A SURVEY OF ESKER MORPHOMETRIES, THE CONNECTION TO NEW YORK STATE GLACIATION AND CRITERIA FOR SUBGLACIAL MELT-WATER CHANNEL DEPOSITS ON THE PLANET MARS;
Stephen M. Metzger, SUNY Buffalo Geology Dept., Buffalo, N.Y. 14260.

The examination of eskers in New York State generally supports current concepts regarding their formation. This information may constrain the search for evidence of Martian glaciation and the conclusions that can be drawn.

Eskers are sinuous ridges of sand and gravel which accumulated in subglacial melt-water drainage tunnels. Such conduits must maintain a dynamic equilibrium between the flow of frictionally warmed meltwater and the overburden pressure of the confining ice (1,2). With only a modest time lag, the passage's ice walls will deform inward to balance ice that is melted out. Consequently large tubular tunnels will grow at the expense of small conduits or basal sheet flow, eventually developing branching networks. Drainage routes along the bed will also receive a continuous influx of sediments produced by the glacier's basal erosion processes and held in the deformable ice. These sediments may be derived from bedrock outcrops close to, but not necessarily directly beneath, the tunnels (3).

While the conduits themselves may be circular in section, the deposits usually form an pseudo-anticlinal ridge due to secondary currents within the pipe (2). Such a ridge may have steep sides, a single crest within a high arched passage and contain coarse sand and gravel if the flow were energetic enough to cause considerable ice melt. Low, broad ridges composed of finer sand result when the flow decreases or decelerates over subglacial topographic highs and water freezes onto the tunnel walls. Moderate, multi-crested ridges represent a transition regime (4). In accordance with hydrostatic equipotential lines, eskers follow the general direction of glacial ice flow (1).

More than 130 eskers have been identified and categorized in glaciated New York State. At least 100 of the known eskers lie within the Adirondack Mountains which cover one tenth of the state's area. Field examinations have validated the use of topographic maps to determine precise cross sections and explore the Shreve model of ridge form as an indicator of paleoflow regimes. In the mountainous regions, however, contour intervals of 20 feet or more may miss most of the low ridges produced by weak discharge and thereby bias results.

The typical Adirondack esker lies on crystalline bedrock, is 80 meters wide, 20 m tall and has side slopes of 26 degrees topped by a single, sharp crest. The lengths vary from a kilometer to an arborescent series of ridges described as "the Adirondack Esker System" that exceeds 136 km (5). The typical esker follows the symmetrical center line of topographic lows, occassionally crossing minor divides. They have an average sinuosity of 1.3. The few quarrying operations that expose undisturbed interiors show antiform bedding structures of interlayered sand and gravel consistent with the depositional process described above. Lateral slumping was minimal. Maximum grain sizes of in situ well rounded clasts reached 330 mm along the B axis. Silt-sized or smaller particles were rare.

Presumably subglacial melt-water drainage tunnels and their associated channel deposits would form in the termini of both active-retreat and stagnant-retreat zones. The continuous forward flow of the active zone would distort and destroy esker features while building end moraines which reflect the ablation rate. Eskers would have improved survival chances in a stagnating area along with other features such as kettles resulting from stranded ice blocks. The Saranac Lake vicinity has numerous small lakes amidst sand and gravel with an esker system that branches and winds through them. For the purposes of this model, the eskers are assumed to predate the ice block stranding.

Beyond the crystalline rocks of the Adirondack Highland, New York State is predominately covered by relatively horizonal sedimentary rocks. Eskers are rare in these "flatland" areas and, when found, are

typically isolated. Several similar eskers occur between Niagara Falls and Rochester. Their northern border is the Niagara escarpment, which contains sandstones, shale and dolostone, and their southern limit is just short of the Onondaga escarpment. The Niagara escarpment may have presented a barrier to waning ice flow from the NNE. A recessional moraine lies along it (6). The ice stranded above and beyond that divide would have stagnated thereby permitting a stable environment for the preservation of the eskers.

The Troy area has a complex kame and esker system, sits atop crystalline bedrock, and lies in the lee of rugged terrain blocking the northern ice source. Directly west, across the Hudson River and atop shale bedrock in an otherwise similar geographic location, there are no eskers. The only other large eskers on the lowlands are found north of Binghamton. They run down significant valleys which are nearly perpendicular to region ice flow. The southwestern portion of the state sports a few minor esker-like ridges generally underlain by shale.

Several speculative explanations are tentatively suggested for the dearth of eskers on the NYS lowlands. Active-retreat zone processes may have been dominant, building moraines at the expense of eskers. Basal sheet drainage may not have permitted focused tunnel formation. Sedimentary rocks, especially shales, may rapidly crumble during fluvial transport to the point that the resultant clasts are easily carried out of the glacier in suspension or wash load. The deforming bed concept of glacial movement states that a plastic basal debris layer will experience flow while the overriding ice remains essentially undisturbed. A deformable bed would inject itself into any developing drainage tunnel and immediately clog it. Thus the presence or absence of eskers may indicate the absence or presence, respectively, of a deforming bed (7).

Growing interest in Martian glaciation suggests that ridges in the Argyre and Isidis impact basins and the South polar region are best explained by esker processes (8,9,10). If valid, the implications are that ice accumulations of great depth, possibly deposited as a volatile veneer around dust grains, had sufficient dust mantling to prevent rapid sublimation. Subsequent pressure melting or geothermal heat flow liberated considerable quantities of liquid water. The ice bed itself and not the basal debris experienced flow deformation over regolith and bedrock materials capable of generating durable coarse sands and gravels. Given that the ridges identified as eskers are much larger than those in the terrestrial study area, the meltwater available must have been greater and/or active over a longer period than the late Wisconsinan deglaciation experienced in NYS. Stagnant-retreat zone mechanisms should also have left kettle depressions but no end moraines locally.

Alternatively, ice deformation may not have been necessary if the drainage occurred within the ice mass and above the bed, with eventual sublimation of the remaining ice. It might be necessary, however, for the clay-sized dust to aggregate into resilient coarse sediment clasts because fine dust would have been flushed from the glacier as wash load. Also some process such as local pyroclastic fallout may have intermittently loaded the developing ice deposits with the particle sizes responsible for clogged meltwater drainage tunnels.

Clearly results based on New York State must be cautiously compared to the processes operating under actual Martian conditions.

References 1) H. Rothlisberger, 1972, J. Glaciol., v11, #62. 2) R.L. Shreve, 1972, J. Glaciol., v11, #62. 3) J.M. and H.B. Trefethen, 1944, Am. J. Sci., v242, #10. 4) R.L. Shreve, 1985, GSA Bull., v96. 5) G.H. Chadwick, 1927, GSA Bull., v39. 6) D. Cadwell et al, 1985, NYGS Glacial Map Series. 7) P. Clark and Walder, 1991, GAC. 8) J.S. Kargel and R.G. Strom, 1990, LPSC XXI. 9) P. Grizzaffi and P.H. Schultz, 1989, ICARUS, 77. 10) P.H. Schultz and A.B. Lutz, 1988, ICARUS, 73.