SYSTEMS APPROACH TO HOLOCENE SEDIMENT AND NUTRIENT CYCLING IN CHESAPEAKE ESTUARIES

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Surficial geologic maps of small, meso-tidal estuaries and their watersheds can be interpreted as scale independent analogs to understand the function of larger estuarine systems. Popes Creek, a minor tributary to the Virginia side of the Potomac River estuary, is an effective trap for sediment and nutrients derived from a variety of forested and farmed watersheds that drain broad, low relief terraces and dissected upland slopes. Situated in Westmoreland County, the watershed of the Popes Creek estuary includes drainage from the George Washington Birthplace National Monument; continuous records of land use document events that have entrained, transported, and moved sediment from the inception of colonial agriculture to present times. This estuary is a particularly effective trap for terrestrially derived sediment because its mouth is plugged by a flood-tide delta resulting from rising sea level and long-shore movement of Potomac River sediment stripped from nearby eroding bluffs and beaches.

The surficial geologic map of the Popes Creek watershed documents a system of weathering, erosion, slope deposition, and fluvial to estuarine terrace deposition that has been moving, storing, weathering, and reworking sediments since the end of the Pliocene. Geomorphic processes, at present, are generating most new sediment from sheet wash on cultivated fields, spring sapping and headward erosion of gullies, and sheet wash on forested, steep slopes. Much of the sediment is stored in ravines and on flood plains of the larger tributaries; we have observed as much as 2 meters of agriculturally derived ravine fill covering logs and stumps that date from the middle of the 17th century. On broad, low gradient flood plains, modern sediment is being transported in a random but peristaltic cadence of storage and erosion; braided channel, alluviated surfaces alternate with deeply gullied reaches. Aliquots of sediment are added from slope deposits and alluvial fans along the valley margins. Entire flood plains are marked by a series of breached and current beaver dams and ponds. Several old millponds also interrupt the flow of modern sediment. Minimal sediment is presently reaching the distal ends of tributary deltas, which are now accumulating freshwater peat. Much of the modern terrestrially derived sediment appears to be stored in the fluvial part of the system.

Anecdotal lore suggests that Popes Creek estuary was navigable by deep draft vessels a century ago; today the estuary is, for the most part, 1 meter or less deep and has a tide range of 0.3 to 0.4 meter. Initial coring in the flood-tide delta has penetrated almost 15 meters of *Crassostrea-* and *Rangia-* bearing sediments overlying fresh water peat and fluvial sand. These deposits are thought to be less than 5,000 years old. The Popes Creek estuary is shoaling as rising sea level drives the products of coastal erosion a kilometer or more inland. As additional data are gathered, the Popes Creek estuary will provide a baseline for comparing other more intensively used Coastal Plain watersheds.

A REGIONAL RECORD OF HOLOCENE HILLSLOPE EROSION FROM LAKE AND ALLUVIAL FAN SEDIMENT, VERMONT

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Little is known about spatial and temporal patterns of Holocene hillslope erosion in New England. However, lakes and postglacial alluvial fans in this hilly terrain preserve sedimentary archives that may reveal such patterns. We have created detailed visual logs of the stratigraphy in deep (1 to 2 m), long (10 to 15 m) trenches in four small (~500 m2), postglacial alluvial fans. We have also retrieved thirteen 6-meter sediment cores from seven small (0.03 to 2 km2), deep (13 to 30 m) Vermont lakes with steep drainage basins. Analyses including visual logging, magnetic susceptibility, X-radiography, and loss-on-ignition document stratigraphic variability in core sediment character.

Alluvial fan interiors reveal a distinct horizontal stratification, often alternating between coarser and finer grain sizes. Thin, organic-rich soil horizons in the fan stratigraphy represent former fan surfaces where paleosol A-horizons were buried rapidly by further fan deposition. These buried paleosols indicate that fan surfaces were stable for long periods of time, allowing an organic-rich forest soil to develop. Soil development was halted when erosion of the adjacent hillslopes caused additional deposition. In each alluvial fan, over 0.5 meter of historic (<250 years BP) sediment buries the most recent paleosol. Three of the four fans overlie river terrace sediments, while the fourth overlies glacial, ice-contact gravels.

In each lake core, several layers of coarse-grained, mineral-rich sediment with abundant macrofossils of terrestrial plants punctuate the otherwise fine-grained, organic-rich gyttja matrix. The character of these coarse layers leads us to believe that they originated as terrestrial sediment eroded from the uplands during severe storm events. If this hypothesis is valid, the ages of these terrigenous layers correspond to the timing of large storms that passed over the lakes' drainage basins.

Numerous radiocarbon dates provide age control for deposition of upland sediment on the fans and in the lakes. Whereas the most recent sedimentation events (<250 years BP) recorded by both the lakes and alluvial fans probably represents deposition due to deforestation and other land-use changes since European settlement began in the area, the earlier depositional episodes were probably caused by periods of increased storminess. The dates of terrigenous layer deposition in cores from different lakes and periods of increased alluvial fan sedimentation will reveal spatial and temporal patterns of hillslope erosion in this region during the Holocene.

DEPOSITIONAL AND EROSIONAL STRATIGRAPHY IN THE APPALACHIANS OF QUÉBEC AND NEW ENGLAND — 50 YEARS OF EVOLUTION

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The foundations for modern understanding of the glacial stratigraphy of the Appalachian Mountains of Québec and New England were laid in areas peripheral to them in the 1950's by N. R. Gadd and P. F. Karrow in Québec and by Paul MacClintock and D. P. Stewart in the St. Lawrence Seaway region of New York and Canada. Gadd and Karrow identified tills of two glacial events separated by nonglacial organic beds which they named the St. Pierre Beds. In numerous Seaway excavations, MacClintock and Stewart identified two glacial events that now appear to be members of the uppermost till described by Gadd and Karrow in the Montréal-Trois Rivières sector of the St. Lawrence Valley. In the 1960's Stewart and MacClintock, building on their "Seaway" model, described a three-till stratigraphy in Vermont in which tills were correlated from section to section on the basis of their fabrics. The model of the three- till stratigraphy of northern Vermont was imported into Southern Québec by B. C. McDonald in 1964. It has stood until present, more or less as it was described in a 1971 paper by McDonald and the present author. Essentially, the depositional stratigraphy of southern Québec and northern New England comprises a lower, pre-Wisconsinan till (Johnville Till), deposited by an ancestral Laurentide Ice Sheet over a preglacial regolith , separated from two Wisconsinan tills by nonglacial sediments with organic remains older than 54,000 years B.P. (Massawippi Formation). The lowermost upper till (Chaudiere Till) was deposited by ice flowing from an Appalachian ice cap centered in Maine and/or New Brunswick; the uppermost till (Lennoxville Till) was deposited by the Laurentide Ice Sheet that traversed all of New England during the latter part of the Wisconsinan. Thirty-five years of testing the validity of the three-till model of MacClintock and Stewart has not altered the concept, though it is doubtful that it applies in southern Vermont and southern New England as they originally suggested. The model is supported by extensive till fabric and striation data, by depositional models for associated waterlain sediment, by till mineralogy, and, above all, by drift geochemistry. Systematic mapping of the region has led to the discovery of many natural and man-made stratigraphic exposures which have been supplemented with more than 50 deep, continuously cored bore holes to bedrock.

In 1971, Robert Lamarche rediscovered a prominent set of northward striations that clearly postdate the widespread, southeastward-trending striations related to the glacial event during which the Lennoxville Till was deposited. The northward flow phenomenon had first been described by Chalmers in the 1890's, but had been largely overlooked until McDonald's research in the mid-60's. Work subsequent to that of Lamarche and McDonald revealed an intricate series of striations reflecting regional flow events related to a relict Appalachian ice mass that was created by the formation of a late-glacial marine calving bay in the lower St. Lawrence estuary. The final ice flow event along the Appalachian Front was a readvance of Laurentide ice up major valleys to the so-called Highland Front moraine position. Although as many as seven distinct ice flow events have been inferred from the erosional stratigraphy, they are represented depositionally by only one or two recognizable till units.

As mapping proceeds in northern New England and Québec, it is important to keep the strengths and weaknesses of this prior work in perspective so that our further development of the regional glacial history is built on the substantial existing foundation.