking the mode between 350-400 Ma (Fig. 7).



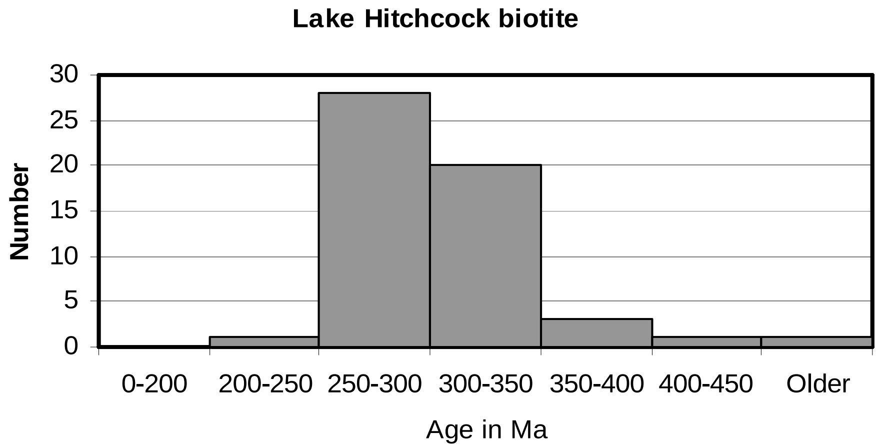


Figure 7. Muscovite and biotite ages in sand from Lake Hitchcock bottom deposit.

The source of Long Island loess is local and it was probably produced by glacial grinding of the bedrock immediately to the north of Long Island in Connecticut and Massachusetts. However, where most of the loess on the north shore came from a provenance area with ages between 300 and 400 Ma, loess from south fork of Long Island mostly came from a younger provenance with ages between 200 and 300 Ma. Both of those provenances can be found in bedrock to the north of Long Island and we can say that the loess on the north shore of Long Island was primarily derived from Acadian and Taconian terranes where loess from the south fork of long Island was derived mostly from Avalonian terrane. This is further reinforced by loess thickness studies on the south fork of Long Island which show thinning towards west and south-west placing the source area east of Long Island (Nieter, 1975). Lake Hitchcock bottom deposit could be the source area for Long Island north shore loess with its muscovite ages falling mostly between 200 and 400 Ma. South fork loess does not have a large proportion of grains in the 300-400 Ma age range and its muscovite is overwhelmingly younger than 300 Ma so the exposed bed of the drained lake Hitchock was probably not a major contributor of sediment for the loess on the south fork of Long Island. Interestingly, when we compare muscovite and biotite ages from the Lake Hitchcock bottom sand we can observe a difference in their age distribution. Muscovite ages have a bimodal distribution with modes 250-300 Ma and 350-400 Ma but biotite ages are lacking the 350-400 Ma mode.

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