Evaluation of Ar-Ar ages of Individual Mica Grains for Provenance Studies of Loess, Long Island, NY

A Thesis Presented

by

Jian Zhong

to

The Graduate School

in Partial Fulfillment of the

Requirements

for the Degree of

Master of Science

in

Department of Geosciences

State University of New York

at

Stony Brook

May, 2002

State University of New York

at Stony Brook

The Graduate School

Jian Zhong

We, the thesis committee for the above candidate for the Master of Science degree, hereby recommend acceptance of this thesis.

Dr. Gilbert N. Hanson, Advisor, Professor of Geology
Department of Geosciences

Dr. Scott M. McLennan, Professor of Geology
Department of Geosciences

Dr. Sidney R. Hemming, Professor of Geology
Columbia University

This thesis is accepted by the Graduate School.

Dean of the Graduate School

Abstract of the Thesis

Evaluation of Ar-Ar ages of Individual Mica Grains for Provenance Studies of Loess, Long Island, NY

by

Jian Zhong

Master of Science

in

Geosciences

State University of New York at Stony Brook

2001

Loess in a one-meter thick section on the SUNY Stony Brook Campus has been studied for grain size distribution and provenance. The loess provenance has been evaluated using single crystal ^{40}Ar/^{39}Ar muscovite and biotite ages.

The grain size distribution of loess shows three modes at fine sand (250 microns), silt (20 microns), and clay (<2 microns). There are also occasional pebbles up to 5 cm in diameter in the loess. The size distribution of the clay and silt fractions of the sediment resemble that of loess in many parts of the world. The size distribution of the fine sand in the loess resembles that of the immediately underlying glacial sand unit and the sand in the underlying gravely till. It is proposed that sand in the loess on Stony Brook campus might be wind blown sand or derived from the underlying sand and till by the combined action of cryoturbation and faunalturbation. Mica has been also dated for samples in a section from Caumsett State Park, Lloyd Harbor, New York about 25 miles west of the campus that includes Cretaceous sands, glacial outwash sand and gravel, and loess.

The occurrence of fine sand in the loess suggests that the loess was deposited when the glacier was nearby and would suggest that the loess was carried to the area by strong katabatic winds flowing off the glacier. Long Island is a good place to evaluate mica ages for provenance studies of loess derived by the glaciers from local bedrock because the Ar-Ar and K-Ar mica ages in the bedrock change essentially continuously from New Jersey and New York in the west to New England in the east, from 900 to 200 Ma.

The muscovite ages from Cretaceous sediments, glacial sediments, and loess at Caumsett State Park are almost identical, ranging from 275 to 375 Ma. Muscovite ages for loess on the Stony Brook campus are younger with a dominant range of 225 to 300 Ma. The younger ages for the campus loess are consistent with a more easterly local source in New England. One muscovite gave an age of 1002 Ma, suggesting that it may have a source outside of New Jersey, Eastern New York and New England.

Biotite was not found in the Cretaceous sands, but was found in the overlying glacial sands and gravels at Caumsett State Park. The reason for this is probably that biotite cannot withstand the extensive weathering or recycling that the source of the Cretaceous sediments had undergone. The biotite in the glacial sediments is probably dominantly derived from glacially scoured local basement rocks. The ages for the biotite from the glacial sediments are mainly between 250 to 400 Ma consistent with their derivation from the basement rocks underlying Long Island Sound or in southern Connecticut. Ages for biotite from the loess range from 44 to 1804 Ma with the majority between 250 to 400 Ma. Some of the biotites have ages ranging from 500 to 850 Ma consistent with derivation of these biotites from Grenville sources further to the west in

the Hudson or New Jersey Highlands. The biotites with ages greater than 1100 Ma most likely have a source outside of New Jersey, Eastern New York and New England. The biotites with ages younger than 200 Ma may have been affect by weathering.

These results suggest that the sediments were derived mostly from the north or west consistent with their having been brought to Long Island by prevailing westerly winds or southerly katabatic winds. It has been suggested that during continental glaciation that anticyclones may have been common. These winds would have been bringing micas from the east with ages dominantly between 200 to 300 Ma. These data would suggest that if there were anti-cyclone winds they were not dominant in transporting mica. The use of single grain mica Ar-Ar age is a promising method for provenance study of loess.

TABLE OF CONTENTS

List Of Figures

ACKNOWLEDGMENTS

I thank my advisors, Dr. Gilbert N. Hanson for his guidance, support, patience and inspiration during my study at the Geosciences Department at Stony Brook. Loess is a totally new English word to me when Dr. Hanson first talked about it. He led me through every of the aspects. I appreciate not only his scientific insight, but also his very nice personality.

Dr. Sidney Hemming did Ar/Ar dating and helped interpret data. I own her a big debt. Her effort of running the Ar lab and her experiences about the dating saved me from learning a complicated method from the beginning. I also appreciate the time staying in her house.

Thanks to Mona Baker, who answered my questions from where to find a paleogeographic atlas to where to find a new state quarter. Also thanks to Dr. Scott McLennan, Dr. Tory Rasbury, Jennifer Cole, Joel Hurowitz, Hongyu Li, Andy Winslow, and everybody in the Isotope Lab and the Department for help in and out.

Many thanks to my family.

INTRODUCTION

Loess is ubiquitous over much of the North American mid-continent and forms some of the most productive agricultural soil. Loess also covers large areas of Long Island's surface, and is the basis of its agriculture (De Laguna, 1963, Sirkin, 1967, Newman, *et al.*., 1968, Nieter, *et al.*., 1975). Loess on Long Island is normally less than one meter thick, and is easily distinguished from the underlying stratigraphic units, which are mainly till, sand, or gravel. This thesis presents a possible scenario of Long Island loess history and provenance based on grain size distribution and Ar/Ar ages of single mica grains.

The provenance of loess may indicate paleo-wind patterns. During the last glacial period, four major winds may have affected loess deposition on Long Island: the prevailing west wind, jet stream, glacial anticyclone, and katabatic wind (a wind that flows down a glacier, Cohmap, 1988). Ages of single grains of mica may help to determine which winds carried the mica, and which winds did not.

Many people have studied the provenance of loess using various methods. Rutledge *et al.* (1975) studied loess in Ohio, USA using major element and mineralogical compositions; Tripathi and Rajamani (1999) studied loessic sediment in Delhi region, India and Ding *et al.* (2001) studied loess in the Chinese Loess Plateau using trace element compositions; Aleinikoff *et al.* (1999) studied Colorado loess using Pb isotopes ratio of K-feldspar and single zircon U/Pb ages; Muhs and Bettis (2000) studied Iowa loess using geochemical and partical size analysis; Nakai (1993) and Pettke *et al.* (2000)

studied dust on the Pacific Ocean floor using Nd and Sr isotope ratio; Ji *et al.* (1999) studied loess in Luochuan, China using clay mineralogy; Fang *et al.* (1999) studied loess in West Qinling, China using magnetic susceptibility; Cilek (2001) studied loess in the Czech Republic using heavy minerals; and Muhs *et al.* (2001) studied Indiana and Iowa loess using major element compositions. These studies suggested that the bulk of the loess traveled only 100's of kilometers, while some dust had traveled several thousand kilometers. Other than the single zircon U/Pb age and single feldspar Pb isotope methods, all the other methods used bulk samples, which may mask a small source by dominant local sources.

Here, we use single-step laser fusion Ar/Ar ages of single grains of muscovite and biotite in loess to see if it is possible to evaluate the relative importance of provenance sources, including distant sources. Mica 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 CO_2 laser, and ages were calculated from Ar isotope ratios corrected for mass discrimination, interfering nuclear reactions, procedural blanks and atmospheric Ar contamination. This method may be better than single grain zircon U/Pb ages because biotite is easily altered during weathering and in the sedimentary cycle and thus may provide more direct provenance information for a bedrock source. Muscovite is a multi-cycle mineral in sedimentary environments because it is resistant to weathering, but it is much less robust than zircon. Furthermore, mica has an advantage for the this study in that there are sufficient quantities of biotite and muscovite in our loess samples and there is reasonable coverage of Ar/Ar or K/Ar ages of these two minerals in the bedrock in America.

Long Island is a good setting to use radiogenic isotopic dating for loess provenance study. The mica ages of the basement rock to the north of Long Island, the local source of loess, change continuously and laterally, from 200 Ma in east Massachusetts and Rhode Island, 300 and 400 Ma in Connecticut and west Massachusetts, 800 Ma in New York, and older than 1000 Ma further to the west in North America (Figure 1). As the glacier advanced to the south, it crushed and ground the basement rocks creating abundant silt, which was deposited in the outwash at the front of glacier. The silt could be picked up and transported by the wind. Under such conditions, assuming most loess is local, mica ages between 200 and 300 Ma would indicate an east wind, those around 500 to 800 Ma would indicate a west wind, and those over 1000 Ma mica may indicate mica from further west in North America.

Geological Background

1. Orogeny

The southern New England area, including southeastern New York, Connecticut, Massachusetts and Rhode Island, has experienced a long and complex history (Zartman, 1988). In general, this area was formed by four major orogenic events, the Grenville, Taconic, Acadian, and Alleghenian Orogenies, with the older Grenville event in the west, and sequentially the later ones developed toward the east (Figure 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.

The earliest orogenic event was the Grenville Orogeny (Figure 1). At approximately 1.0 to 1.4 Ga, the continental plate carrying what would become North America (proto-North America) converged with a plate from the east. Grenville granulite grade rocks are exposed in the Hudson Highlands in New York and western Connecticut and the New Jersey Highlands (Long and Kulp, 1962). Biotite in the Grenville terrane southwest of Hudson River give ages between 850 to 750 Ma. Biotite from Grenville rocks northeast of the Hudson River give ages from 750 to 700 Ma in the west to 500 to 400 Ma in the east (Dallmeyer and Sutter, 1976). Muscovite is not common in these granulitic Grenville rocks.

About 660 million years ago, proto-North America began to rift, forming the Iapetus Ocean. About 450 million years ago, the proto-North American oceanic plate collided with a volcanic island arc. This event is called Taconian Orogeny. Taconian rocks are found in Taconic Mountains of eastern New York and western New England, with biotite and muscovite Ar-Ar or K-Ar ages between 400 to 350 Ma (Long, 1962, Ratcliffe *et al.*, 1998).

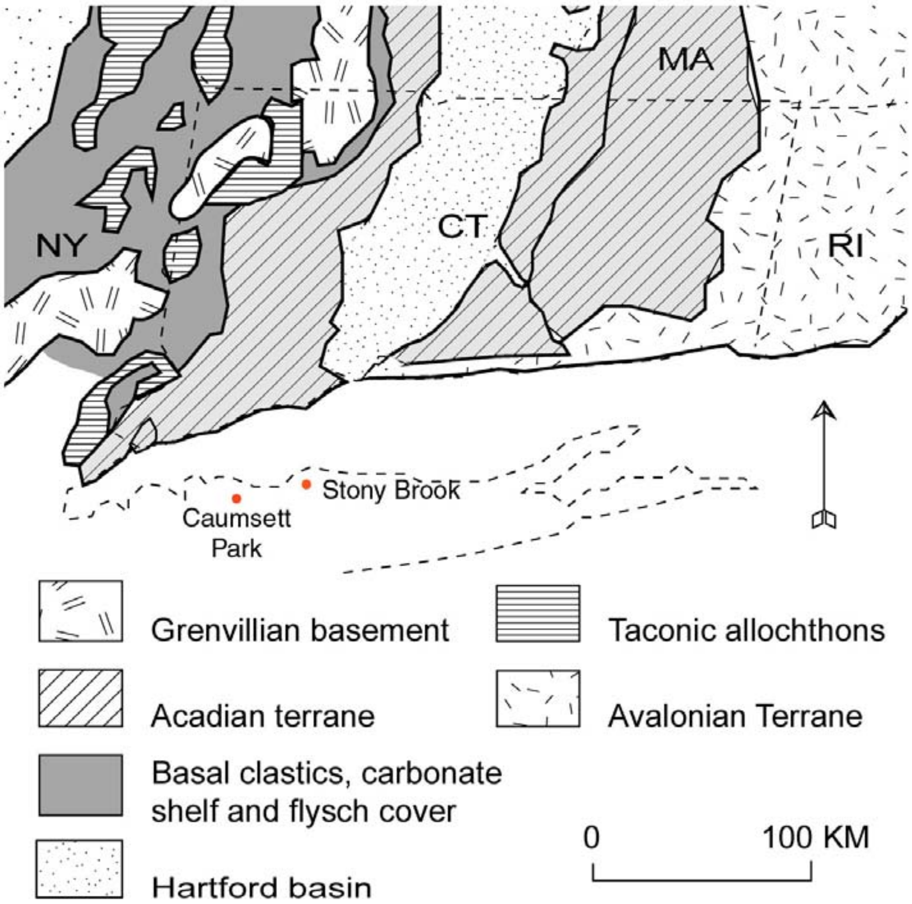

Figure 1. Regional Geology Map

The area effected by the Acadian Orogeny (420 to 360 Ma) largely overlapped that affected by the Taconian Orogeny and reset the K-Ar system of mica in the Taconian rocks (Hames etc., 1991). The rocks affected by the Acadian region are in western and central Connecticut, and have biotite and muscovite Ar-Ar or K-Ar ages between 350 to 320 Ma (Scott *et al.*, 1980, Seidemann, 1980).

The rocks affected by the last Orogeny, Alleghanian, have mica ages between 220 to 300 Ma (Zartman *et al.*., 1970, Scott *et al.*, 1980, Dallmeyer, 1982, Moecher *et al*. 1997), with older ages in the west and younger in the east. The rocks affected by the Alleghanian orogenesis are known mainly at the Narragansett basin and the Avalon terrane (Mosher, 1983; Wintsch and Sutter, 1986; Wintsch *et al.*, 1992), but also recognized within other terranes of southern New England by Gromet (1989).

Figure 2 and 3 show the biotite and muscovite Ar/Ar ages in New England area, complied from National Geochronological and Natural Radioelement Databases (1995), which include all radiogenic ages analyzed before 1995 in USA. From figure 2, we can see that the biotite in New England area have ages from younger than 200 Ma to 900 Ma. The biotite ages change continuously and generally with the older ones at the southwest, and younger ones at the northeast. Muscovites ages range from 200 to 450 Ma (Figure 3). Muscovite ages also change continuously and generally with older ones at the southwest and younger muscovite at the east.

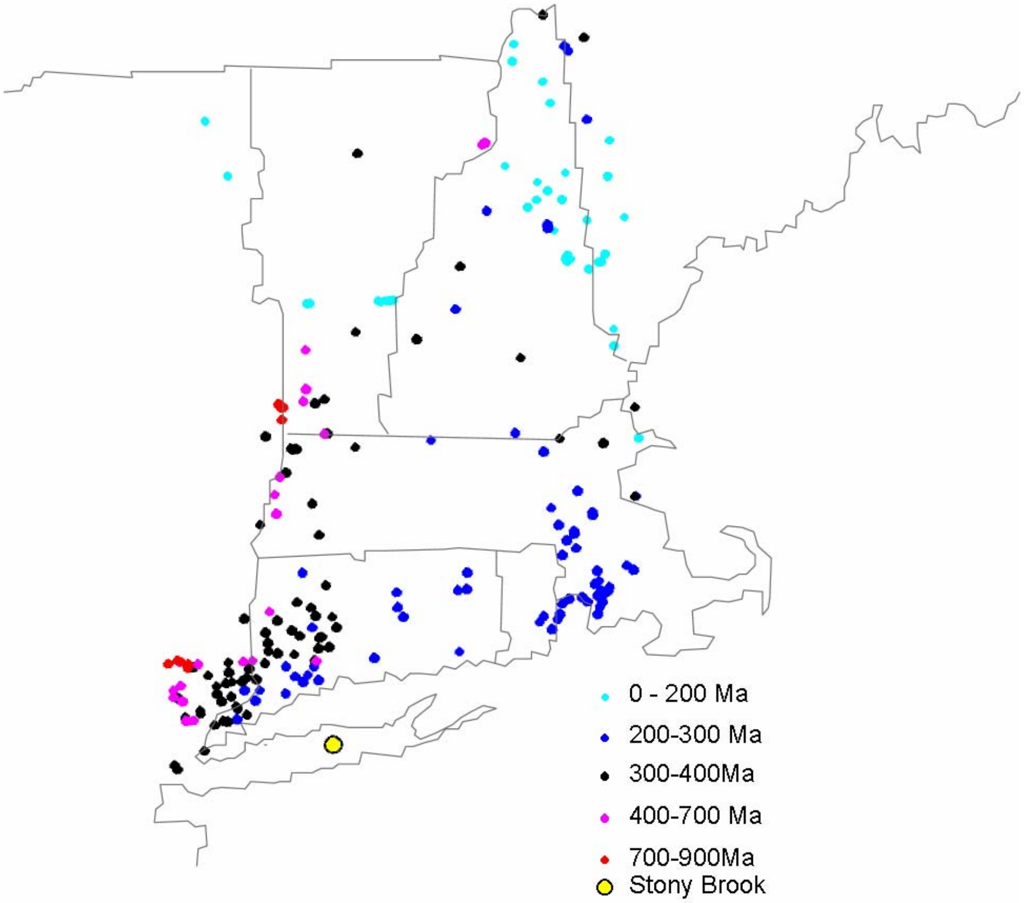

Figure 2. Biotite Ages in New England Area, Complied from National Geochronological and Natural Radioelement Databases

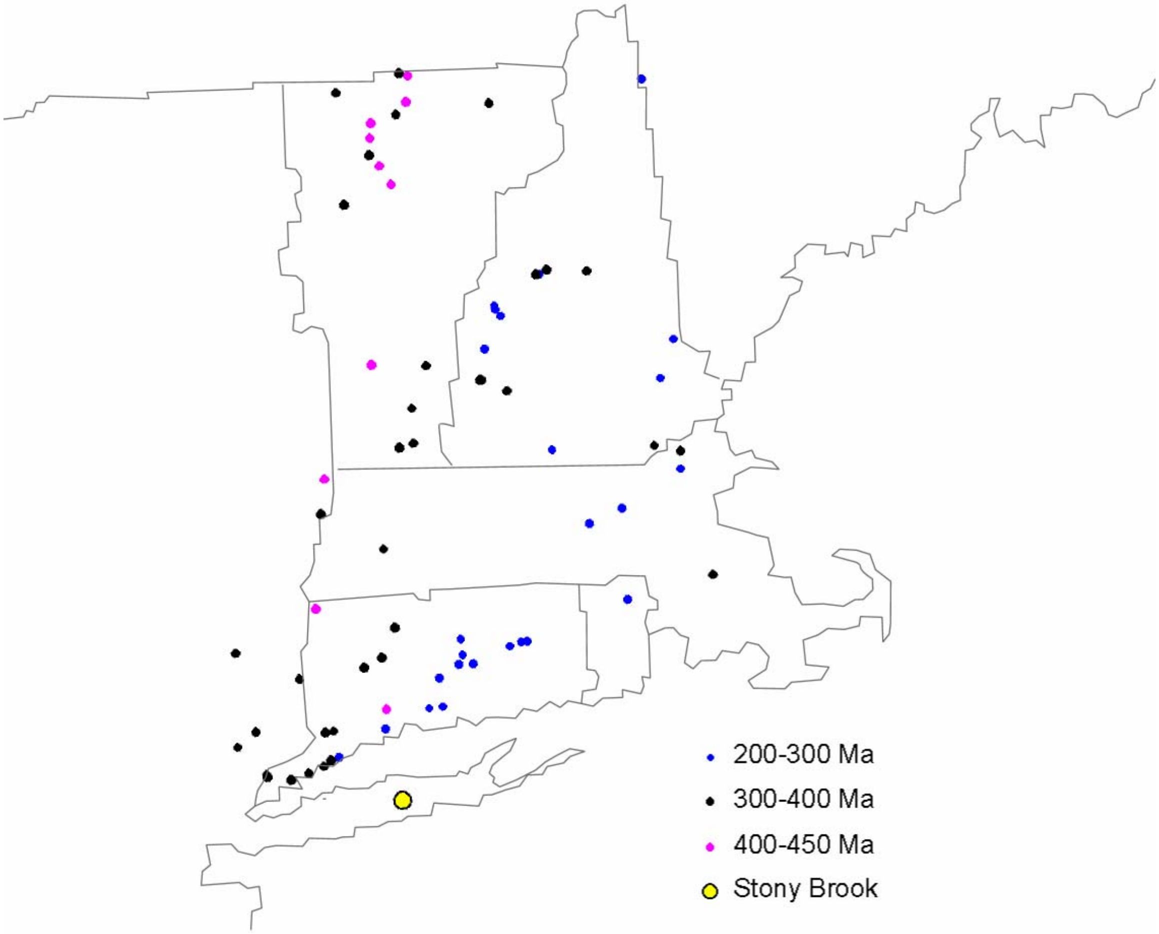

Figure 3. Muscovite Ages in New England Area, Complied from National Geochronological and Natural Radioelement Databases

2. Cretaceous sediment

During the Cretaceous, streams from the remnants of the Appalachian Mountains to the north and west carried sediment (mostly sand sized and smaller) and deposited them in flood plain, channels, and deltas in the vicinity of Long Island. These sedimentary layers underlie Long Island, and are known as the Lloyd Sand and the Raritan Clay of the Raritan Formation, and the Magothy Formation. The Cretaceous sediment is from a highly weathered source, dominated by quartz and muscovite, with no biotite. The sources of these sediments might be eroded from bedrock during the Cretaceous, or might also be from older sediments that were derived from the mountains formed during the Appalachian Orogenies. We have found no studies of the provenance of Cretaceous sediments in northeastern United States.

3. Long Island Sound

A seismic study (Lewis and Stone, 1991) shows that the pre-Pleistocene basement and sediments in the Long Island Sound are covered by glacial sediments. Under the glacial sediments, the northern part of the Sound is Avalonian crystalline bedrock (Pacholik and Hanson 2001), while the southern part is a glacially modified, stream-carved surface of Cretaceous coastal plain.

During the Pleistocene, the Sound may have been occupied by glacial lakes several times as the glaciers advanced toward Long Island and retreated. The lakes formed because of the low eustatic sea level, the large quantity of water melt from the glacier to the north, and the damming of the Sound by moraines.

4. Glacial outwash

Dreimanis and Vagners (1971) found that the size of glacial debris decreases progressively during transportion. Within 75 kilometers from the source, more than 70% are fractured to smaller than 100 μm. So, sediments carried by the glacier should be dominated by local components for the fraction larger than 100 micron in diameter.

The bluffs on the north shore of Long Island at Caumsett State Park in Lloyd Harbor, New York contain Cretaceous sediment and glacial sediment including the remnants of a Gilbert delta. Sirkin (1996) suggested that the Gilbert delta was originally deposited some distance north of its present location in Long Island Sound during the Wisconsinan glacier. After deposition, the Gilbert delta sequence and the underlying Cretaceous sediments were pushed southward by the advancing glacier.

The glacial sediment consists of Cretaceous sands and local basement fragments. Biotite in the glacial sediment may be derived mainly from the local basement rock in Long Island Sound and Connecticut because biotite is not present in the Cretaceous sediments.

5. Loess

Loess is commonly found on the surface above underlying glacial sediments. Most loess in the United States was deposited during the last glacial period, when glaciogenic silt is abundant. The loess we studied was deposited after the last glacier retreated from Long Island because there is no overlying outwash or till. The loess can potentially come from a large distance, because wind distributes them so widely. Hence, Cretaceous sediment, glacial outwash, and far traveling dust carried by the wind may be sources of loess.

Lewis and Stone, 1991, suggest that a glacial lake occupied Long Island Sound as the last glacier retreated. Under such conditions, the basement rock and overlying glacial sediments in the Sound would not be exposed. Glacial sediments were being carried by streams to the lake from the north in Connecticut and surrounding areas. After the glacial lake drained, the glacial sediments deposited at the bottom of the lake were exposed and may have become the local source of silt for the loess.

Sample Location

The loess samples in this study were collected from the SUNY Stony Brook campus, in the square outlined by Center Drive, North Loop Road, SAC drive, and Service Road (Figure 4). Samples studied were collected from a natural cliff cut by a small stream. The loess deposit is about 1 meter thick, underlain by 30 cm of sand which overlies till. The freshly exposed loess has soil developed in the upper 50 cm. The lower 50 cm of loess is yellowish brown in color, 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. Ten samples were collected from 0.5 meter to 1 meter below the ground surface, at about 5 cm intervals. The soil above 0.5 meter below ground surface was not sampled as it is heavily altered by soil development. One sample of glacial till and one sample of sand were also collected for grain-size analysis.

Cretaceous and Pleistocene sediments were collected from a bluff at Caumsett State Park in Lloyd Harbor, New York. At this site, the bluff sits majestically on the north shore of Long Island facing Long Island Sound and Connecticut (Mandell, 1999).

The lower 1/3 of the cliff is occupied by Cretaceous sediment, characterized by bright white and pink fine grained, cross-bedded sands and clay. The entire Cretaceous unit in the cliff is deformed indicating glaciotectonic emplacement at this site.

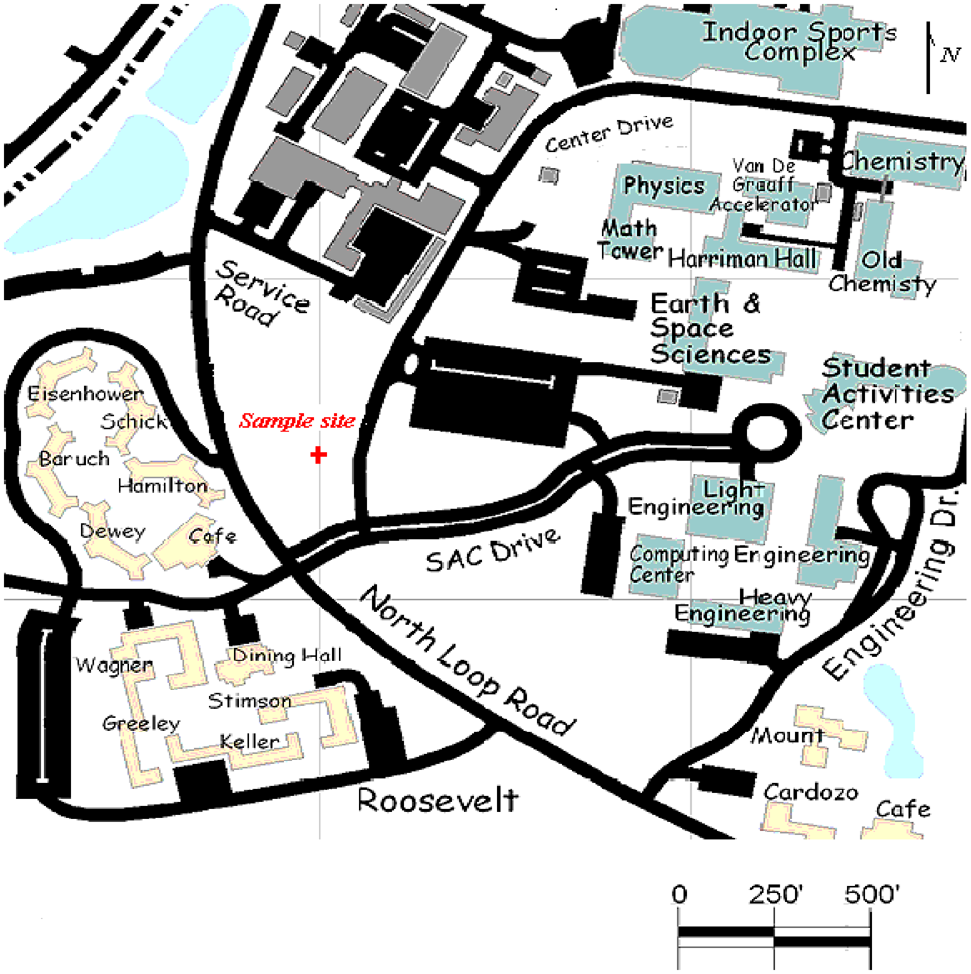

Figure 4. Location of loess on Stony Brook campus

Pleistocene beds of a Gilbert delta overlie the Cretaceous sediments. The Gilbert delta unit is about 30 meters thick, including sand and clays of bottom set beds, sand and gravel of fore set beds, and sand and gravel of the top set beds. An advancing glacier pushed the glacial lacustrine deposits and the underlying brightly colored Cretaceous sand and clay to their present position. Folding and faulting are common. Above the Gilbert delta segment, there is a layer of till about 2 meters thick which includes many large boulders. A layer of loess, about 1 meter thick, overlies the till.

Seven samples were collected from Caumsett State Park from the Cretaceous and Pleistocene units. The stratigraphic section at Caumsett State Park (Mandell, 1991) is shown in Figure 5.

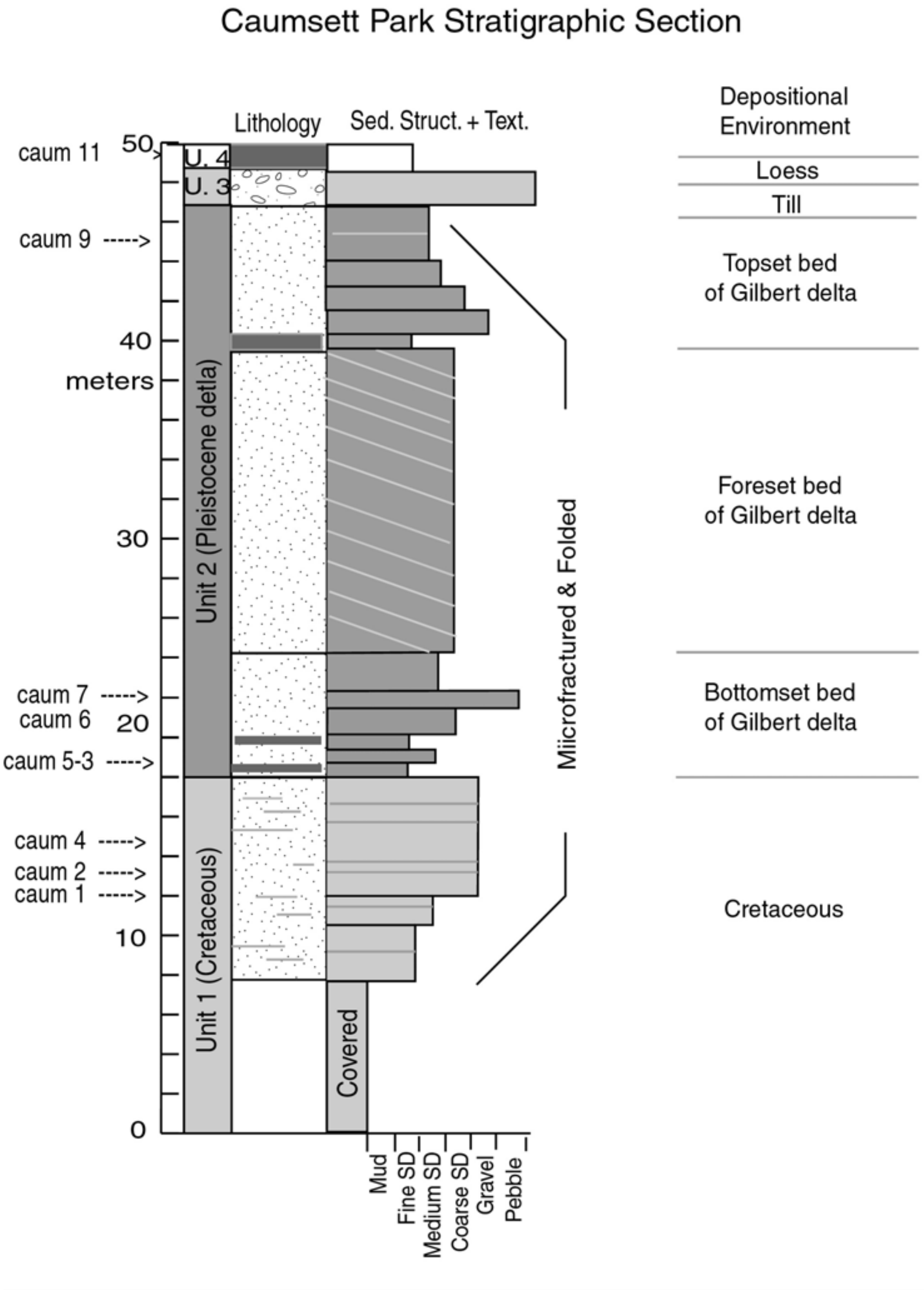

Figure 5. Generalized stratigraphic section at Caumsett State Park showing the location of samples. (Modified from Mandell, 1991).

ANALYTICAL METHODS

All samples were naturally dried at room temperature. Loess, sand and till samples from Stony Brook campus were analyzed for grain-size distribution. ^{40}Ar/^{39}Ar ages were obtained on single grains of biotite and muscovite from the loess samples on campus and the Cretaceous, glacial and loess samples at Caumsett State Park.

For grain size analysis, wet sieving, dry sieving, and settling tube pipetting were used. For each sample, an aliquot of about 10 grams was weighed, agitated with 40 grams of 1% Sodium Hexametaphosphate (HMP) dispersant solution overnight, placed in a sonic bath for 20 minutes, and washed through 63-μm sieve immediately after sonic treatment. The portion larger than 63-μm was dried under a heating lamp, then mechanical sieved into five grain size fractions, from 63-μm to 2mm with 1 Φ interval, following the procedure described by Folk (1968). Larger than 2 mm gravel was ignored. The grain-size distribution of the portion smaller than 63-μm was determined using settling tube into seven grain-size fractions, from 63-μm to 1 μm with 1 Φ interval, following the procedure described by Folk (1968).

Biotite and muscovite to be analyzed for ^{40}Ar/^{39}Ar ages were prepared by the following procedure. Aliquots of about five grams for each sample were disaggregated in about 20 ml of 1% Sodium Hexametaphosphate (HMP) solution and placed in a sonic bath for 20 minutes to remove the very fine fraction. This also cleaned the mica. Biotite and muscovite were handpicked under a reflected light binocular microscope. Biotite and muscovite occur in the glacial sediment and loess. No biotite, only muscovite is found in the Cretaceous sand. Muscovite in the Cretaceous sand consisted mostly of thin flakes about 0.2 to 2 mm in diameter. The muscovite and biotite in the loess and glacial outwash were thicker, especially the biotite. Also the mica was less than 0.2 mm in diameter.

At least 5 individual muscovite grains were analyzed for $^{40}Ar/^{39}Ar$ dating from each of the samples from Caumsett State Park, except for the cret-5-3 sample where only three grains were large enough to give reliable ages. Five biotite grains from the loess sample at Caumsett State Park were analyzed. For loess samples on Stony Brook campus, at least 12 biotite grains and 4 muscovite grains were analyzed for $^{40}Ar/^{39}Ar$ ages per sample.

Samples were irradiated in the Cd-lined, in-core facility (CLICIT) at the Oregon State reactor. When sent to irradiation, samples were loaded into wells drilled into a single Aluminum disc 1.9 cm in diameter and 0.5 cm thick. There are 12 wells on each disc, each well is 0.2 cm diameter.

Single-step laser fusion $^{40}Ar/^{39}Ar$ analyses for individual grains were made at the Lamont-Doherty Ar geochronology laboratory. The Ar lab facility consists of a fully custom built and automated micro-extraction system and a VG5400 mass spectrometer. Samples were fused with a CO_2 laser. Gases released during the heating of the samples are scrubbed of reactive gases such as H_2, CO_2, CO, and N_2 by exposure to Zr-Fe-V and Zr-Al sintered metal alloy getters. The remaining inert gases, principally Ar, are then admitted to the mass spectrometer. The Ar mass spectrometer is operated in static mode and the Ar-isotopic ratios are determined using automated data collection software (Al Deino, Berkeley Geochronology Center). The detection limit of the VG5400 mass spectrometer is about 50 times lower than the Ar blank, and thus the sample size is limited by the ratio of sample to blank.

J, the value used to determine the mineral age, was calculated from analyses of co-irradiated Mmhb hornblende, assuming an age of 520.5 Ma (Samson and Alexander, 1987). Ages for the samples were calculated from Ar isotope ratios corrected for mass discrimination, interfering nuclear reactions, procedural blanks, and atmospheric Ar contamination.

Further refinement of samples was made by examining the combination of the ^{39}Ar content and the radiogenic content after Ar isotopes analysis. Samples with low ^{39}Ar content or less than 10% radiogenic ^{40}Ar were discarded due to the large uncertainties in the ages.

Grain-size Distribution

The particle size of the loess ranges widely, from smaller than 1 µm to larger than 4 cm in diameter. Pebbles with diameters of 2 to 4 cm were found in the section (about 5 pebbles/m^2). The particle size data are on a gravel-free basis, because it is difficult to obtain a representative sample for the larger than 2 mm fraction. Figure 6 shows the grain-size distribution of loess. The grain-size distribution of all loess samples is similar. They have 3 modes at: fine sand (0.25 mm), silt (20 µm), and clay (smaller than 1 µm). Fine sand in loess varies from less than 1% in the Mississippi Valley (Snowden, 1966) to over 30% in North Norfolk, England (Catt. etc, 1971).

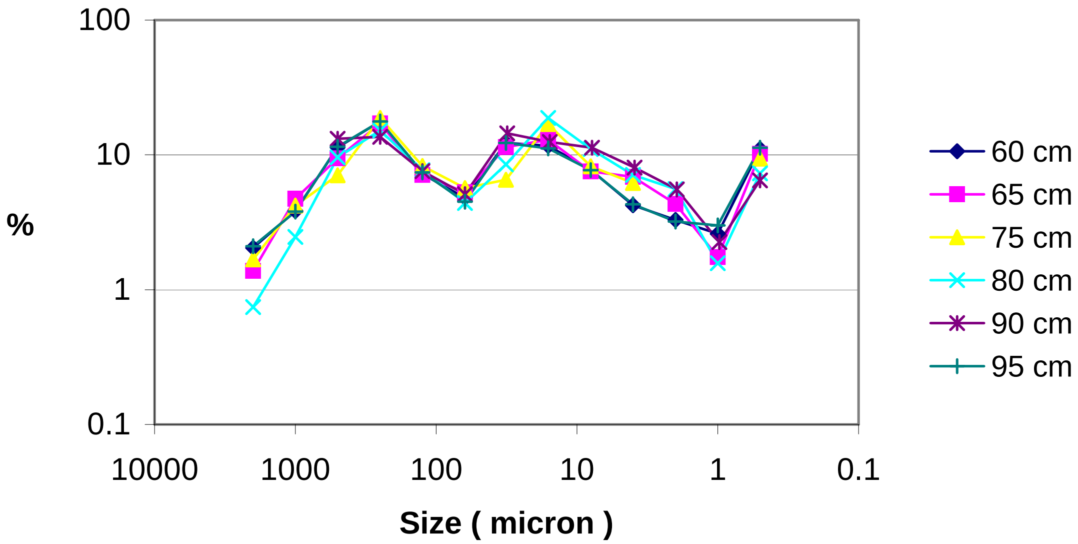

Figure 6. Grain-size Distribution Of Campus Loess

The grain-size distribution (on pebble-free basis) of the till and sand is shown in figure 7. Sand has a mode at fine sand (0.25 mm), and till has modes at coarse sand (0.5 mm) and pebble size (larger than 2 mm).

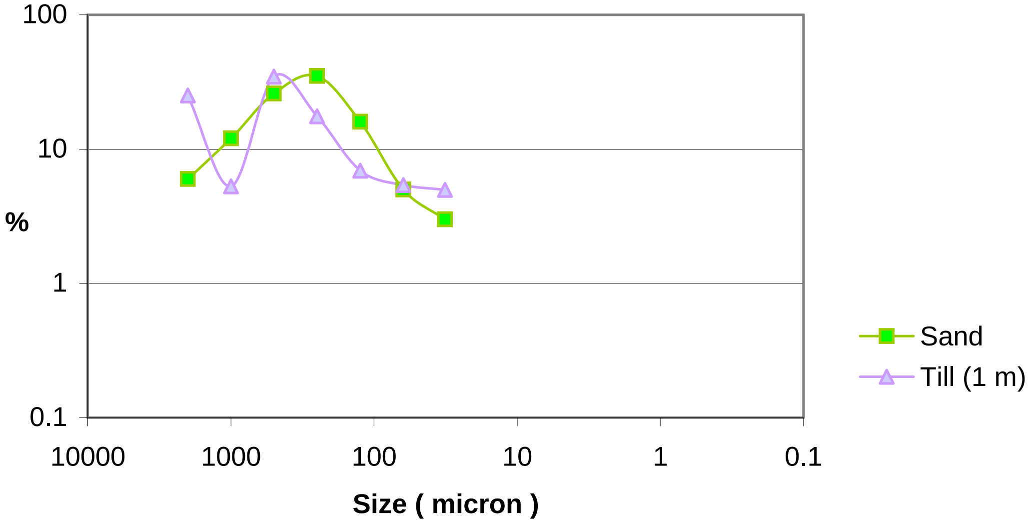

Figure 7. Size distribution of campus sand and till

The grain-size distribution of our loess samples is typical of loess near a glacial front (Catt *et al*.. 1971), where wind blown sand is deposited with loess. The loess in this study also includes pebbles, though it is almost impossible for silt and pebble to be deposited at the same time by the same hydrodynamic forces. Our question is: where do those pebbles come from? We found that similar pebbles can be found in the till underlying the loess unit.

Then, how do the pebbles move to the loess unit? We propose a combination of cryoturbation and faunalturbation. Cryoturbation is the result of repeated soil freezing and thawing, and it moves large particles in the soil matrix up. It is well known to bring cobbles and boulders up to the ground surface in the winter in northern states as long as

1) matrix is composed of fine-grains; 2) temperature falls below freezing; and 3) moisture is abundant.

At our sample site, silt and sand make up the fine matrix, and the soil is usually moist. At present, the maximum freezing depth on Long Island is about 1 m, which may be deeper or shallower as climate varies. Since the last glacier, cryoturbation may have happened many times in the area.

Faunalturbation might be another method that mixes soil. An important study about faunalturbation was performed by Charles Darwin (1881) on earthworms. The results of his study may also be applicable for other soil dwelling animals. Two aspects are important here: mixing soil and sinking large object. By churning the soil, earthworms receive nutrition and protection. Darwin reported earthworms sink and eventually bury a "great stone" as large as 64 by 17 by 9 inches in 50 years. It is known that earthworms were eradicated on Long Island during glaciation, and were introduced only in the last few hundred years by European settlers (Conover A, 2000). However, a few hundred years are long enough for earthworms to work the pebbles down, and other soil dwelling animals have similar mixing and sinking effects on soil. Another evidence of faunal-turbation is that dark glassy material assumed to be coal ash was found at a depth of 90 cm in the loess below ground surface.

Cryoturbation moves pebbles up, while faunal turbation mixes soil. These processes may account for the pebbles in the loess unit.

Mica Ages – Result and Discussion

Ar/Ar ages were obtained on about 100 muscovite and 400 biotite samples. Most muscovite contains greater than 90% radiogenic argon and give ages with uncertainties of less than a few million years. For biotite, only 20% have more than 10% radiogenic argon, the least amount necessary to give reliable ages. The uncertainties for muscovite ages are mostly below 0.5%, with a few between 0.5% and 1%. The uncertainties for the accepted biotite ages are mostly below 5%, with a few between 5% and 10%. Histograms of the mica ages from Caumsett State Park are shown in figure 6. Histograms of the mica ages in loess from SUNY stony Brook campus are shown in figure 8. The analytical data for the ages are given in appendix I.

Ages of muscovite from the Cretaceous sand ranges from 275 to 400 Ma (Figure 8). All of the muscovite ages can be related to local sources to the north of Caumsett State Park in Connecticut (Figure 3), corresponding to a local derivation from a highly weathered basement. We also found that the quartz grains are angular, which also support a local bedrock derivation of Cretaceous sand. However, we cannot rule out the possibility that some of the Cretaceous sediments may be second cycle coming from sedimentary rocks deposited elsewhere during or after the Alleghenian Orogeny.

Muscovite from the glacial sand has a similar age distribution to that from the Cretaceous sand: all ages are between 200 Ma and 400 Ma, with the majority between 300 Ma and 350 Ma (Figure 8). Cretaceous sediments may make up a large component of the glacial sediments. Comparing muscovite ages from glacier sand and Cretaceous sand in 25 Ma groups, Figure 9, we can see that the glacial sand has more 300 to 325 Ma muscovite ages, while Cretaceous sand has more 325 to 350 ones. This difference may imply that the muscovite in the basement rock north of Caumsett State Park in Connecticut or northern Long Island Sound has ages of around 315 Ma. Or, this difference is insignificant and a result of small number statistics.

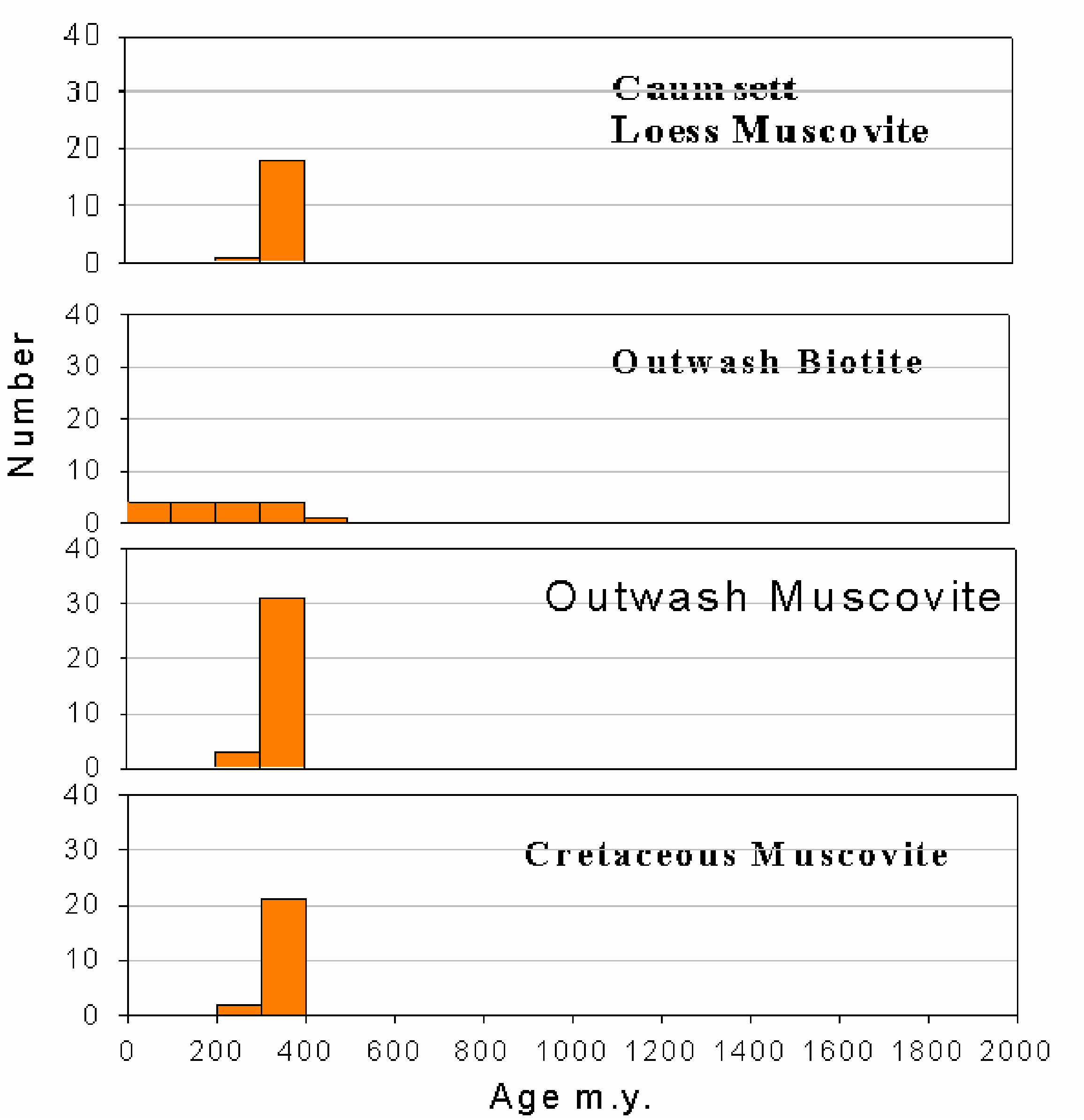

Figure 8. Mica ages from Caumsett State Park

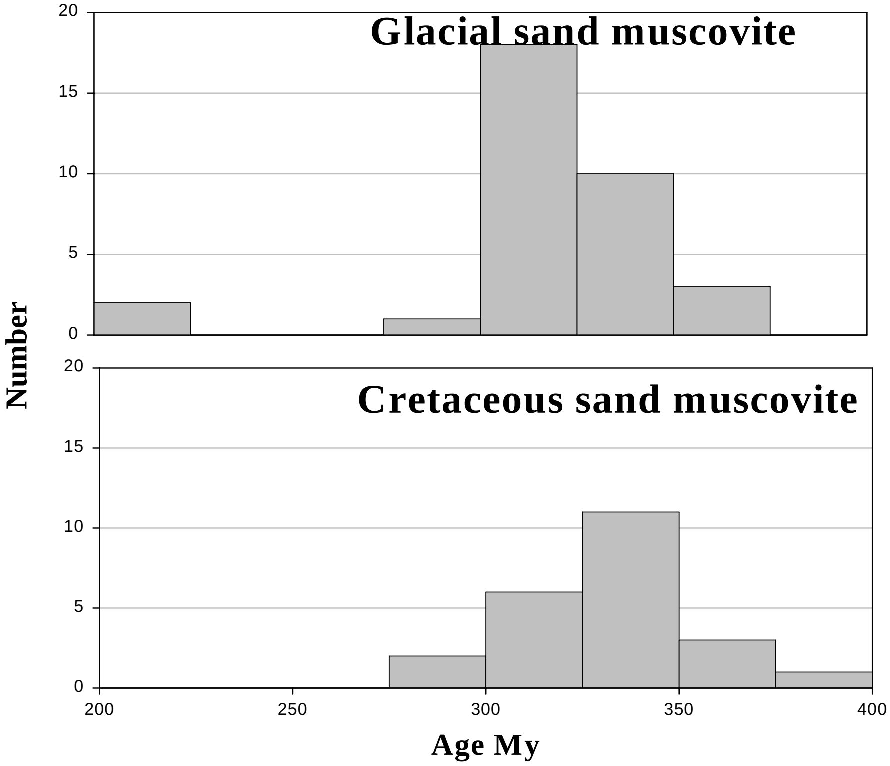

Figure 9. Muscovite from Cretaceous and Glacial sand of Caumsett State Park with a 25 Ma grouping histogram

Biotite from the glacial sand gives a range of ages from 60 Ma to 500 Ma with no apparent mode (Figure 8). The biotite age distribution is probably different from that of muscovite for two reasons: 1) the biotite grains are all of glacial origin because there is no biotite in Cretaceous sediments; 2) weathering may be responsible for ages for biotite younger than 200 Ma. Biotite may be weathering in both basement rock and after loess deposition. Hammerschmidt and Vonengelhardt (1995) found that partially weathered biotite grains from bedrock tend to give younger Ar/Ar ages in their study of an impact crater. During the Cretaceous time, weathering occurred in the local bedrock to the depth of 30 to 50 m. So the glacier may have picked up some slightly weathered biotite. Blum and Erel (1997) found that biotite weathers rapidly in soil environment in the first 20 thousand years based on Rb-Sr isotope ages of biotite from soils developed on terminal moraines. So, we are suspicious that at least some of the young ages may be due to the weathering.

Muscovite ages from Caumsett loess resemble those in the glacial sand (Figure 8). None of the biotite grains in this loess gave reliable ages.

Muscovite from the campus loess has modes between 300 to 400 Ma (Figure 10), as do those from the loess, glacial sand and Cretaceous sand from Caumsett State Park. However, two major differences are observed. First, there is a larger percent of muscovite ages between 250 and 300 Ma on campus than that at Caumsett. The higher percent of Avalonian muscovite grains may be the result of bedrock type changes in Connecticut or Long Island Sound to the north of the two sample sites, consistent with the Avalonian bedrock character found by Pacholik and Hanson (2001) on boulders at Stony Brook campus. The Avalonian muscovite grains might also be carried by anticyclone winds from the east of sample site. However, the possibility of anticyclone winds is low because the muscovite age distribution in loess at Caumsett State Park is very similar to the age distribution of glacial outwash at Caumsett State Park. This might be resolvable if we could obtain the age distribution of muscovite in glacial sediments in Long Island Sound. Second, three muscovite grains give ages of 436, 509, and 1002 Ma. The 436 and 509 Ma muscovite may come from Hudson Highlands or New Jersey Highlands. The 1002 Ma muscovite grain can only come from further west, because muscovite at or east of the highlands were reset to younger ages.

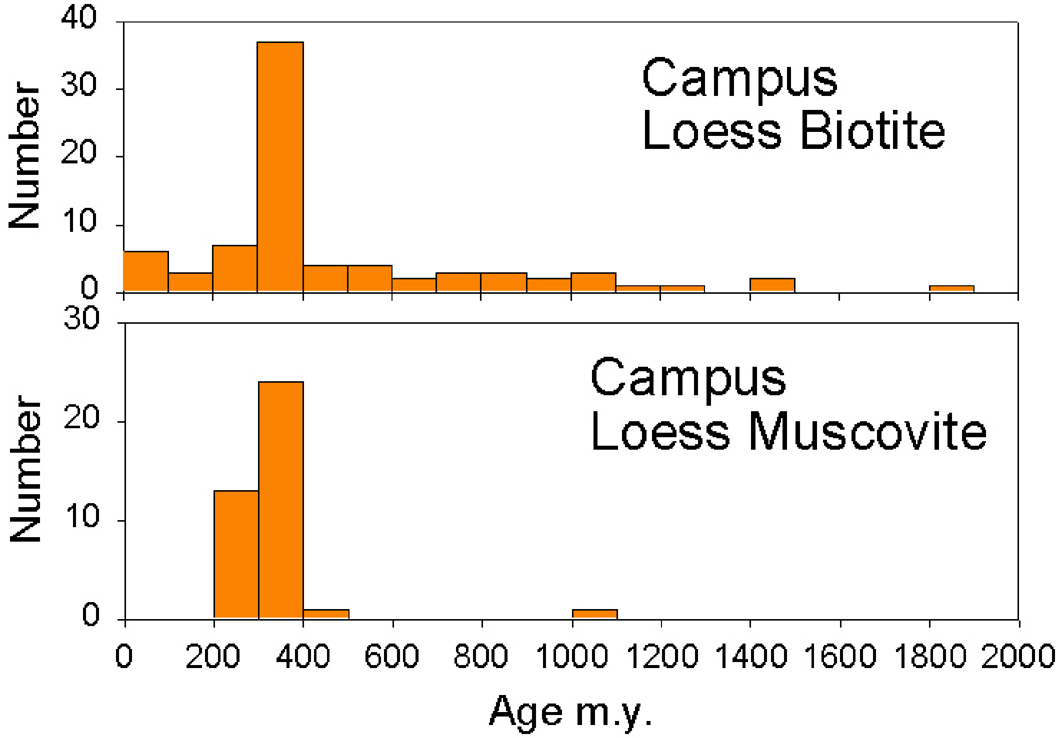

Figure 10. Muscovite and biotite in campus loess

Biotite ages of loess on Stony Brook campus range from 70 to 1800 Ma (Figure 10). The mode between 200 to 400 Ma suggests local sources to the north in Connecticut (Fugure 2). Some biotite grains from the glacial sand are also younger than 200 Ma suggesting these younger ages may due to alteration for example weathering. If this is so, we have to consider that some of ages the younger than 200 Ma for biotite from the loess may also due to weathering. These data suggest that the biotite grains are mainly from the north or west with little evidence of an eastern source suggestive of anticyclone winds.

Biotite grains that give ages from 400 to 900 Ma may be have a source in the Grenville terrane. Those ages between 400 and 700 Ma are consistent with biotite ages found in Hudson Highlands, while those between 700 and 900 Ma could come from the New Jersey Highlands. Grenville age biotite is consistent with westerly prevailing winds.

Biotite older than 900 Ma can only be found further west (National Geochronological and Natural Radioelement Databases, 1995, Figure 2) or at the Grenville Front (Cosca *et al.*, 1992). Other isotope methods such as analyzing the Pb isotope ratio for older grains might help determining the actual sources. If a westerly source is confirmed, the jet stream or prevailing westerly winds would be suggested for the transporting agent to this region.

CONCLUSIONS

Grain size distribution indicates that the loess on the Stony Brook Campus is a mixture of silt and sand. The mixing may be due to faunal- and cryoturbation, or wind-blown sand deposited at the same time as the loess.

Ar/Ar ages for single grain biotite and muscovite show that the dominant source of the mica in the loess is the bedrock in Connecticut directly to the north. About 10% of biotite grains may have a source in the Grenville bedrock in the Hudson and New Jersey Highlands, and about 5% are older and may come from bedrock further to the west. These data suggest that a westerly wind is an important mechanism for transporting the loess. There is no evidence of an eastern anticyclone wind. The mica may have been carried by katabatic winds from the north and by the jet stream and prevailing westerlies from the west.

Single grain mica Ar/Ar dating is a promising method for the provenance study of loess. Its utility would be enhanced if combined with other isotope methods. Biotite in loess is particularly valuable because it is mainly a single cycle mineral and should represent the provenance of bedrock that is contemporaneously abraded by glaciers.

References Cited

Armstrong RL, and Stump E, 1971, Additional K-Ar Dates, White Mountain Magma Series, New England: Amer. Jour. Science, v. 270, p. 331-333.

Blum JD and Erel Y, 1997. Rb-Sr Isotope Systematics of a Granitic Soil Chronosequence: the Importance of Biotite Weathering. Geochimica et Cosmochimica Acta, 61 (15): 3193-3204.

Cilek V, 2001. The Loess Deposits of the Bohemian Massif: Silt Provenance, Palaeometeorology and Loessification Processes, Quaternary International, 76-7: 123-128.

De Laguna W, 1963. Geology of Brookhaven Nation Laboratory and Vicinity, Suffolk County, New York. Bull. USGS. 11S6A, A1-A35.

Derbyshire E, 1983. Origin and Characteristics of Some Chinese Loess at Two Location in China, in Brookfield and Ahlbrandt, p. 69-90.

Ding ZL, 2001. Geochemistry of the Pliocene Red Clay Formation in the Chinese Loess Plateau and Implications for Its Origin, Source Provenance and Paleoclimate Change. Geochimica et Cosmochimica Acta, 65 (6): 901-913.

Fang XM, Li JJ, Van der Voo R., 1999. Age and Provenance of Loess in West Qinling, Chinese Science Bulletin. 44 (23): 2188-2192.

Folk RL, 1968. Petrology of Sedimentary Rocks, 34-40.

Gromet LP, 1989. Avalonian Terranes and Late Paleozoic Tectonism in Southeastern New England: Constraints and problems. GSA Special paper 230, p. 193-211.

Hames WE, Tracy RJ, Sutter JF, 1991. Petrologic, Structural, and Geochronological Characteristics of the Acadian Metamorphic Overprint on the Taconide Zone in Part of Southwestern New England, American Journal of Science. 291: (9) 887-913.

Hammerschmidt K and Vonengelhardt W, 1995. Ar-40/Ar-39 Dating of the Raguainha Impact Structure, Mato-Grosso, Brazil. Meteoritics, 30 (2): 227-233.

Heizler MT and Harrison TM, 1998. The Thermal History of the New York Basement Determined from Ar-40/Ar-39 K-feldspar Studies, Journal Of Geophysical Research-Solid Earth. 103: (B12) 29795-29814.

Ji JF, Chen J, Lu HY, 1999. Origin of Illite in the Loess from the Luochuan Area, Loess Plateau, Central China, Clay Minerals. 34 (4): 525-532.

Kutzbach JE, 1987. Model Simulations of the Climate Patterns during the Deglaciation of North America. The Geology of North America, vol. K-3, p. 425-446.

Lewis RS, and Stone JR, 1991. Late Quaternary Stratigraphy and Depositional History of the Long Island Sound Basin: Connecticut and New York. Journal of Coastal Research, Special Issue No. 11, p. 1-23.

Liu TS, 1991. Loess, Environment and Global Change. Science Press, Beijing. p. 288.

Long LE, 1962, Isotopic Age Study, Dutchess County, New York: Geol. Soc. America Bulletin, v. 73, p. 997-1006.

Long LE, and Kulp JL, 1962, Isotopic Age Study of the Metamorphic History of the Manhattan and Reading Prongs: Geological Society America Bulletin, v. 73, p. 969-996.

Mandell G, 1999, The Cliffs at Caumsett State Park,
http://pbisotopes.ess.sunysb.edu/esp/589_99/mandell/Caumsett_report_2_00.htm

Moecher DP, Cosca MA, Hanson GN, 1997. Petrologic and Ar-40/Ar-39 Geochronological Constraints on the Middle to Late Paleozoic Thermotectonic History of the Southern Connecticut Valley Zone, New England Appalachians, GSA Bulletin, 109, 164-175.

Mosher S, 1983. Kinematic History of the Narragansett Basin, Massachusetts and Rhode Island - Constraints on Late Paleozoic Plate Reconstructions, Tectonics. 2 (4): 327-344.

Muhs DR, and Bettis EA, 2000, Geochemical Variations in Peoria Loess of Western Iowa Indicate Paleowinds of Midcontinental North America During Last Glaciation: Quaternary Research, 53 (1): 49-61.

Muhs DR, Bettis EA, Been J, McGeehin JP, 2001, Impact of Climate and Parent Material on Chemical Weathering in Loess-derived Soils of the Mississippi River Valley. Soil Science Society of America Journal, 65 (6): 1761-1777.

Nakai S, Halliday AN, Rea DK, Provenance of Dust in the Pacific-Ocean, Earth and Planetary Science Letters. 119 (1-2): 143-157.

National Geochronological and Natural Radioelement Databases, USGS Digital Data Series DDS-14. USGS Denver Federal Center, 1995.

Newman WS, 1968. The Pleistocene Geology of the Montauk Peninsula, N.Y. State Geology Assiscoation Guidebook, 40, 155-173.

Nieter WM, etc, 1975. A late Wisconsin Loess Deposit in South-eastern Long Island, New York. Geol. Soc. Am. Northeast. Sec. 10th Ann. Meet. Abstract. 100.

Pettke T, Halliday AN, Hall CM, Rea DK, 2000. Dust Production and Deposition in Asia and the North Pacific Ocean over the Past 12 Myr, Earth and Planetary Science Letters, 178 (3-4): 397-413.

Pacholik W, and Hanson GN, 2001. Boulders on Stony Brook Campus May Reveal Geology of Long Island Sound Basement. http://pbisotopes.ess.sunysb.edu/lig/Conferences/abstracts-01/Pacholik/Pacholik-GNH-abst.htm

Ratcliffe NM, Hames WE, Stanley RS, 1998. Interpretation of Ages of Arc Magmatism, Metamorphism, and Collisional Tectonics in the Taconian Orogen of Western New England: American Journal of Science. 298 (9): 791-797.

Rutledge EM, 1975. Loess in Ohio in Relation to Several Possible Source Areas .2. Elemental and Mineralogical Composition, Soil Science Society Of America Journal, 39 (6): 1133-1139.

Samson SD, and Alexander EC Jr., 1987, Calibration of the Interlaboratory ^{40}Ar-^{39}Ar Dating Standard, MMhb-1, Chemical Geology (Isotope Geoscience Section), v. 66, p. 27-34.

Scott RB, Armstrong RL, Hartung JR, 1980. K-Ar Dates for Two Post-Orogenic Alkalic Plutonic Rocks of Western Connecticut: Contributions to Geochronology in Connecticut, II, Report of Investigations No.10, p. 5-11.

Seideman DE, 1980. K-Ar and Rb-Sr Dates For The Reynolds Bridge Gneiss and A Post-Metamorphic Thomaston Granite Dike At Reynolds Bridge, Western Connecticut: Contributions To Geochronology In Connecticut, Ii, Report Of Investigations No.10, p. 17-19.

Sirkin L, 1967. Late-Pleistocene Pollen stratigraphy of western Long Island and Easter Staten Island, New York. Quaternary Paleoecology, 7:249-274.

Sirkin L, 1991. Stratigraphy of the Long Island Platform, Journal of Coastal Research. Special Issue No. 1, pp. 217-227.

Sirkin L, 1996. Western Long Island Geology with Field Trips. Book and Tackle Shop: pp, 179.

Tripathi JK, Rajamani V, 1999. Geochemistry of the Loessic Sediments on Delhi Ridge, Eastern Thar Desert, Rajasthan: Implications for Exogenic Processes, Chemical Geology. 155 (3-4): 265-278.

Wintsch RP, Sutter JF, 1986. A Tectonic Model for the Late Paleozoic of Southeastern New England, Journal of Geology. 94 (4): 459-472.

Wintsch RP, Sutter JF, Kunk MJ, Aleinikoff JN, Dorais MJ, 1992. Contrasting P-T-T Paths - Thermochronological Evidence for A Late Paleozoic Final Assembly of the Avalon Composite Terrane in the New England Appalachians, Tectonics. 11 (3): 672-689.

Zartman RE, Hurley PM, Krueger HW, Giletti BJ, 1970, A Permian Disturbance of K-Ar Radiometric Ages in New England: Its Occurrences and Causes: Geological Society American Bulletin, v. 81, p. 3359-3374.

Zartman RE, 1988. 3 Decades of Geochronologic Studies in the New England Appalachianszartman Regeological Society of America Bulletin. 100 (8): 1168-1180.

Appendix I. Result of Mica Ar-Ar Dating

Run ID	Sample No.	Date	Mineral	Ca/K	36/39	40*/39	Mol 40	Mol 39	%40Ar*	Age	±
10414-01	Caumsett 6	1/5/01	Muscovite	0.0007	0.02824	168.528	7.7221	0.0437	95.3	335.56	3.16
10414-02	Caumsett 6	1/5/01	Muscovite	0.0005	0.16952	161.512	2.3797	0.0112	76.3	322.77	1.88
10414-03	Caumsett 6	1/5/01	Muscovite	0.0002	0.0043	163.236	15.4293	0.0938	99.2	325.92	1.32
10414-04	Caumsett 6	1/5/01	Muscovite	0.0002	0.00489	178.954	52.9582	0.2935	99.2	354.41	1.52
10414-05	Caumsett 6	1/5/01	Muscovite	0.0006	0.00721	163.036	20.7431	0.1256	98.7	325.56	1.48
10414-07	Caumsett 6	1/5/01	Muscovite	0.001	0.07758	156.359	1.5387	0.0086	87.2	313.31	1.51
10414-09	Caumsett 6	1/5/01	Muscovite	0.0002	0.01149	152.494	7.2519	0.0465	97.8	306.19	1.35
10414-10	Caumsett 6	1/5/01	Muscovite	0	0.0403	159.49	1.022	0.006	93.1	319.07	1.68
10414-06	Caumsett 6	1/5/01	Muscovite	0.0086	0.5845	27.234	3.5375	0.0177	13.6	58.64	3.15
10414-08	Caumsett 6	1/5/01	Muscovite	0.0041	1.0079	8.872	7.2698	0.0237	2.9	19.31	4.41
10415-01	Caumsett 5-3	1/6/01	Muscovite	0.0058	0.06754	150.092	1.2894	0.0076	88.3	301.75	1.43
10415-02	Caumsett 5-3	1/6/01	Muscovite	0	0.19987	154.927	1.2812	0.006	72.4	310.68	2.19
10415-03	Caumsett 5-3	1/6/01	Muscovite	0.0056	0.1143	150.667	1.0521	0.0057	81.7	302.81	2.04
10416-01	Caumsett 1	1/6/01	Muscovite	0.0056	0.01205	148.303	1.368	0.009	97.7	298.44	1.22
10416-02	Caumsett 1	1/6/01	Muscovite	0.002	0.00712	175.795	3.6152	0.0203	98.8	348.72	0.97
10416-03	Caumsett 1	1/6/01	Muscovite	0	0.01326	157.356	3.2155	0.0199	97.6	315.15	1.43
10416-06	Caumsett 1	1/6/01	Muscovite	0	0.00862	182.917	2.2847	0.0123	98.6	361.52	1.65
10416-07	Caumsett 1	1/6/01	Muscovite	0.0028	0.01984	184.433	1.6768	0.0088	96.9	364.23	1.82
10416-09	Caumsett 1	1/6/01	Muscovite	0.0025	0.00467	165.092	1.2533	0.0075	99.2	329.31	1.29
10416-10	Caumsett 1	1/6/01	Muscovite	0.008	0.00623	154.139	0.577	0.0037	98.8	309.23	1.4
10417-01	Caumsett 11	1/6/01	Muscovite	0.0023	0.0494	152.245	4.5109	0.027	91.3	305.73	1.16
10417-02	Caumsett 11	1/6/01	Muscovite	0.0008	0.01345	200.754	52.0476	0.2542	98.1	393.18	1.65
10417-03	Caumsett 11	1/6/01	Muscovite	0.0014	0.02889	163.429	2.5855	0.015	95	326.27	1.49
10417-04	Caumsett 11	1/6/01	Muscovite	0.0005	0.00418	166.116	4.0867	0.0244	99.3	331.17	1.57
10417-05	Caumsett 11	1/6/01	Muscovite	0.0019	0.01009	164.54	3.7703	0.0225	98.2	328.3	1.21
10417-06	Caumsett 11	1/6/01	Muscovite	0	0.01151	158.232	2.878	0.0178	97.9	316.76	1.08
10417-07	Caumsett 11	1/6/01	Muscovite	0	0.00766	155.44	1.302	0.0083	98.6	311.62	1.13
10417-08	Caumsett 11	1/6/01	Muscovite	0	0.00785	158.505	2.0255	0.0126	98.6	317.26	1.06
10417-09	Caumsett 11	1/6/01	Muscovite	0.0016	0.00546	160.98	4.3051	0.0265	99	321.8	1.08

10417-10	Caumsett 11	1/6/01	Muscovite	0.0718	0.30862	238.041	3.3418	0.0102	72.3	457.64	3.28
10429-01	Caumsett 11	1/17/01	Muscovite	0.0049	0.00215	149.852	0.6928	0.0046	99.6	301.31	1.34
10429-02	Caumsett 11	1/17/01	Muscovite	0.0007	0.00253	156.429	0.8629	0.0055	99.5	313.44	1.12
10429-03	Caumsett 11	1/17/01	Muscovite	0	0.01972	150.411	4.4406	0.0284	96.3	302.34	0.96
10429-09	Caumsett 11	1/17/01	Muscovite	0	0.00471	159.287	12.309	0.0766	99.1	318.69	0.95
10429-10	Caumsett 11	1/17/01	Muscovite	0.0031	0.00177	162.131	0.6832	0.0042	99.7	323.9	1.4
10429-11	Caumsett 11	1/17/01	Muscovite	0.0053	0.00244	154.625	1.1142	0.0072	99.5	310.12	1.46
10429-12	Caumsett 11	1/17/01	Muscovite	0.0004	0.01307	157.253	0.4655	0.0029	97.6	314.96	1.65
10429-13	Caumsett 11	1/17/01	Muscovite	0.002	0.01972	148.586	1.4063	0.0091	96.2	298.96	1.09
10429-14	Caumsett 11	1/17/01	Muscovite	0.0014	0.00526	156.067	4.5226	0.0287	99	312.78	0.88
10429-15	Caumsett 11	1/17/01	Muscovite	0.0039	0.00199	154.878	1.2504	0.008	99.6	310.59	1.28
10429-05	Caumsett 11	1/17/01	Biotite	0.0041	0.25112	33.306	0.6234	0.0058	31	71.45	1.77
10429-06	Caumsett 11	1/17/01	Biotite	0	0.59022	159.707	0.1066	0.0003	47.8	319.46	14.96
10418-01	Caumsett 2	1/6/01	Muscovite	0.0018	0.00776	154.48	2.5152	0.016	98.5	309.85	1.8
10418-02	Caumsett 2	1/6/01	Muscovite	0.0637	0.92874	150.668	0.2875	0.0007	35.4	302.82	13.21
10418-03	Caumsett 2	1/6/01	Muscovite	0.0005	0.00666	140.398	1.796	0.0126	98.6	283.71	1.55
10418-04	Caumsett 2	1/6/01	Muscovite	0	0.00206	162.175	5.6889	0.0349	99.6	323.98	2.11
10418-06	Caumsett 2	1/6/01	Muscovite	0	0.01045	172.381	0.4036	0.0023	98.2	342.55	2.39
10418-07	Caumsett 2	1/6/01	Muscovite	0	0.0039	171.942	0.9164	0.0053	99.3	341.75	2.01
10418-09	Caumsett 2	1/6/01	Muscovite	0	0.00722	161.153	0.4599	0.0028	98.7	322.11	2.12
10418-10	Caumsett 2	1/6/01	Muscovite	0	0.0051	162.207	1.4098	0.0086	99.1	324.04	1.24
10419-01	Caumsett 4	1/6/01	Muscovite	0.0001	0.00199	163.763	10.7731	0.0655	99.6	326.88	1.37
10419-02	Caumsett 4	1/6/01	Muscovite	0.0031	0.04055	163.55	3.1536	0.018	93.2	326.49	1.37
10419-03	Caumsett 4	1/6/01	Muscovite	0.0015	0.01414	168.673	4.0212	0.0233	97.6	335.83	1.28
10419-04	Caumsett 4	1/6/01	Muscovite	0.0059	0.02737	186.553	1.7017	0.0087	95.8	368.02	1.45
10419-05	Caumsett 4	1/7/01	Muscovite	0	0.03284	166.967	2.0591	0.0117	94.5	332.72	1.43
10419-06	Caumsett 4	1/7/01	Muscovite	0.0012	0.0028	169.642	3.8802	0.0228	99.5	337.58	1.59
10419-07	Caumsett 4	1/7/01	Muscovite	0	0.01093	168.685	0.866	0.005	98.1	335.85	1.8
10419-08	Caumsett 4	1/7/01	Muscovite	0.005	0.01741	195.519	0.9209	0.0046	97.4	383.95	2.54
10419-09	Caumsett 4	1/7/01	Muscovite	0.005	0.01729	165.49	0.7238	0.0042	97	330.03	1.6
10420-02	Caumsett 9	1/7/01	Muscovite	0	0.00515	161.524	10.1163	0.062	99.1	322.79	1.32
10420-03	Caumsett 9	1/7/01	Muscovite	0.0017	0.04385	157.507	8.2547	0.0484	92.4	315.43	1.39
10420-05	Caumsett 9	1/7/01	Muscovite	0.0003	0.00713	162.204	5.9056	0.0359	98.7	324.03	1.26
10420-06	Caumsett 9	1/7/01	Muscovite	0	0.00462	158.47	5.2951	0.0331	99.1	317.19	1.05

10420-07	Caumsett 9	1/7/01	Muscovite	0.0002	0.00411	160.632	8.4279	0.0521	99.2	321.16	1.05
10420-09	Caumsett 9	1/7/01	Muscovite	0	0.00625	169.85	7.8528	0.0457	98.9	337.96	1.76
10420-01	Caumsett 9	1/7/01	Muscovite	0.0181	1.00424	181.215	1.1318	0.0024	37.9	358.47	6.78
10420-04	Caumsett 9	1/7/01	Muscovite	0.0045	0.67934	35.265	2.3073	0.0098	14.9	75.57	3.65
10420-08	Caumsett 9	1/7/01	Muscovite	0.0042	0.54217	189.407	3.6291	0.0104	54.2	373.1	3.97

10421-01	Caumsett 7	1/7/01	Muscovite	0.0152	0.00165	155.311	2.202	0.0141	99.7	311.39	1.83
10421-02	Caumsett 7	1/7/01	Muscovite	0.0003	0.00145	159.52	0.6831	0.0043	99.7	319.12	1.65
10421-03	Caumsett 7	1/7/01	Muscovite	0	0.02086	157.033	1.166	0.0071	96.2	314.56	1.42
10421-05	Caumsett 7	1/7/01	Muscovite	0	0.00799	164.609	1.11	0.0066	98.6	328.43	1.45
10421-06	Caumsett 7	1/7/01	Muscovite	0.0007	0.0039	150.763	5.7264	0.0377	99.2	302.99	0.9
10421-07	Caumsett 7	1/7/01	Muscovite	0.0075	0.00056	158.398	0.5071	0.0032	99.9	317.06	1.7

10423-01	Loess 17.5	1/10/01	Muscovite	0.0181	0.05136	170.647	0.476	0.0026	91.8	339.41	2.52
10423-02	Loess 17.5	1/10/01	Muscovite	0.0048	0.01136	133.481	3.2716	0.0239	97.5	270.73	0.89
10423-04	Loess 17.5	1/10/01	Muscovite	0.004	0.01312	146.453	14.4204	0.0959	97.4	295	1.05
10423-08	Loess 17.5	1/10/01	Muscovite	0.0125	0.07581	149.724	0.7965	0.0046	87	301.07	1.73
10423-09	Loess 17.5	1/10/01	Muscovite	0.0103	0.07451	167.497	0.5413	0.0029	88.4	333.69	2.74
10423-10	Loess 17.5	1/10/01	Muscovite	0.0086	0.01316	155.531	0.7292	0.0046	97.6	311.79	1.6
10423-12	Loess 17.5	1/10/01	Biotite	0.0019	0.03932	150.876	0.3152	0.0019	92.8	303.2	2.4
10423-03	Loess 17.5	1/10/01	Biotite	0.1172	1.32664	90.635	0.5105	0.0011	18.8	188.18	11.8

10424-08	Loess 5.5	1/10/01	Muscovite	0.0037	0.10393	128.75	0.9954	0.0063	80.7	260.52	1.4
10424-09	Loess 5.5	1/10/01	Muscovite	0	0.02208	162.661	1.3672	0.0081	96.1	324.87	1.3
10424-10	Loess 5.5	1/10/01	Muscovite	0	0.05629	180.245	1.2273	0.0062	91.6	356.73	1.79
10424-12	Loess 5.5	1/10/01	Muscovite	0.0002	0.01551	145.495	0.634	0.0042	96.9	293.22	1.48
10424-01	Loess 5.5	1/10/01	Biotite	0.002	0.06931	153.93	3.1294	0.0179	88.3	308.84	1.27
10424-02	Loess 5.5	1/10/01	Biotite	0.0144	0.35929	152.887	0.7566	0.0029	59	306.92	3.36
10424-05	Loess 5.5	1/10/01	Biotite	0.032	0.25488	123.168	1.4037	0.0071	62.1	251.2	2.12
10424-06	Loess 5.5	1/10/01	Biotite	0	0.04758	189.742	0.5829	0.0029	93.1	373.7	2.02
10424-13	Loess 5.5	1/10/01	Biotite	0	0.54747	191.254	0.1284	0.0004	54.2	376.39	13.8

10425-01	Loess 3	1/10/01	Muscovite	0.0002	0.02754	157.93	12.4427	0.0749	95.1	316.2	1.19
10425-02	Loess 3	1/10/01	Muscovite	0.0033	0.02409	182.323	3.5177	0.0186	96.2	360.45	1.53
10425-03	Loess 3	1/10/01	Muscovite	0.0028	0.03942	120.016	1.6279	0.0124	91.2	245.19	1
10425-04	Loess 3	1/10/01	Muscovite	0.0076	0.10124	191.223	0.6168	0.0028	86.5	376.33	2.33
10425-06	Loess 3	1/16/01	Biotite	0.0411	0.90159	262.485	0.4645	0.0009	49.6	498.67	11.72

10425-07	Loess 3	1/16/01	Biotite	0	0.0159	172.056	4.2092	0.0238	97.3	341.96	1.03
10425-09	Loess 3	1/16/01	Biotite	0	0.59009	20.583	0.1002	0.0005	10.6	44.49	8.21
10425-10	Loess 3	1/16/01	Biotite	0	1.11815	204.351	0.0428	0.0001	38.2	399.5	37.32
10425-11	Loess 3	1/16/01	Biotite	0.0162	0.211	154.344	0.9545	0.0044	71.2	309.6	2.5
10426-01	Loess 15.5	1/16/01	Biotite	0.5226	2.41903	516.931	0.1484	0.0001	42	878.15	54.14
10426-02	Loess 15.5	1/16/01	Biotite	0.0763	0.29097	145.003	0.1364	0.0006	62.8	292.3	6.56
10426-03	Loess 15.5	1/16/01	Biotite	0.2297	2.56935	160.805	0.1931	0.0002	17.5	321.48	31.86
10426-04	Loess 15.5	1/16/01	Biotite	0.1245	1.32938	77.91	0.3161	0.0007	16.5	162.91	13.73
10426-05	Loess 15.5	1/16/01	Biotite	0.0072	0.06063	159.626	0.5265	0.003	89.9	319.31	2.03
10427-06	Loess 12	1/16/01	Muscovite	0.034	0.0899	147.529	12.6279	0.0725	84.7	297	0.95
10427-07	Loess 12	1/16/01	Muscovite	0.0029	0.05825	152.117	2.9531	0.0174	89.8	305.49	1.11
10427-08	Loess 12	1/16/01	Muscovite	0	0.00885	152.975	1.3898	0.0089	98.3	307.08	1.05
10427-09	Loess 12	1/16/01	Muscovite	0	0.01164	166.698	2.1211	0.0125	98	332.23	1.23
10427-10	Loess 12	1/16/01	Muscovite	0.0005	0.0264	154.366	0.5632	0.0035	95.2	309.65	1.61
10427-11	Loess 12	1/16/01	Muscovite	0	0.02233	140.47	0.2614	0.0018	95.5	283.85	2.15
10427-01	Loess 12	1/16/01	Biotite	0.09	0.08416	155.334	0.1027	0.0006	86.2	311.43	4.14
10427-05	Loess 12	1/16/01	Biotite	0.01	0.52847	166.508	3.9192	0.0121	51.6	331.89	2.46
10427-13	Loess 12	1/17/01	Biotite	0.427	5.5809	380.874	1.3718	0.0007	18.8	685.2	35.07
10427-14	Loess 12	1/17/01	Biotite	0.2068	5.59527	858.37	0.879	0.0003	34.2	1287.28	45.72
10427-16	Loess 12	1/17/01	Biotite	0.0058	0.08547	149.845	1.5921	0.0091	85.6	301.29	1.29
10428-01	Loess 9	1/17/01	Muscovite	0.011	0.15409	148.538	2.1111	0.0109	76.5	298.87	1.63
10428-02	Loess 9	1/17/01	Muscovite	0.0074	0.13553	152.123	1.2052	0.0063	79.2	305.51	1.9
10428-03	Loess 9	1/17/01	Muscovite	0.0032	0.04248	151.099	1.6275	0.0099	92.3	303.61	1.15
10428-04	Loess 9	1/17/01	Biotite	0.0009	0.50769	140.281	0.4614	0.0016	48.3	283.5	4.56
10428-06	Loess 9	1/17/01	Biotite	0.0015	0.00945	173.966	1.8906	0.0107	98.4	345.42	1.17
10428-07	Loess 9	1/17/01	Biotite	0.3548	0.16736	174.358	0.1546	0.0007	77.9	346.12	7.74
10428-09	Loess 9	1/17/01	Biotite	13.4332	0.26096	163.173	0.0656	0.0003	67.9	325.81	10.51
10428-12	Loess 9	1/17/01	Biotite	0.1782	1.44846	207.788	0.1859	0.0003	32.7	405.52	23.71
10428-21	Loess 9	1/17/01	Biotite	0.0018	0.00672	156.649	2.0766	0.0131	98.7	313.85	2.2