1980

An Example of Eskers Formed in Stagnant Ice

David H. Coupland

Paul Andrew Mayewski
University of Maine, paul.mayewski@maine.edu

AN EXAMPLE OF ESKERS FORMED IN STAGNANT ICE [1]

David H. Coupland[2] and Paul A. Mayewski
Department of Earth Sciences, University of New Hampshire, Durham, N.H.

[2]current address: Geospectra Corporation, Ann Arbor, Michigan

ABSTRACT

Study of stratified glacial deposits near Farmington, New Hampshire reveals that the retreat of Late Wisconsin ice in this area proceeded by means of ice-marginal stagnation. Eskers in this area were formed within localized ice masses at or near the base of thin ice by streams which had dendritic patterns and were subaerially exposed.

INTRODUCTION

During the period of deglaciation of Late Wisconsin ice in northern New England the surface of the ice sheet lowered and in so doing became dissected in the mountainous areas. Northwest-southeast trending valleys that parallelled regional ice flow became the main conduit for remaining ice masses. Theories concerning the mode of recession of these ice masses have been actively disputed in the literature. Models suggested range from ice marginal stagnation retreat (Woodworth, 1898; Flint, 1930; Goldthwait, 1938; Currier, 1941; White, 1947; Jahns, 1953) to active marginal retreat (Lougee, 1940; Lougee and Vanderpil, 1951). In order to help resolve this issue we present an example of glacio-environmental conditions during the latter stages of ice occupation in one of the northwest-southeast trending valleys of southeastern New Hampshire. To characterize this period of deglaciation we examined the distribution of ice-contact deposits along a portion of a former ice flow-line in this valley.

SURFICIAL DEPOSITS IN THE STUDY AREA

The study area (fig. 1) includes a portion of the Cocheco River valley near Farmington, New Hampshire, extending from this town 4.0 mi. southward to a point at which the valley narrows abruptly. It contains several types of glacial deposits (fig. 1) including in stratigraphic order, oldest to youngest: drumlins, kame terraces and eskers, collapsed outwash, outwash, and dune sands. Special emphasis was placed on examination of the eskers because these deposits are the best displayed ice-contact deposits in the area and Goldthwait (1968), working in the next valley to the east, was able to extract considerable detail concerning the mode of deglaciation in that valley by study of the massive Pine River valley esker complex.

All Deposits Exclusive of Eskers

The oldest glacial deposits in the area include elongate, north-northwest to south-southest trending drumlins. Kame terraces flank both walls of the Cocheco River valley. The larger of the two exposed kame terraces, on the southwest wall, has a top surface elevation of 300-305' asl and appears conformable with the tops of several rounded hillocks to the northeast and toward the valley center. The kame terrace on the northeast wall has a top surface elevation of 291' asl and is overlapped in part by mixed outwash and collapsed outwash that has a surface elevation of 317' asl. Outwash is common throughout the study area in the form of broad, steep-sided, flat-topped erosion remnants which rise up to 65' above the surrounding lowlands. The surface of the outwash is conformable over an area 3.0 mi. by 0.5 mi., its larger dimension parallels the valley axis. The outwash surface ranges in elevation from 305' asl in the northwest to 270' asl in the center of the study area to 270' asl in the southeast. North of the outwash surface are areas of collapsed outwash characterized by irregular topography with up to 12' of relief and deformed internal structures. The most recent deposits in the field area are cross-bedded, fine dune sands, at least 20' thick, found in a low spot between two drumlins.

Eskers

Two esker complexes ~~are~~ present in the study area (fig. 1). At esker complex 1 a bifurcated esker ridge (fig. 2) was found adjacent to, but not covered by, collapsed outwash. This ridge continues southeast along the Cocheco River valley, punctuated by several erosional gaps, until it terminates in outwash. From north to south the ridge ranges in elevation from 293' asl to 267' asl. Esker complex 2 consists of short, roughly parallel ridge segments that are as high as 45' and as long as 300' with an elevation range of 290' asl to 300' asl. The top surface of esker F at esker complex 2 is concordant with the top surface of the kame terrace which is held against the southwestern valley wall. Other esker ridge segments are exposed throughout the area; some are partially buried by outwash and/or kame terrace deposits.

ESKER STRATIGRAPHY

A depositional history was developed for the deposits comprising esker complex 1 because this site contained the best esker exposures in the study area. To facilitate correlation of depositional units between the three cuts (fig. 3), particle size distributions were measured for each labelled unit, and for pebbly units, 100 pebbles were measured for size, shape, roundness, and lithology. Based principally on stratigraphic position, mode of the sand sized fraction, and lithologic frequencies, four depositional stages were identified that correlate between the three cuts. The stage numbers may be identified with the unit numbers in figure 3. Depositional stages are illustrated in figure 4 and described in table 1.

Lithologic frequencies in pebbly units may be used to test the hypothesis that these depositional stages are indeed correlative, via the chi-squared test for homogeneity of a collection of samples. Pebble samples from Stage I units of all three cuts are found to form a homogeneous group, suggesting that they were drawn from the same population. Lithologic frequencies from Stage III bouldery gravels are not homogeneous and form three distinct groups, not all of which are present at each cut, perhaps due to nonuniform deposition or post-depositional erosion. Particle size distributions and stratigraphic positions support this division of Stage III units, implying three different depositional events with somewhat different sources of sediment. The greatest total thickness and number of bouldery gravel units was found at cut C, downstream from the confluence of two

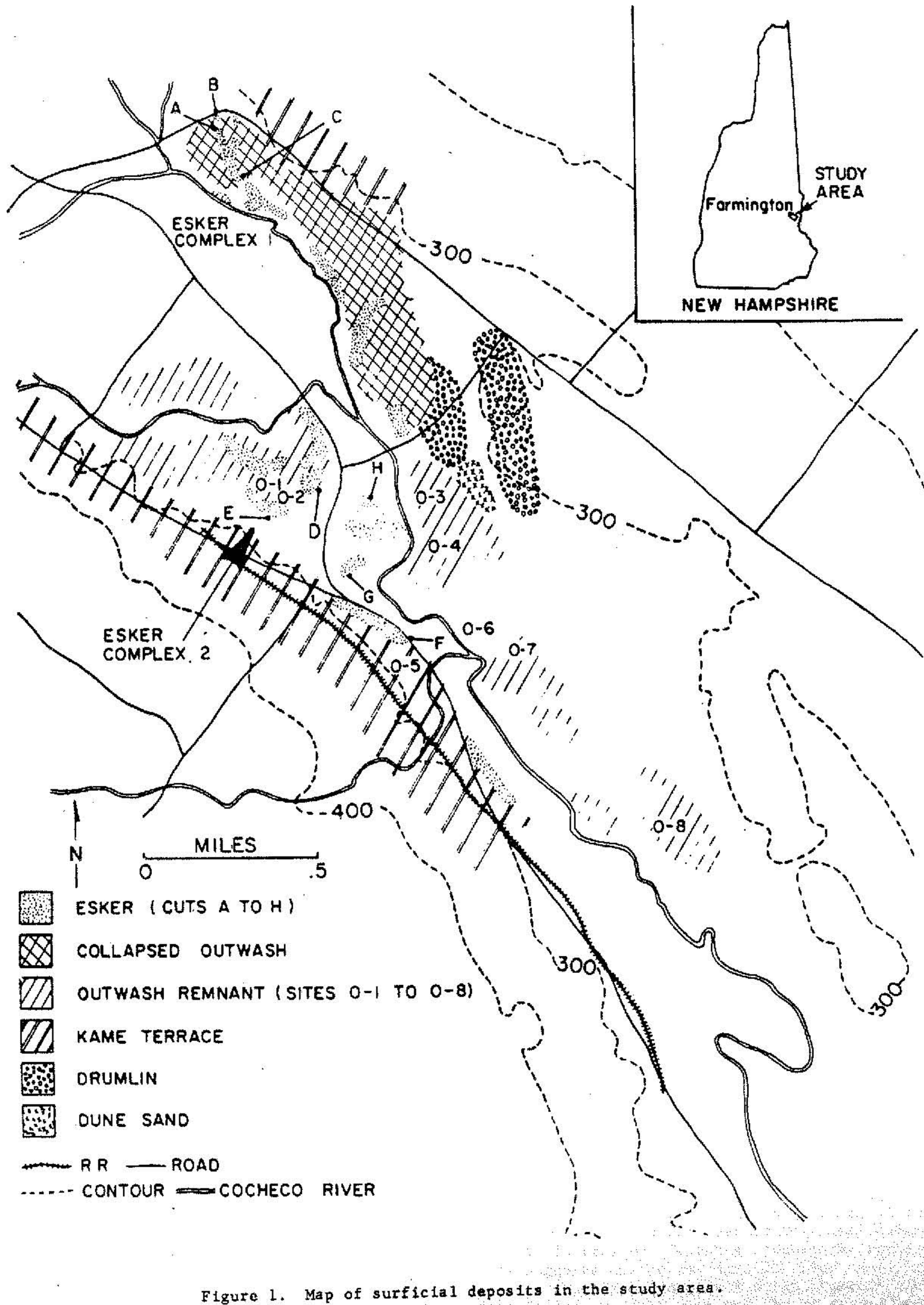

Figure 1. Map of surficial deposits in the study area.

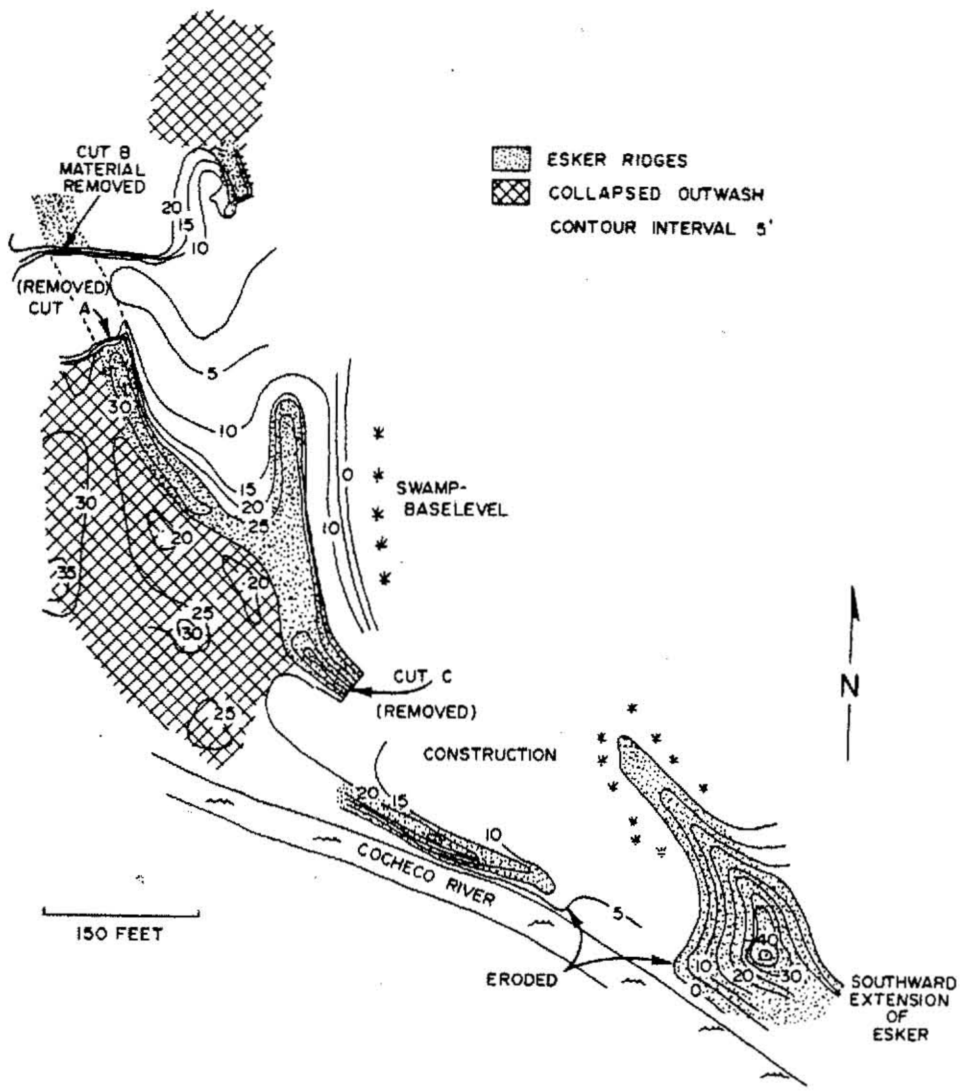

Figure 2. Enlargement of surficial deposits in the vicinity of esker complex 1. Contours are in feet above swamp baselevel.

esker ridges. Stages II and IV are believed correlative between the cuts based on stratigraphic position and particle size distribution.

The existence of units several feet thick which are continuous over a distance of 500' with no change in stratigraphic position indicates that the mode of deposition was fluvial rather than deltaic. All cuts have pseudo-anticlinal bedding, probably due to slumping after the enclosing ice walls had melted. All cuts also exhibit a trench-like feature that lies stratigraphically below the Stage II silt layer and above the Stage I pebbly sands (figs. 4 and 5). This feature is probably erosional in origin. Younger units fill the trench, while older units appear to have slumped into it, partially via faulting. The general lack of deformation and maintanance of fine structures in these eskers suggests that they were deposited at or close to the base of the ice mass.

GENERAL STRATIGRAPHY

Examination of the relation between the esker complexes and other stratified glacial sediments in the study area provides additional details concerning the mode of formation of the eskers.

Outwash in the study area is in most cases flat lying, hence these large outwash remnants were not deposited on ice. Several esker ridges in esker complex 2 lie between two of these large outwash remnants, but are not covered by them. This situation can be explained by postulating a small ice block surrounding esker complex 2 at the time of outwash deposition which was at least as high as the outwash surface. Relative relief of eskers and outwash implies a minimum ice thickness of 50' during outwash deposition. The ridge at cut F, esker complex 2, is flanked on one side by outwash, indicating that this ridge formed before outwash deposition had begun and that by the time outwash deposition was in progress part of the ice mass within which the esker formed had melted.

Similar conditions can be ascribed to the area around esker complex 1, except that in this area collapsed outwash instead of outwash surrounds the esker complex. This suggests that a residual ice block was also in place around esker complex 1 at the time of outwash deposition, but that this ice block was partially covered by the outwash. Perhaps outwash deposition and esker formation were simultaneous.

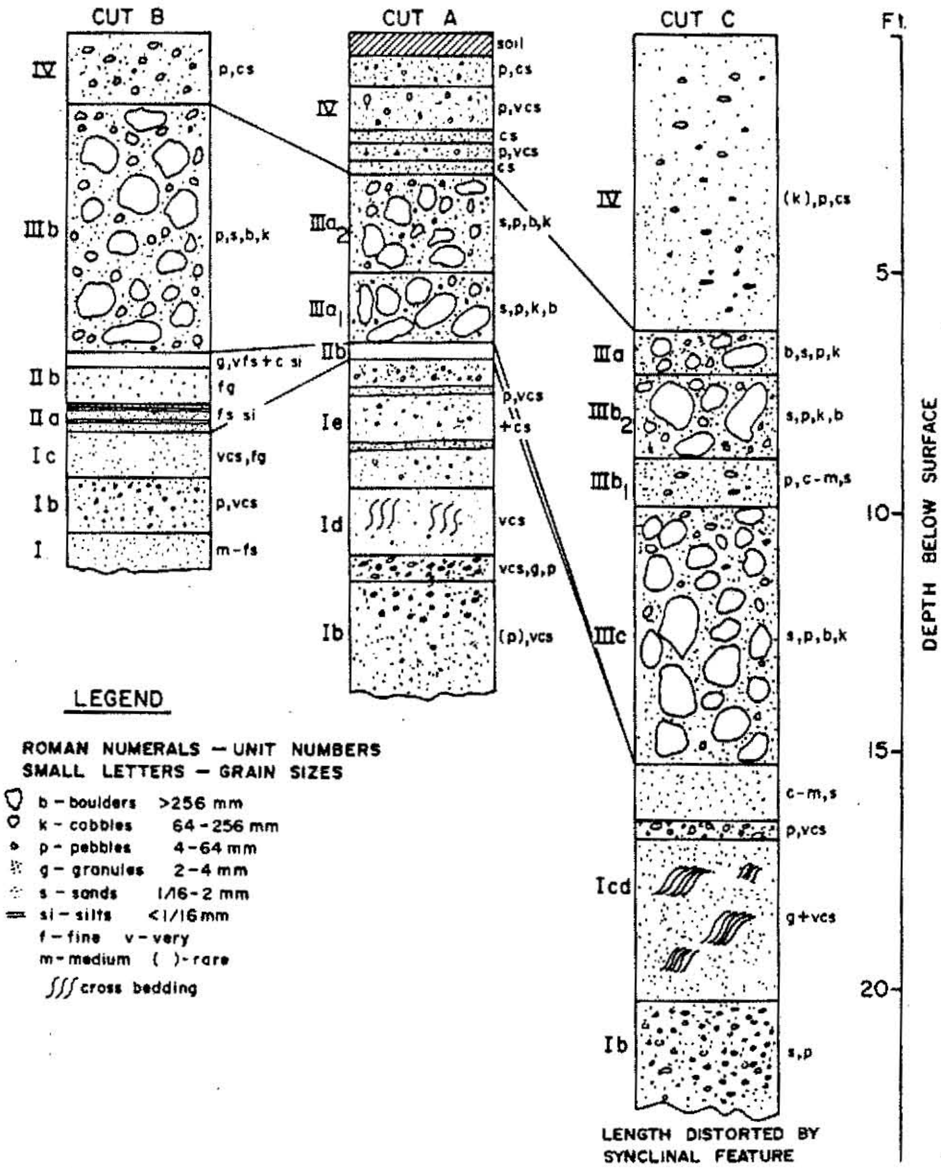

Figure 3. Stratigraphic sections for the three exposed cuts at esker complex 1.

South of esker complexes 1 and 2 all outwash is flat-lying except for a few isolated kettles and one site, near outwash cut O-7, with deformed structure. Gaps between these outwash remnants are due to post-depositional erosion by the Cocheco River and perhaps also to the presence of ice masses during outwash deposition.

Ice contact deposits and some proglacial deposits in the study area can be shown to have been controlled by a common base level. Ridges at esker complexes 1 and 2, kame terraces and the three northernmost outwash remnants all have mean surface elevations of 295' ± 8' based on 25 altimeter measurements. Local relief in the area is commonly 50', so the surface elevations of these deposits form almost a plain. The Cocheco River valley is partially constricted in the vicinity of outwash sample O-8 and ice blocking the valley at this point may have determined base level for these deposits.

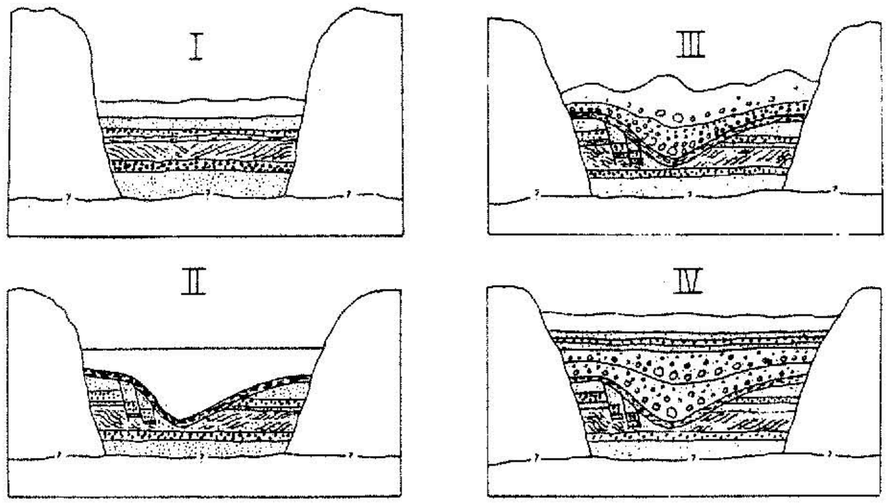

Figure 4. Depositional stages in the formation of the eskers at esker complex 1. See table 1 for details.

Table 1. Depositional stages at esker complex 1.

Stage I:	Deposition of interbedded sandy pebble units and coarse sands; moderate, but variable stream velocity relative to other units in complex; interpreted as outwash perhaps deposited from braided streams. Deposition followed by a high velocity erosional event, which dug a trench-like feature into which existing sediments slumped and faulted.
Stage II:	Relatively low stream velocity event, deposition of fine sands and silts.
Stage III:	At least three high velocity, short term flood events with rapid deposition of bouldery-gravels showing graded bedding.
Stage IV:	Deposition of pebbly sands similar to Stage I units.

CONCLUSIONS

The mass of ice from which the ice contact deposits in the study area formed was comprised of several stagnant, discontinuous ice bodies each approximately 1 mi. across and 50' thick. The margin of the ice mass from which these sediments were deposited extended at a maximum to the point of valley constriction, near outwash cut 0-8 (fig. 1), or perhaps only to the contact between collapsed outwash and outwash, 1.3 mi. north of the valley constriction. This constriction, in conjunction with stagnant ice masses in the area helped to dam some of the water issuing through the melting ice, producing a local base level for this drainage. The ice mass description and state of activity we suggest suits most closely an ice-marginal stagnation retreat model.

Eskers in the study area appear to have formed at or very close to the base of wasting ice in fairly continuous dendritic stream paths similar to those in the Pine River valley (Goldthwait, 1968). The ice confines of the esker streams were either open ceilinged or nearly open ceilinged. At least four depositional stages characterized by different stream velocities and sediment loads were involved in the formation of these eskers.

ACKNOWLEDGMENTS

We wish to thank F.S. Birch (Department of Earth Sciences) and S.L. Dingman (Institute of Natural and Environmental Resources) for reviewing this paper and making helpful criticisms. Mr. W. Celli (College of Engineering and Physical Sciences) kindly drafted most of the figures. University of New Hampshire Central University Fund (CURF 614) supplied the funds necessary to undertake this project.

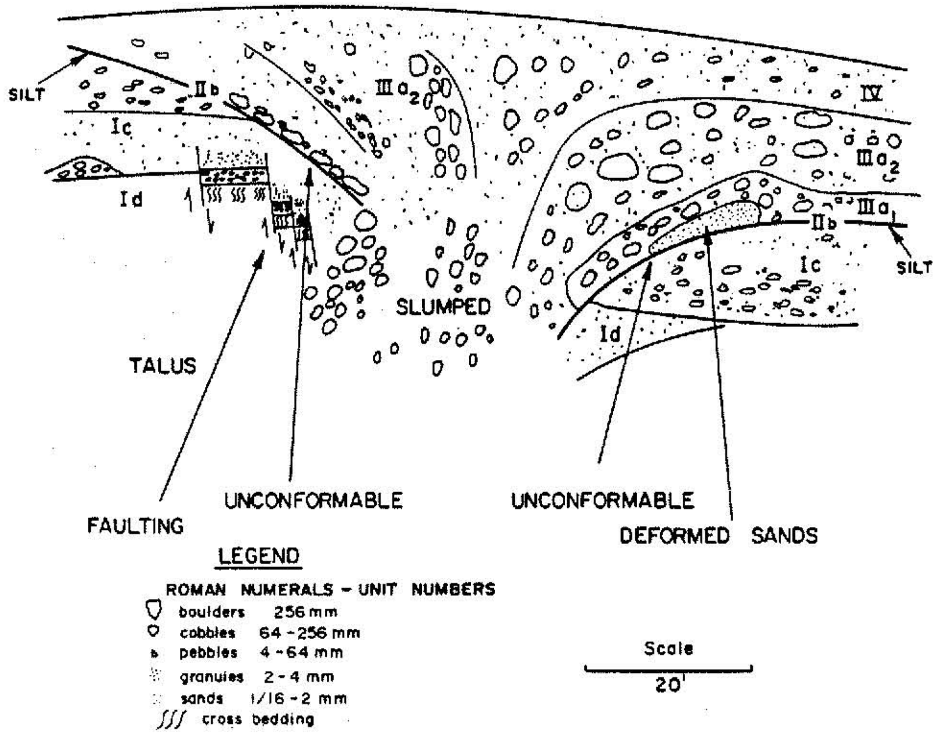

Figure 5. Sketch of esker cross section at cut A, esker complex 1. The attitude of the bedding near the center of the cut is uncertain due to slumping.

REFERENCES

CURRIER, L.W., 1941, Disappearance of the last ice in Massachusetts by stagnation retreat (abst.): Geol. Soc. Amer. Bull., v. 52, p. 1895.

FLINT, R.F., 1930, The glacial geology of Connecticut. Conn. Geol. and Nat. Hist. Surv. Bull., v. 47, 294 pp.

GOLDTHWAIT, J.W., 1938, The uncovering of New Hampshire by the last ice sheet: Amer. Jour. Sci., v. 36, p. 345-372.

GOLDTHWAIT, R.P., 1968, Surficial geology of the Wolfeboro-Winnipesaukee Quadrangles and New Hampshire. New Hampshire Dept. Res. Econ. Develop., Concord, New Hampshire, 60 pp.

JAHNS, R.H., 1953, Surficial geology of the Ayer Quadrangle, Massachusetts. U.S. Geol. Surv. Quad. Map GQ-21.

LOUGEE, R.F., 1940, Deglaciation of New England: Jour. Geomorph., v. 3, p. 189-217.

LOUGEE, R.F., and A. W. VAN DER PYL, 1951, Glacial water levels in the Thames-Willimatic River valley: Sci. Month., v. 73, p. 275-283.

WHITE, S.B., 1947, Two tills and the development of glacial drainage in the vicinity of Strafford Springs, Connecticut: Amer. Jour. Sci., v. 245, p. 754-778.

WOODWORTH, J.B., 1898, Some glacial wash plains of southern New England: Essex Instit. Bull., v. 29, p. 71-119.

[1]Manuscript received August 16,1979; accepted February 28, 1980.