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GEOLOGIC AND HYDROLOGIC EFFECTS OF A CATASTROPHIC FLOOD IN THE COLD RIVER, SOUTHWESTERN NEW HAMPSHIRE

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INTRODUCTION

The southwestern portion of New Hampshire is characterized by small, steep-gradient watersheds which drain into the Connecticut River. The valley sides in these watersheds are exceptionaly steep, are often composed of fine-grained impermeable till, and are subject to frequent slumps and slides. Although there are terraces of sand and gravel locally, they have little moderating effect on the flashy characteristics of the watersheds. Intense summer rainstorms have produced the record runoffs in this area. One such event occurred in August, 1986, and the effects of this storm are the subject of this field trip.

On August 7, 1986, about 6 inches (15 cm) of rain fell within a 2-hour period in a portion of the Cold River watershed in the towns of Acworth, Alstead, and Langdon, New Hampshire (Fig. 1). This intense rainfall was concentrated in roughly circular area of about 30 mi^2 (78 km^2) located in the middle third of the 100 mi^2 (260 km^2) watershed of the Cold River.

GEOLOGIC EFFECTS OF THE 1986 FLOOD

Surface runoff from the steep hillsides of this watershed formed new gullies, widened and deepened existing streams. Numerous road were washed out (Stops 1 and 3) and at least one home was severely damaged.

In one such gully, erosion exposed a complex section of saprolite overlain by till (Stop 5). The saprolite is developed on sufide-bearing andesite (Ammonoosuc volcanics) and is overlain by a deeply weathered diamicton, probably colluvium, although it does somewhat resemble till. Exposures of saprolite do exist in other parts of New England and Quebec, but are rare enough to be noteworthy (LaSalle et al., 1985). The concensus of opinion about these saprolite exposures, especially those such as that at Stop 5 that underlie till, is that they were formed during the Tertiary Period. The clay mineralogy of the sub-till saprolites described by LaSalle et al. (1985) suggested to these authors that they were formed under a warmer and wetter climate than either interglacial or Holocene conditions. These same authors presume that saprolite was widespread in New England and Quebec prior to glaciation and that the known exposures are remnants of this extensive soil cover.

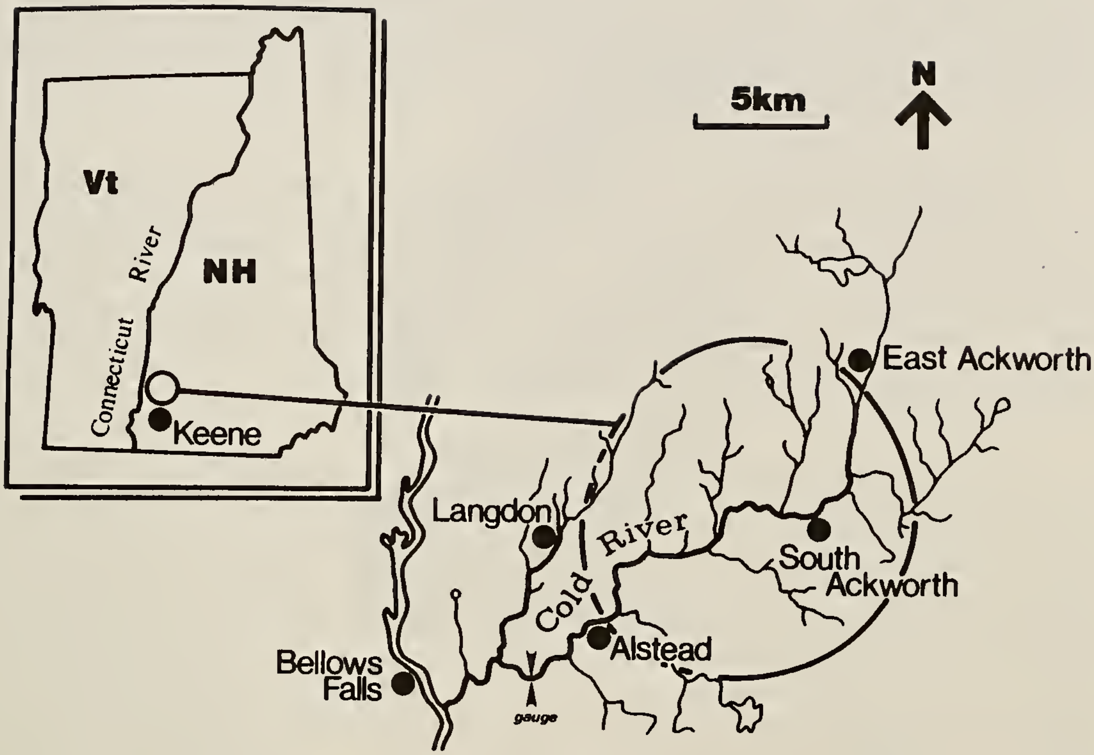

Figure 1. Location of the Cold River watershed. Area of intense rainfall during August, 1986 flood is roughly outlined by circle.

Deposits of the 1986 flood

At the base of many hillside gullies, coarse gravel was deposited on alluvial fans on the edges of flood plains (Stop 4). The fans existed prior to the 1986 flood and appear to consist largely of material similar to that deposited in that flood. It may thus be possible that events similar to the 1986 flood were responsible for the formation of these fans.

Coarse gravel nearly fills the channel of at least one tributary stream near its juncture with the Cold River (Stop 6). This gravel was graded to the flood level of the Cold River, and forms a kind of delta within the channel of the tributary and is one of a number of records of the stage of this flood. The gravel in this delta was eroded from within the watershed of the tributary and thus represents a deposit that is different from the slack-water deposits described by Kochel and Baker (1982) in which sediment is carried into a tributary from the trunk stream.

The flood waters generated within the central portion of the Cold River had major effects far downstream. At the mouth of the Cold River, flood waters estimated to be about least 10-feet (3 m) deep, with a velocity 5 feet (150 cm) per second, moved into the Connecticut River. Gravel clasts up to 15 inches (400 mm) in intermediate diameter was deposited as a delta which prograded nearly three-fourths of the way across the Connecticut (Stop 8). When the flood waters lowered and the delta was exposed, the Connecticut was confined in a channel about 100 feet (30 m) wide. The very high flow and associated turbulence of this flow caused extensive bank erosion on the Vermont side of the river.

On the delta surface, a number of features indicated that the flow durng this flood was in a direction that combined the flow from the Cold River and the Connecticut (Fig. 2). These flow indicators include shingled gravel, oriented trees and scour pits around the base of the trees, and gravel bedforms with crests spaced about 8 feet (2.4 m) apart (Fig. 2). Subsequent floods in January and April, 1987 have moved the trees, wiped out the bedforms, and reoriented the clasts of the delta surface. The delta has not moved measurably downsteam, but the distal end of the delta has been eroded, widening the channel. At this writing (July 6) the delta has reappeared, as spring and early summer high water has receeded. There is a small channel between the delta and the river bank (Fig. 2), and the delta can be reached only by a knee-deep wade.

HYDROLOGICAL EFFECTS OF THE 1986 FLOOD

About 2 weeks prior to the intense rainfall, an observation well had been placed near the bottom of a kettle in a small delta. A steep bedrock hill rises above the delta surface. Figure 3 is the hydrograph of this well that covers the period of the August, 1986 flood. As may be seen in the summary of rainfall in Figure 3, abundant rain had fallen prior to the major storm. This figure also shows that the the water table when the well was installed was over 40 feet (12 m) below the ground surface. Within a few weeks of the August storm, recharge had found its way from the surface to the water table and eventually added about 9 feet (2.7 m) to the saturated thickness of the aquifer and as quickly the water was dissipated. The aquifer is abruptly terminated to the

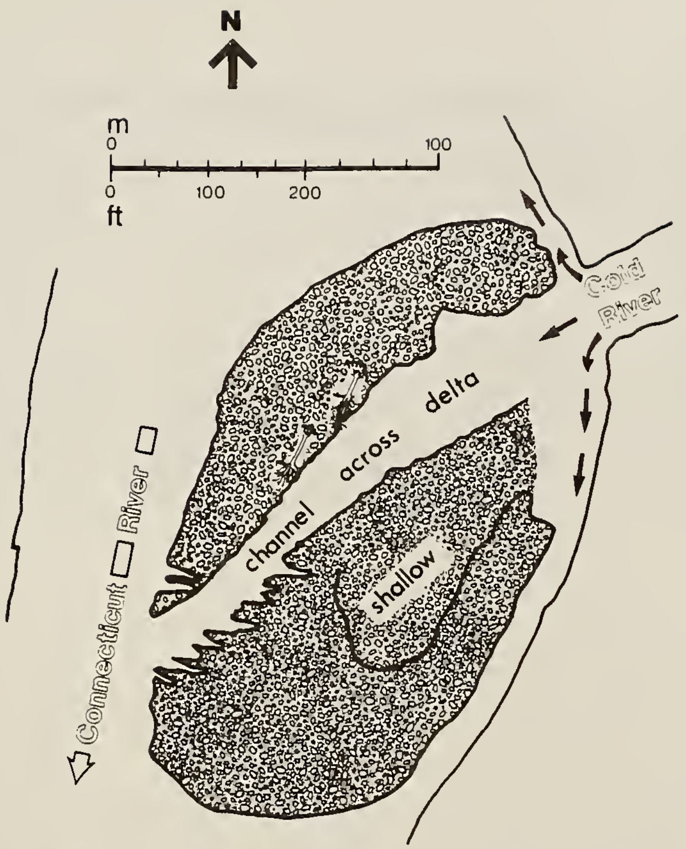

Figure 2. Map of the delta deposited at mouth of Cold River during August, 1986 flood (See Figure 1). Trees on delta surface and gravel bedforms (jagged edges of distal end of delta) indicate flow direction during flood. Plane table and alidade map by D.W. Caldwell and Ed Kelly, September 20, 1986.

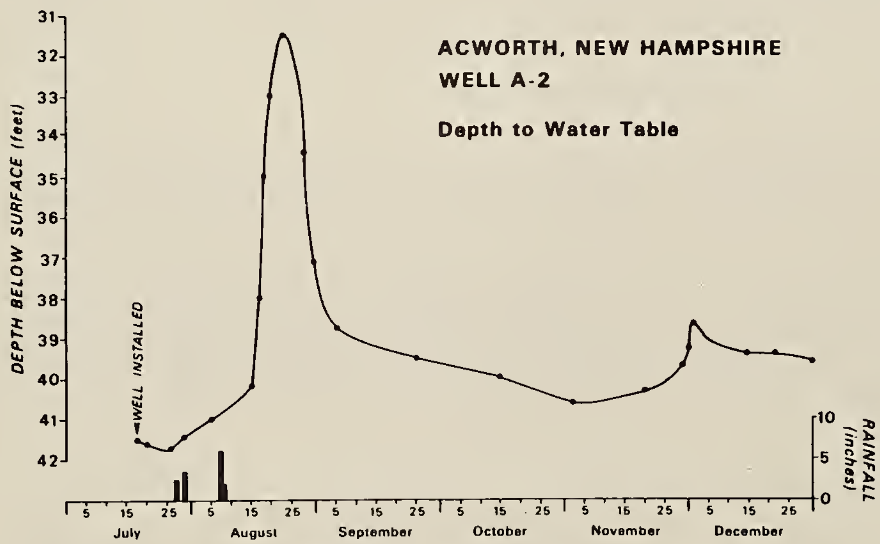

Figure 3. Hydrograph of observation well showing recharge during flood of August, 1986. Bar graph at bottom of figure indicates rainfall during period July 26 - August 8, 1986. Note the very rapid rise and recession of water table. The recharge of the aquifer was a result of direct rainfall combined with runoff from steep hillside that was concentrated into a kettle in a glacial lake delta.

north, and groundwater is discharged in a series of contact springs along the base of the valley wall, more than 100 feet (30 m) below the delta surface. Using the concept of Specific Yield (Sy), we may estimate the amount of water recharged during the event:

$$Sy = \frac{Vwa}{Va} \quad (1)$$

where Sy is Specific Yield (or effective porosity), Vwa is the volume of water added (or released) to storage, and Va is the volume of aquifer into which the water is added or released. This analysis conceives of a unit prism of the aquifer 1 foot (or other unit) square in cross section and with a length equal to the change in water table elevation. Because this analysis uses a unit prism, volume and length are equal. Rearranging equation 1 to solve for Vwa, and assuming a reasonable Specific Yield of 0.20,

$$Vwa = Sy \times Va \quad (2)$$

and $Vwa = 0.2 \times 9 \text{ feet} = 0.2 \times 2.7 \text{ m}$

and $Vwa = 1.8 \text{ feet or } 21.6 \text{ inches} = 548 \text{ mm}$

This analysis indicates that the aquifer in the vicinity of the kettle recieved about 21 inches (548 mm) of recharge while about 6 inches (150 mm) of rain were falling. It should be remembered that other rain preceeded and floowed the principal storm on August 7 (Fig. 3). The total of all the rainfall in late July and early August was about 12 inches (305 mm). We believe the excess recharge occurred when runoff from the steep hillside above the aquifer was concentrated into the kettle. This secondary recharge was not observed in other parts of the watershed. We believe that in situations like this one, unless secondary recharge from steep hillsides is considered total aquifer recharge may be underestimated.

REFERENCES

Kochel R.C. and Baker, V.R., 1982, Paleoflood hydrology: Science, vol. 215, p. 535-561.

LaSalle, Pierre, DeKimpe, C.R., and Laverdiere, M.R., 1985, Sub-till saprolites in southeastern Quebec and adjacent New England, in Borns, H.A., LaSalle, P., and Thompson, W.B., eds., Late Pleistocene history of northeastern New England and adjacent Quebec: Geological Society of America Special Paper 197, p. 13-20.

ROAD LOG, COLD RIVER FIELD TRIP

Field trip meeting place is on Route 12 in North Walpole, New Hampshire, about 1 mile south of Bellows Falls, Vermont. From the north or south, take exit 6 from Interstate 91, go south on Route 5 to Bellows Falls and follow signs for Route 12. Meeting place is 1/2 half mile south of Green Mountain Railway roundhouse at traffic light. Turn right on off-ramp to Connecticut River. From Boston area take Route 140 off Route 2 near Gardiner to Route 12. Follow Route 12 through Keene to North Walpole. From eastern New Hampshire and from Maine follow Route 101 from Portmouth to Keene and then Route 12 to North Walpole. As parking is somewhat of a problem, we may want to consolidate into as few vehicles as possible. We will pass this way to Montpelier this afternoon and can retrieve vehicles left here.

Mileage	Road Log
0.00	Leave off ramp, south on Route 12.
0.20	North Walpole Gauge. Mouth of Saxon's River across Connecticut.
0.50	Turn left on Route 123. Mouth of Cold River.
0.70	Turn left onto Cold River Road. Glacial Lake Hitchcock delta across valley.
1.5-1.9	Whitcomb Sand and Gravel across Cold River.
2.6	STOP 1. Mouth of Great Brook. Cold River Road was washed away in flood by large eddy in river at this point. We are nearly 3 miles downstream from area of intense rainfall in August, 1986 storm. There was no evidence of large flows from Great Brook itself. Continue along Cold River Road.
3.5	Intersection with Route 123. Cross Route 123 and park on right for Optional stop. STOP 2. (Optional Stop). Drewsville Gauge, discontinued by USGS in 1978. Operated by Department of Geology, Boston University since 1980. Inclined staff gauge allowed estimation of 1986 flood stage of 13.00 feet. By extrapolation of stage - discharge rating curve this is equivalent to about 10,000 cfs. This exceeds previous record stage of 12 feet, and compares with the stage of 11 feet during April 1987 floods. Note gorge below bridge and numerous bridge abutments. Return to cars and proceed south (east) along Route 123.
5.5	Juncture of Route 123 with Route 12A. Turn right, cross Cold River and bear left through village of Alstead. Note till cut in stream channel on left, behind playground. This is near the downstream (western limit) of intense rainfall and erosion during August 1986 flood.
6.1	Turn left at Gulf station to Route 123A.

6.50 STOP 3. Park on left. Note gravel deposits in woods beyond pool. This is result of both the 1986 and 1987 floods. Walk a few hundred feet along road. Note abrasion of trees in ditch on left which resulted from transport of coarse sediment in floodwaters. Cross Route 123 to juncture with dirt road. This road was completely washed away in flood, leaving a channel about 30 feet wide and 10 feet deep. The road was rebuilt and the road replaced with a 12-inch culvert. Return to cars and proceed along Route 123A.

8.60 Cross Cold River, find parking on shoulder.
STOP 4. Alluvial fan on edge of valley. Cobble size gravel was deposited during intense runoff in August, 1986. Numerous fans like this one were also covered with gravel in this flood.

9.40 Turn right on Route 123A. Note small slide scars on left.

9.50 STOP 5. Find parking along right side of road and return to clearing on left side of road with blue sap lines. Large gully cut to bedrock during August, 1986 storm. Exposure on east side of gully near large maple tree shows the following stratigraphy:
3 feet laminated grey till
2 feet reddish-brown diamicton, probably colluvium
1 foot yellow-brown saprolite
bedrock (Ammonoosic volcanics)
Other exposures of saprolite along gully channel up the hill.
Return to vehicles and continue along Route 123A.

10.00 Turn right. Home of Dr. and Mrs. George Hanson. We will have lunch here and also visit Stop 6. Pull past house and barn and park in indicated area.

Stop 6 is within walking distance of the Hanson house. Walk along path to Cold River and along bank in upstream direction to juncture with Millikens Brook.
STOP 6. Cobble and boulder gravel was deposited by Milliken Brook in its own channel as the flow was slowed by flooding in the Cold River. This channel deposit was graded to the level of the flood stage of the Cold River during August, 1986 flood. This deposit is in effect an in-channel delta. This stream now flows between coarse channel deposit. During spring flood in 1987, the channel was so diminished in capacity that water was diverted onto flood plain.

10.01 Return to Hanson's for afternoon stops (2). Return to 123A, turn right.

11.4 Turn right and cross one way bridge.

12.0 Park in lot of Acworth highway garage. Washed out road on left leads to Beryl Mountain pegmatite quarry. Continue along road and descend dirt road on right.
STOP 7. Washover fan from steep slopes of Beryl Mtn. covers road and continues to floor of kettle on right. Observation well beyond

fan experienced rise in water table of about 9 feet within a few weeks of the flood. Analysis of the hydrograph of this well (see Fig. 2) and assuming a specific yield of 0.2, indicates as much as 1.8 feet of water were recharged into the aquifer from the kettle. This suggests that water from the steep slopes above was concentrated into the kettle and this water plus the direct rainfall accounts for the high recharge.
Return to vehicles. Continue ahead on road.

12.2 Acworth dump. Uncollapsed delta surface exposed in rear. Bedrock on left side of road.

13.0 Turn right at mineral shop.

14.2 Turn left on Route 123A

17.0 Juncture with Route 123 and Route 12A. Straight ahead.

17.8 Turn left on Route 123.

19.6 Turn left at blinking light on Route 123.

19.9 Lake Hitchcock delta surface.

20.3 Pits on right expose forset beds in Hitchcock delta.

21.2 Descend foreset slope of Hitchcock delta.

21.8 Turn right.

22.0 Cross Cold River.

22.3 Turn right on Route 12 and almost immediately turn left onto grassy area beside road. Be careful of crossing Route 12.
Walk south along roadbed of abondoned railroad. Upon reaching bridge abutment, descend slope to right. Careful of poinson ivy. Reach bank of Connecticut River.
STOP 8. Delta in Connecticut River was deposited from coarse sediment carried down the Cold River during the flood of August, 1986. "Paleo" flow indicators included oriented trees and gravel bedforms, as well as shingled gravel (Fig. 2). Debris in fallen trees indicated water in Cold River was about 10 feet deep when delta was deposited. Subsequent floods in January, 1987 and April, 1987 have eroded the distal end of the delta, but the delta has stayed pretty where as it was formed. The channel between delta and Vermont side of river has been widened by erosion on both sides. Soon after delta was formed, this channel was about 100 feet wide.
Return to vehicles.

On Friday trip: turn north (left) on Route 12. At second light, turn left over Connecticut River, then right and find Route 5. Follow Route 5 for about 3 miles to I-91.

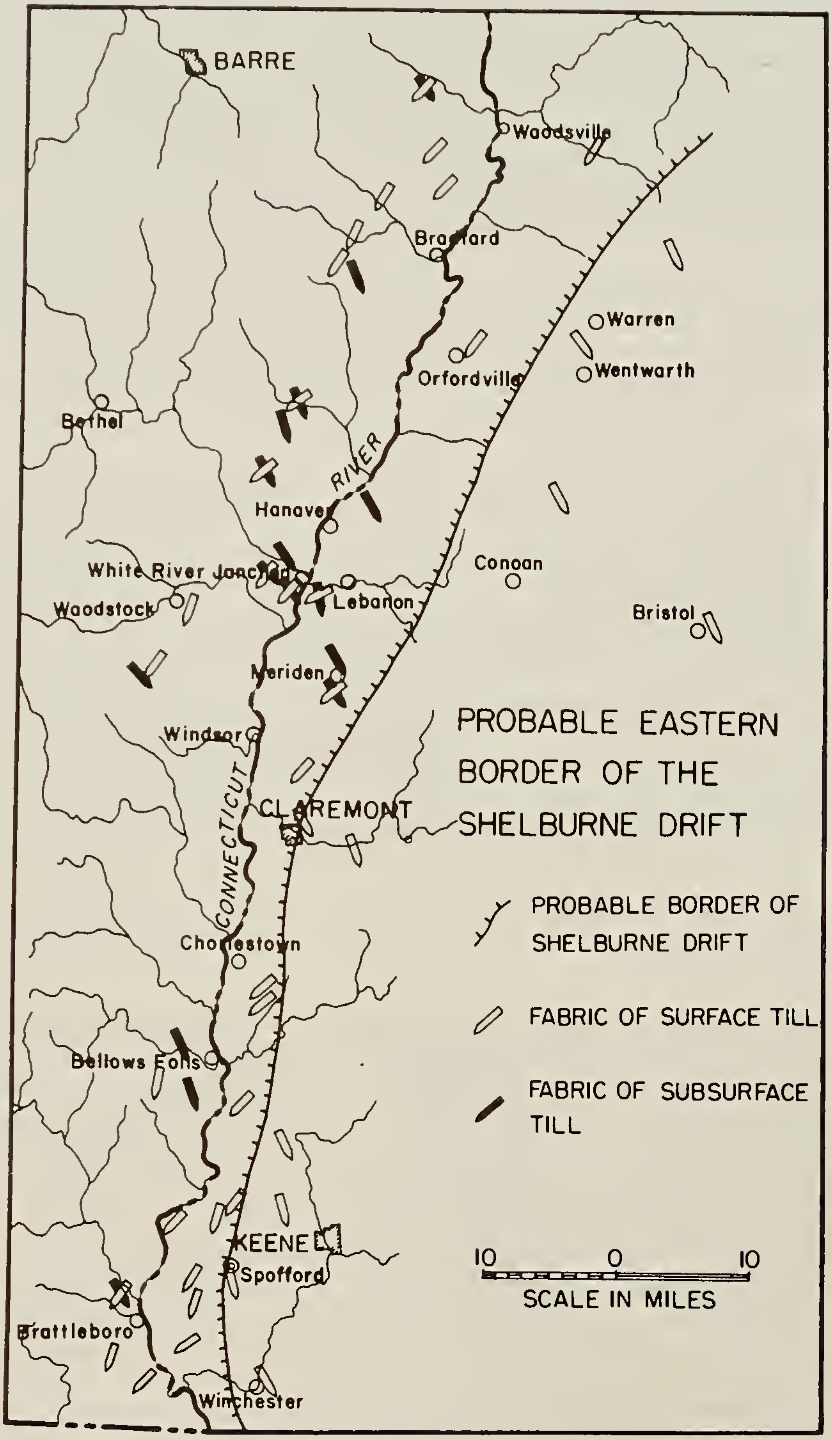

Figure 1. "Probable eastern border of the Shelburne drift". According to Stewart and MacClintock (1969, p.99), the Shelburne drift presumably was derived by ice moving from the northeast. Note that surface-till fabrics west of the border between Winchester and Charlestown indicate that the Shelburne drift came from older drift east of the border. That situation would be highly unlikely if not impossible.