RECONSTRUCTION OF PALEOGEOGRAPHIC HISTORY OF THE HUDSON RIVER AT NEWLY EXPOSED PLEISTOCENE STRATA AT BEAR MOUNTAIN

A Final Report of the Tibor T. Polgar Fellowship Program

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ABSTRACT

Sedimentary deposits provide historical records regarding the glacial environment during periods of ice sheet and glacier expansion and retreat. The best method to decipher these environments is to study sediments in their natural settings. Recently exposed horizontal strata at Jones Point, New York, made it possible to analyze and reconstruct the paleogeographic environment of Hudson River during the late Pleistocene at this location. Field observations and dry sieving granulometric analyses of each of the fourteen layers in the strata revealed deltaic-fluvial processes, both large-scale and seasonal, and localized flood events. These depositional changes took place in the Pleistocene epoch, during the Woodfordian sub-stage of the Late Wisconsinian stage, approximately 14,000 years ago, as the climate warmed and glaciers quickly and repeatedly advanced and retreated. Glacial directional movement and formation of moraines and glacial lakes, such as Lake Hudson and Lake Albany, have resulted in the reversal or slowing down of the flow of water in the Hudson River Valley, thus changing the direction and processes of sediment deposition. Measured angles of the layers of deposits established three distinguishable directions of flow that took place at Jones Point, New York: from the northwest, northeast and east. In addition, Global Positioning System readings of elevation indicated that the rates of isostatic rebound at our sites correspond with the results from a previous report.

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INTRODUCTION

The geology of the Hudson Valley in New York State is extremely diverse from the northern Adirondacks south to the Palisades. The Hudson River itself has been active geologically through the cycles of erosion, transportation and deposition of sediments. Glacial activity considerably affected these processes during the Pleistocene epoch. As glaciers migrated southward, they carried vast amounts of sediments including clay, silt, sand, pebbles, rocks and boulders. Transportation and preservation of this material occurs within the glacier (englacial zone), on the surface and edges (supraglacial zone), and on the bottom of the glacier in contact with the bedrock (basal or subglacial zone) (Reading 1986). It is due to the movement of the glacier and its bedrock-basal zone contact where the majority of the erosion and transportation of parent rocks takes place (Reading 1986).

As the climate warmed towards the end of the Pleistocene in the Wisconsinian age, lasting from 24,000 to 12,600 years ago, there was major glacial retreat (Connally and Sirkin 1973). However, colder periods persisted and the glaciers still advanced periodically from different directions, though not as far as the Ronkonkoma moraine on Long Island (Borns 1973). Within the Lower Hudson River valley region of New York State, the Hudson Highlands, this intermittent glacial advance and retreat continued at the leading edges of the glaciers. Several studies describe glacial movements in detail (Thwaites 1946, Reading 1986, Sanders and Merguerian 1998).

Till deposits are poorly sorted, unstratified sediments consisting of a clay and sand matrix with inclusions of gravel, pebbles, and boulders. They indicate the presence of glacier activity and are found throughout the Hudson River Valley and surrounding vicinity (Press and Siever 2001).

However, to describe the specifics of a glacial paleoenvironment scientists need more information regarding the presence of glacial features that leave stratified layers of deposits. Vegetative cover and increasing regional development make it difficult to find an undisturbed, horizontal sequence of layers that may generate an ideal stratigraphic sequence study.

The finding of the exposed horizontal strata at Jones Point made it possible to analyze and reconstruct the paleogeographic environment of Hudson River during the late Pleistocene at this location. The location of our research sites are approximately ¼ and ½ mile southwest of Jones Point, NY, on the eastern and western sides, respectively, of Route 9W/202 (Figs.1 & 2). This newly-exposed strata, due to a localized landslide at the first site (Fig. 3), is visible from the road as one travels north on Route 9W and was first noticed in autumn of 2001 by Dr. Yuri Gorokhovich, geology professor at Purchase College. We noticed the second site, a functioning small-scale sand and gravel pit, while looking for other exposures in the area along Route 9W/202 (Fig. 4). Since it is still functioning as a gravel pit, removal of gravel and sand exposes new material from each layer altering the face of the strata.

The first objective of the research was to reconstruct the paleogeographic history of the area during the late Wisconsinian stage using granulometric and mineral analysis. The second objective was to estimate the isostatic rebound rate of the area, i.e., uplift due to large-scale glacial retreat at the end of the Pleistocene epoch.

Granulometric and mineral analysis will define the grain size distributions and the mineral composition of each sample of the stratigraphic sequence of sediment particles. To establish the origin of the parental material, we will implement the glycerin density-separation technique to allow the identification of the mineralogical associations between layers in exposed strata. This procedure segregates the heavy fractions of sediment containing iron and magnesium minerals from the light fraction containing silica rich minerals.

The fact that the top of the exposed strata are found on a high elevation mark, approximately 100 feet above sea level according to the United States Geological Survey 7.5 minute Peekskill quadrangle, makes it possible to estimate the rate of isostatic rebound for the area. A Global Positioning System unit was used to locate the sites and measure the elevations of each site in order to complement past research carried out by Connally and Sirkin in 1984 regarding isostatic rebound of the Mid-Hudson Valley.

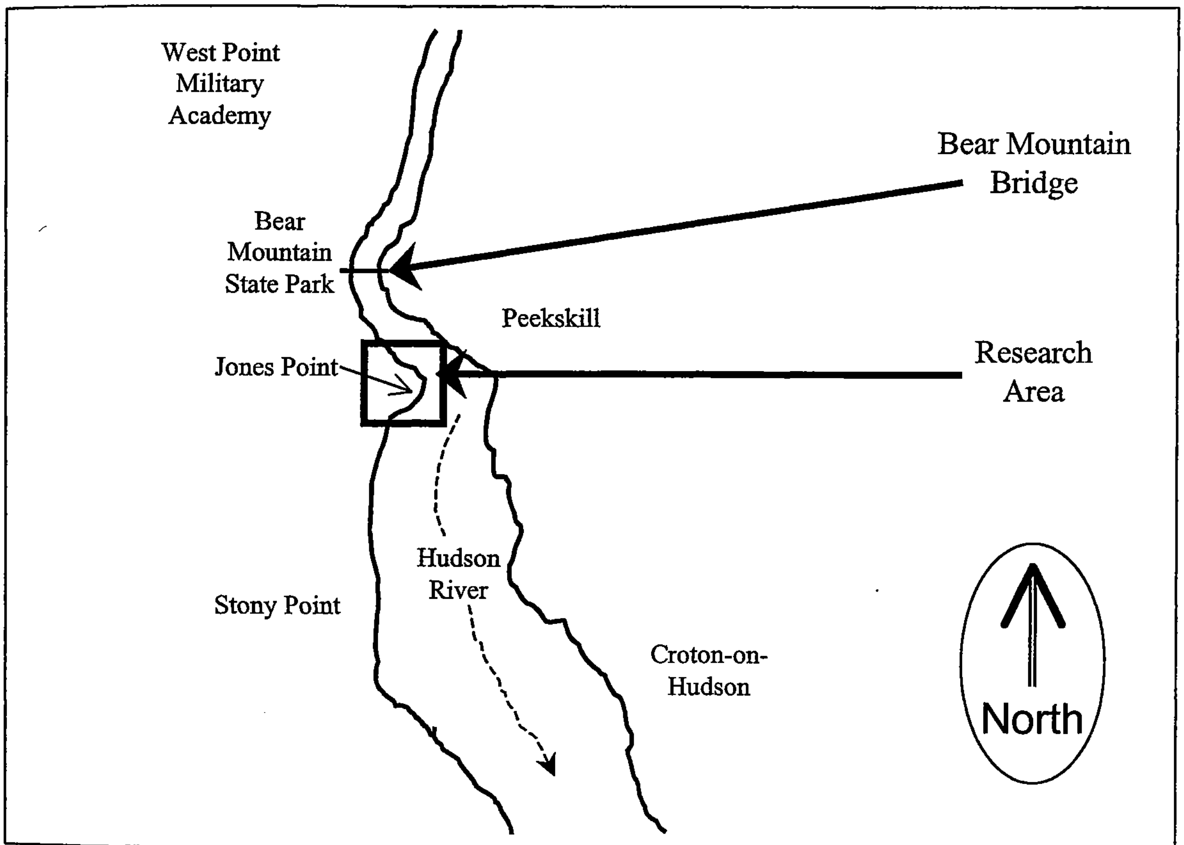

Fig.1. Box shows location of research area at Jones Point, Bear Mountain State Park, New York.

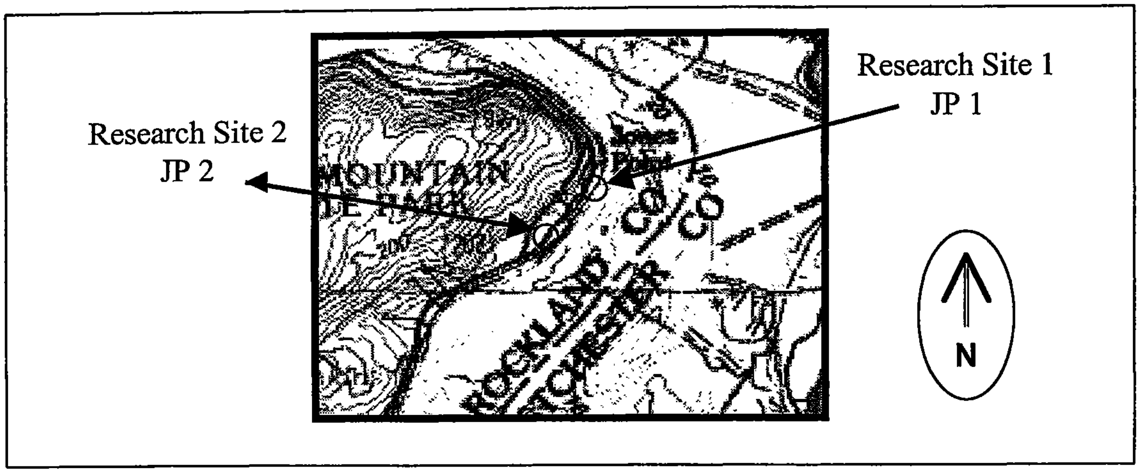

Fig. 2. Close-up view of the two research sites at Jones Point, Bear Mountain State Park, New York. Image courtesy of USGS 7.5 minute Peekskill quadrangle.

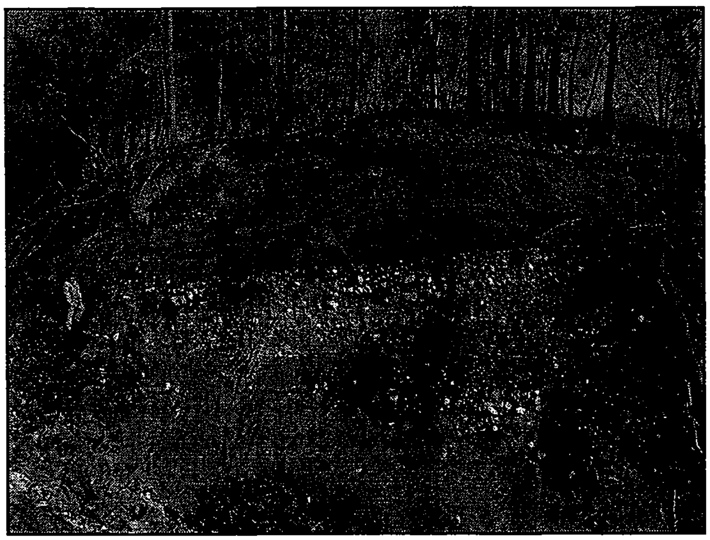

Fig. 3. Site JP1, north-northeast view of the exposed stratified layers, February 2002. Frequent localized storm events have eroded the strata and exposed new material. Note the fallen tree on the right.

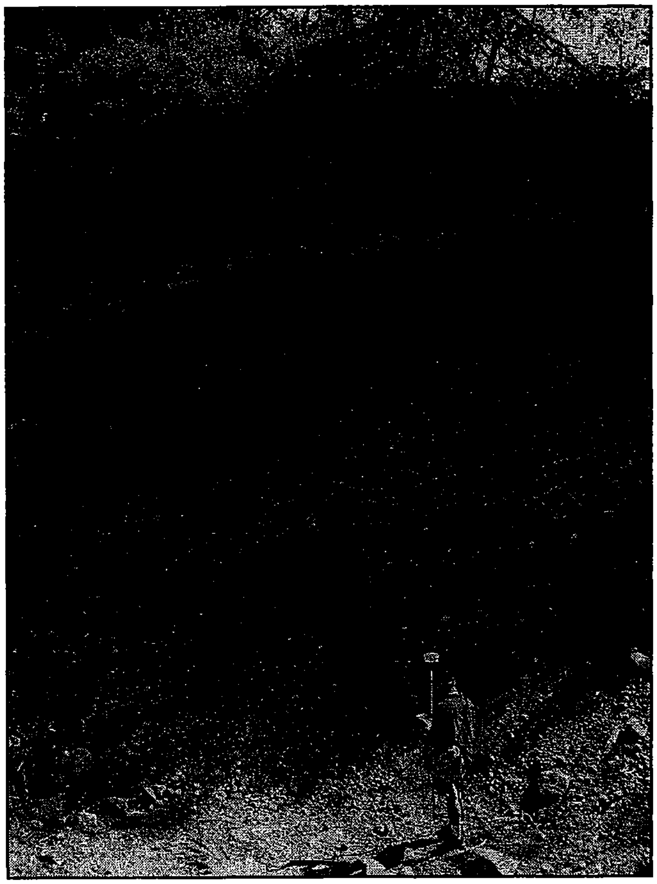

Fig. 4. Site JP2, north view of the exposed stratified layers, summer 2002.
Note the downward dip of the layers between horizontal layers in the middle of the image.

Methods

Initial field methods in February 2002 included photographing and sketching the cross-section of the strata, recording the color, grain texture and measuring the thickness of each of the fourteen distinct layers at the first site, JP1. Also noted were such features as cross-bedding, drastic differences in grain-size, as well as noticeable changes in dip and angle between the separate layers.

Using a cylindrical open-ended container, we collected three representative samples from each layer in labeled sampling bags. On each was marked the layers starting with "A" as the uppermost layer and continuing down to layer "L" at the bottom.

Unsorted landslide debris covering strata below layer L made it impossible to obtain additional samples of layers below this point. Layer K contained predominantly cobbles and boulders too large to fit into the sample bags, therefore, we only removed a few hand samples and left this layer for morphological analysis in the field.

After allowing the samples to air-dry for approximately two weeks, we weighed the contents of the first sample bag from layer A to the nearest $1/100^{th}$ gram. We then emptied the sample into the uppermost sieve, greater than 8mm, (phi value of -3), of the sieve stack, allowing separation of grains throughout the stack, seven sieves in total, each sieve decreasing by one-half in size as the grains pass through the sieves. Grains less than 0.0062mm in diameter (phi-value = +4), were collected in the bottom pan. Note that the sieve for grain-size 4mm (phi-value = -2), was not used in the analysis as the main focus of this research was the finer sand size grains, less than 2mm, and the localized processes involved in the formation of each layer in the sequence of the strata. By placing the sieve stack on the electric sieve shaker for 10 minutes at setting number 5, we continued separation of the grains. We analyzed the contents of the sieve containing the larger grains; layer K with most grains larger than 8mm, using visual morphological analysis in the field as well as in the lab.

Upon completion of the sieve shaking, the contents of each sieve layer, starting with the coarsest (>8mm), were emptied onto a clean board and the screen on the sieve was carefully cleaned of lodged particles, adding the collected grains to the present fraction. This fraction was weighed and recorded, to the nearest one-hundredth of a gram, and deposited into an envelope for later mineralogical analysis. Each grain size fraction for the stack required repeating these steps and noting the location, date, sample layer, sample number, range of the grain-size and the weight for the respective fraction.

Once we weighed the fractions from all three samples, it was possible to compute the average for each fraction in that layer and generate relative frequency histograms and cumulative frequency curves for each layer in order to interpret the depositional processes involved for the strata. For the cumulative frequency curves, we used an XY scatter plot chart in Excel with smoothed lines connecting the points. This aided in determining the grain sizes for the 25th, 50th and 75th percentiles needed to verify the median grain size and compute the sorting coefficient for each layer. The median grain size, *Md*, is equal to the corresponding grain size for the 50th percentile as read from the cumulative curve. We used Trask's formula for the sorting coefficient, $So = P_{75}/P_{25}$, where P_n equals the grain size corresponding to the respective percentile on the graph (Blatt 1972). For the cumulative frequency graphs for each layer, the X-axis is $\log_{10}$ of the grain size in millimeters, from 0.01 to 10.00, while the Y-axis is the cumulative relative frequency percentage of each grain size fraction.

Using samples from the 0.25-0.50 mm fractions for each layer, attempts were made to employ the glycerin-density separation method to isolate the heavy fractions for determining the mineral content of the respective layer. This would aid in the provenance research and help determine the direction of glacial movement that resulted in the deposition of the individual layer.

We collected two samples from Shinnecock Beach on Long Island, NY, and one sample from the west bank of the Hudson River, east of JP1, and performed similar analyses to distinguish between the samples from the exposed Pleistocene strata at Jones Point to the other recent depositional environments and processes that formed these three samples.

At JP1, the Trimble TDC-2 GPS unit recorded the location and elevation at the top of the profile. The vertical accuracy is within three meters while the horizontal accuracy is less than one meter with sufficient satellites present. The unit was also employed to record the elevations of the base of the profile as well as the top of layer K, the boulder-cobble layer. At site JP2, seven locations along the floor of the gravel pit were recorded as was one point at a boulder-cobble layer, similar to layer K at JP1. One additional point was logged at another distinct boulder-cobble layer at JP2.

While unsuccessfully attempting to climb to the top of the JP2 site to record the elevation, two supplementary points were recorded. One spot was located on the side of a steep hill where we rested and observed a distinct grouping of boulders and cobbles similar in size to those encountered at JP1 and JP2. The other position was the top of the rocky terrace, well above the two study sites. A final GPS reading was recorded at the bank of the Hudson River to establish the present day elevation for the river bank.

RESULTS

Granulometric analysis of the individual layers yielded interesting results clearly signifying that various processes were present at the time of deposition. After recording the weights for each fraction of each sample and averaging the results of each fraction's weight, it was possible to calculate the relative frequencies for each total sample weight. The following table represents these relative frequencies in the form of average cumulative frequencies for each layer (Table 1).

	Average Cumulative Frequency							
Grain Size (Φ)	5	4	3	2	1	0	-1	-3
Grain Size (mm)	< 0.062mm	0.062-0.125	0.125-0.25	0.25-0.50	0.50-1.00	1.00-2.00	2.00-8.00	> 8.00mm
Layer								
A	0.61	1.19	2.21	4.47	8.67	16.27	37.78	100.00
A'	0.71	1.48	3.43	9.25	17.54	53.98	99.86	100.00
B	0.32	0.78	2.04	5.65	11.83	27.07	53.08	100.00
C	0.44	0.93	2.41	8.28	32.50	73.72	97.93	100.00
D	1.12	2.33	8.03	55.78	92.95	97.78	99.70	100.00
E	0.66	1.22	2.08	5.29	14.24	41.30	92.06	100.00
E'	0.58	1.08	2.32	12.74	51.29	89.40	99.32	100.00
F	48.97	83.07	97.64	99.04	99.50	99.70	99.76	100.00
G	0.88	1.56	3.08	17.72	62.76	86.52	99.13	100.00
H	0.82	1.57	6.80	46.17	87.78	96.84	100.00	100.00
I	14.71	39.01	83.92	99.30	99.99	100.00	100.00	100.00
J	1.50	6.29	45.15	96.39	99.88	99.97	100.00	100.00
K	0.00	0.00	0.00	0.00	0.01	0.11	1.61	100.00
L	0.79	1.54	3.14	7.89	19.28	42.16	79.82	100.00
Beach	0.03	0.05	2.50	84.23	99.98	100.00	100.00	100.00
Dune	0.00	0.01	12.28	93.39	100.00	100.00	100.00	100.00
Hudson Bank	0.03	0.05	0.09	0.92	14.00	52.99	96.41	100.00

Table 1. Average cumulative frequencies for each layer including Shinnecock beach and dune sand as well as Hudson river bank deposits.

Graphs of cumulative frequency versus grain size were derived for each layer using the table above. From the curves on each grid, we used the 25th and 75th percentiles to cross-reference the grain size for the percentiles on each layer in order to calculate the sorting coefficients. The median grain size for each layer was also obtained from the graph.

Sand from Shinnecock Beach shows excellent sorting at 1.46 for the beach sand and 1.43 for the dune sand, typical results for a tidal beach setting. Either constant tidal motion along the beach removes the finer particles, which are transported back into the water where they settle out, or they are carried by the wind out to sea or inland past the dunes forming eolian deposits. The median grain size for the beach and dune sand were 0.38mm and 0.35mm, respectively.

The sediment from the Hudson River bank had a sorting coefficient of 2.91 and the median grain size was 1.91mm, much larger than the beach sand. Figure 5 shows the three cumulative frequency curves for the Shinnecock sand and the Hudson River bank.

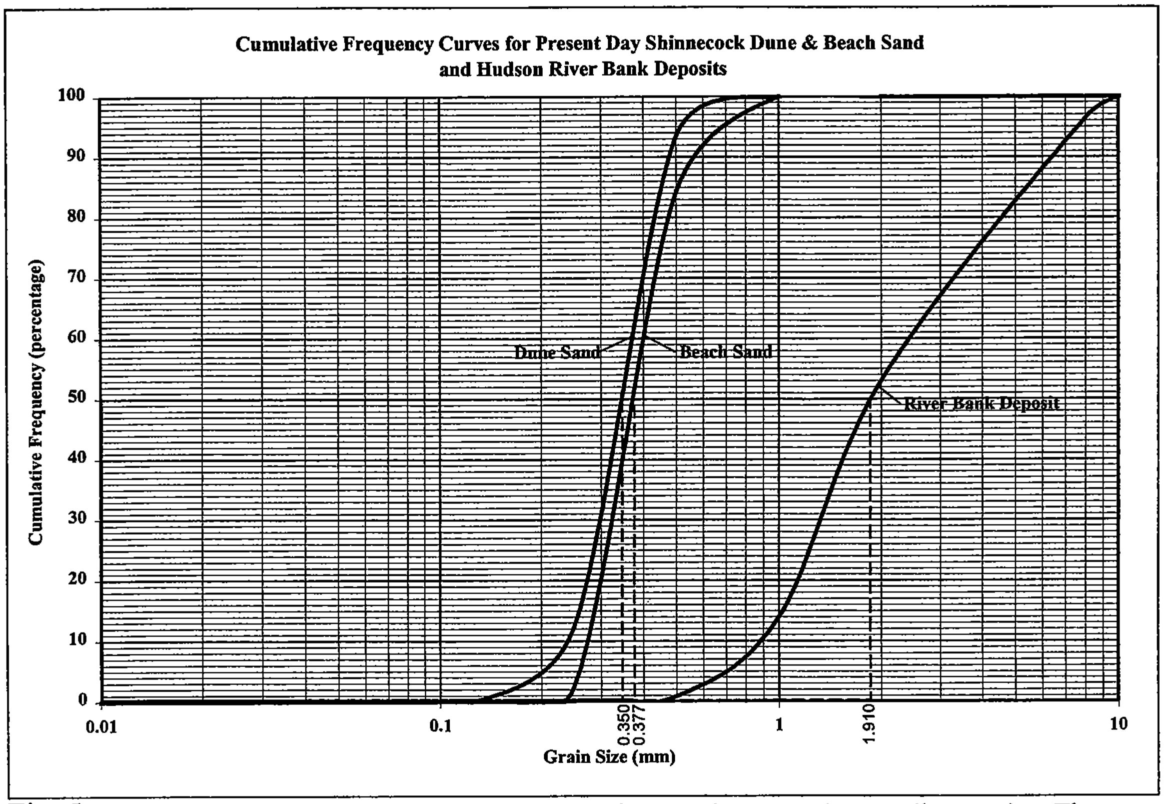

Fig. 5. Note the near vertical curves for the beach and dune sand representing excellent sorting. The riverbank deposit curve covers a broader range of grain sizes, poorer sorting, and a larger median grain size at the 50th percentile, 1.91mm than the beach and dune sand at 0.38 and 0.35mm, respectively.

In order to make it easier to visualize the depositional processes as they occurred chronologically, we begin with the lowest layer, L, and work our way up to the most current deposits at layer A. As shown in Fig. 6 for layer L, the median grain size was 2.75mm, with a very poor sorting coefficient of 5.26. This may be the result of turbulent water flow with enough energy to carry a particle measuring almost 3mm in diameter, larger than the present day riverbank particles at 1.91mm. The thickness of layer L measured over 300cm, illustrating the considerable amount of time necessary to build up such a substantial deposit.

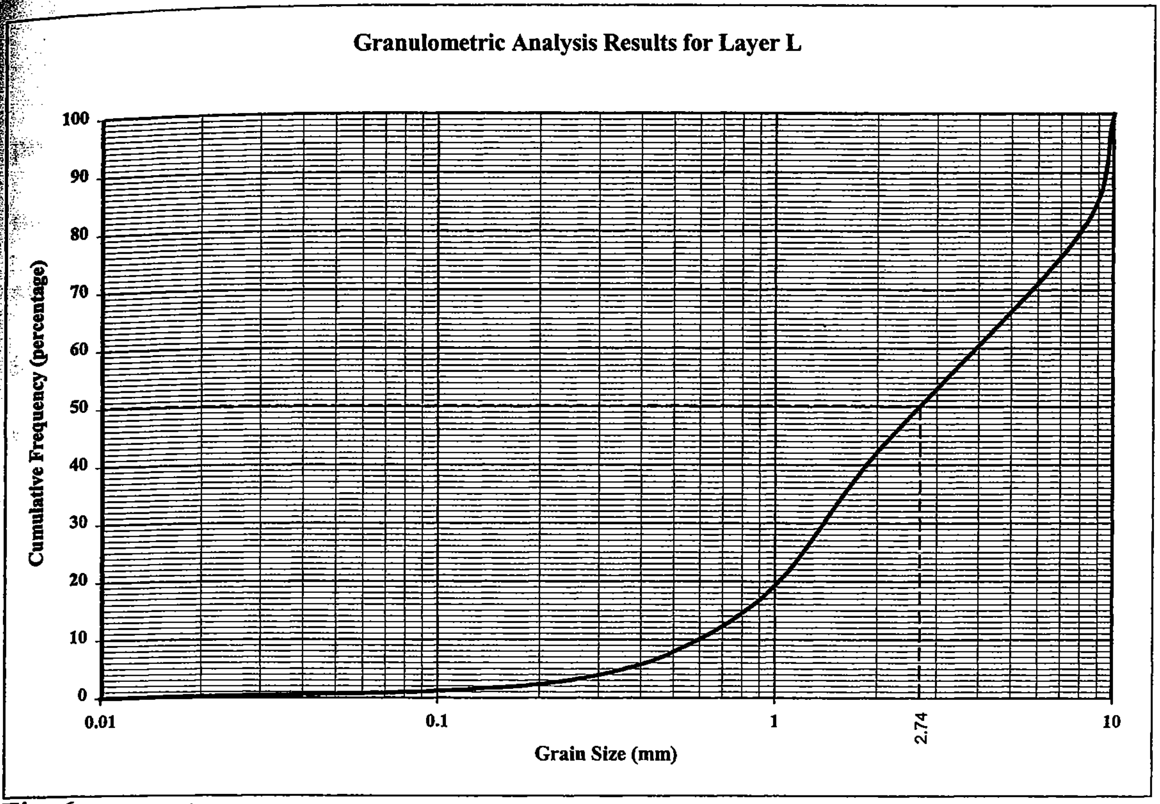

Fig. 6. Layer L demonstrates poor sorting as the curve is somewhat shallow, encompassing substantial grain size frequencies from 1 to ~10mm between the 20th and 80th percentiles.

The curve for layer K (Fig. 7) is somewhat speculative as the median grain size from the samples collected was 9.56 mm, while field observations of this layer at the two sites indicate a wider range of grain sizes, with some boulders measuring upwards of 80cm in diameter. The roundness of the cobbles and boulders signify the glacial forces that must have been necessary to remove them from their place of origin, carry them in the sub-glacial zone where they were weathered and eroded through physical scraping and scouring against the bedrock as the ice sheet advanced, and then deposited during ice-margin recession and ablation and the resulting dynamic meltwater discharge. This layer appears to be the lowest in a graded bed sequence that includes the layers covering it, layers J and I (Figure 7).

Meltwater flow has slowed considerably at layer J due to either less discharge or a blockage upstream allowing transportation of only the medium size grains and subsequent deposition on top of layer L. With a sorting coefficient of 1.92, this layer is well sorted and comprised predominantly of grains with a median grain size of 0.27mm, classified as medium sand. This layer measured 95 cm in thickness, so there was a constant current of meltwater in order to achieve such a substantial accretion.

As we reach layer I, with a median grain size of only 0.16mm and thickness of 20cm, we interpret the hydrologic process as being slowed down as the large amounts of sediment from layer J and K may have altered the grading of the bed. This allowed just the finer particles to accumulate into a well-sorted, fine sand layer with a sorting coefficient of 2.27. This may also be a sign of a colder climate as less water is available due to freezing and possible ice margin readvance.

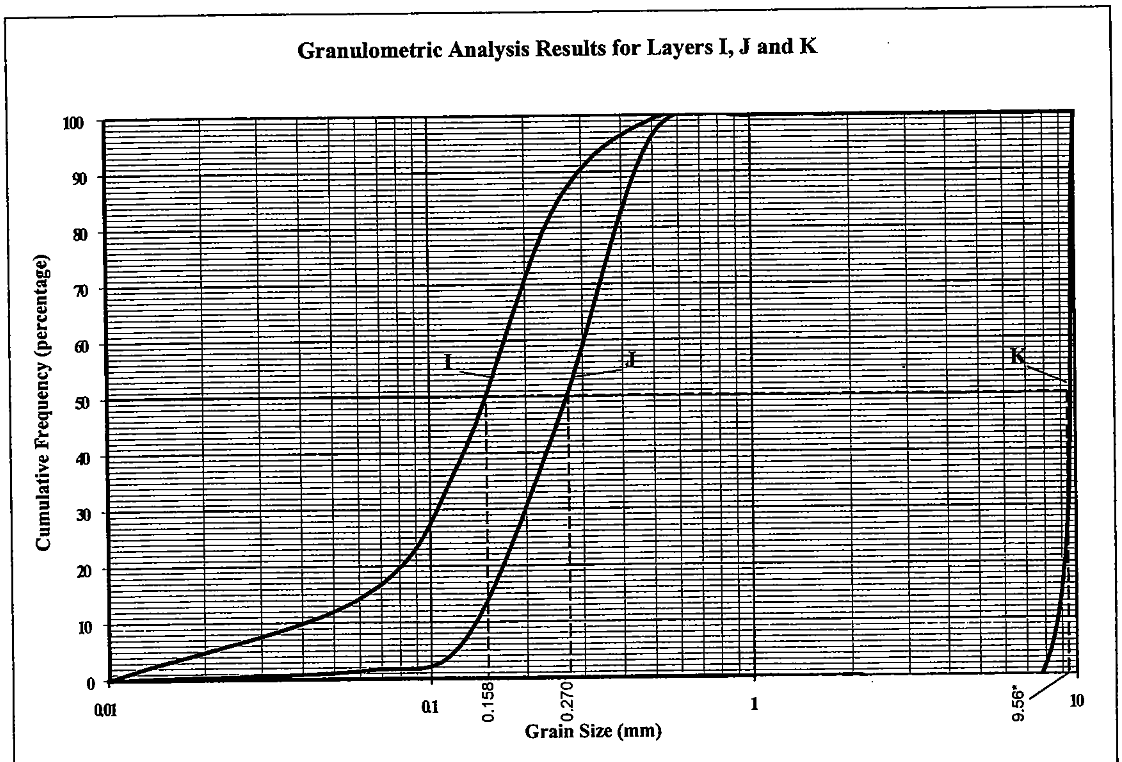

Fig. 7. Layers I, J and K characterizing a graded bed sequence. The cumulative curve and median grain size for layer K were determined from a few hand samples, as some of the cobbles and boulders measured upwards of 80cm making it difficult for sieve analysis.