MISFIT STREAMS AND THE POSSIBLE GLACIAL ORIGIN OF THEIR VALLEYS[1]

BENJAMIN H. RICHARD AND FREDERICK L. PAILLET, Department of Geology, Wright State University, Dayton, Ohio 45431

Abstract. A study of misfit streams and meandering depressions developed in ground moraine deposits near Dayton, Ohio has indicated that streams are re-establishing old stream courses, which persist as buried channels previously carved into bedrock. The erosion of deep meandering channels in bedrock appears consistent with melt-water streams let down through glacial ice. Such channels would subsequently be filled with porous stream deposits in post-glacial times, allowing for rapid groundwater flow and enhanced solutioning of predominantly carbonate stream gravels. Once the depressions were lowered below the water table through groundwater solution, misfit channels were established by normal stream erosion. The detailed study of one misfit stream located near Byron, Ohio has indicated the presence of a buried bedrock channel 90 feet deep with a bedrock surface gradient of 400 feet per mile.

OHIO J. SCI. 76(3) 123, 1976

In the vicinity of Dayton, Ohio, many relatively shallow surface depressions with large meanders may be observed in the ground moraine material deposited at the end of the Wisconsin glaciation. Some of these depressions contain no regularly observable stream flow, while others contain well-defined channels with meanders at least one order of magnitude smaller than those of the main depression. The depressions are most clearly seen at the boundary between valley train deposits and ground moraine. Proceeding into the ground moraine from this boundary, the depressions appear progressively less well defined until the lack of any channel and the shallow relief make them imperceptible. They may be followed even further towards their sources during periods of high intensity rain, when many temporary streams are flowing in depressions which could not otherwise be observed. Perennial tributaries to major streams also fit this description, but there are many more depressions which are dry most of the time, and which are not apparent to the untrained eye. The density of these misfit streams and meandering depressions without channels is much greater than the density of current stream development.

The presence of misfit streams is not peculiar to the Dayton area, but is a common feature of many regions which were once glaciated, and where melting ice once greatly augmented stream flow. The particular misfit streams being considered here give some definite clues to the circumstances and climate under which they originated. Seismic data and other factors suggest that these streams are re-occupying gravel filled channels previously developed into bedrock.

MISFIT STREAM CHARACTERISTICS

The meandering depressions and misfit channels are observed to fit a remarkably consistent pattern throughout the area under study. In tracing a stream down from its headwaters, a nearly imperceptible depression is seen to connect into a well-incised depression, first containing an intermittent stream and then, down valley, a perennial stream. In all cases, the sinuous stream which eventually flows in the meandering valley has a meander wavelength much smaller than that of the valley itself. Valleys can be seen in all stages of development, and they locally pass through patches of relatively undisturbed woodland (sug-

[1]Manuscript received July 28, 1975 and in revised form March 25, 1976 (#75-50).

gesting that the depressions are in no way related to the farming practices of the last century). The misfit streams are readily found in ground moraines, but are never found in valley train and outwash deposits, and are only poorly defined in end moraines.

During heavy rains and the spring thaws, all of these depressions have springs issuing from them in various places. Farmers frequently leave the centers of depressions grassed in when the rest of the vicinity is being plowed because such areas are either too wet to plow or will be periodically wet during the growing season. Depression centers are also frequently outlined by arcs of water loving trees (phreatophytes) like American Sycamore and Eastern Cottonwood. These facts point to a water table which frequently intersects the surface in depressions during periods of high intensity rain, and which remains within the reach of phreatophytes throughout the driest parts of the summer. The meandering depressions have watersheds which could not possibly provide the discharge rates required to produce a sinuous stream with meanders of the wavelength observed.

STREAM ORIGIN AND CLIMATIC IMPLICATIONS

Sediment transport rates in rivers flowing from moist temperate regions are normally limited by the rate at which mechanical weathering and hillslope processes can deliver material to the tributary channels. These rivers thus flow well below capacity for all but the coarsest components of bedload. During immediately post-glacial times, the situation is reversed, and much more sediment is available for transport than can possibly be carried by existing streamflow (Church and Ryder, 1972). Immediately post-glacial fluvial processes thus appear incapable of rapid erosion of deep bedrock channels. We believe the erosion of deep, meandering channels in bedrock is consistent with streams let down onto bedrock through glacial ice during the initial waning stages of the Wisconsin ice sheet. These streams began either beneath or on top of the ice sheet, but eventually developed into a dendritic system of open channels. This dendritic system would be distinct from the discontinuous channels normally associated with glacial meltwaters (discussed by Price, 1972). The same hydrological relationship between meander size and discharge holds for stream channels eroded in glacial ice (Knighton, 1972); and meandering channels incised into bedrock after being lowered through the ice of mountain glaciers have been documented (Leopold *et al*, 1964). During the period in question at least one major stream draining glacial meltwater from the ice, the Mad River, was at least 180 feet lower than at present as illustrated by one well log near Springfield (Alvord *et al*, 1952). The well was drilled for the Springfield Water Company, and intercepted gravel from the surface all the way to bedrock. We believe this gravel was deposited during the last glacial retreat. The location and geometry of the buried channel now associated with the Mad River is illustrated in figure 1.

We believe that the present system of meandering depressions and misfit streams could have developed according to the sequence shown in figure 2, after initial glacial meltwater had cut a network of deep, sinuous channels. As the ice sheet finally retreated, the meltwater discharge remained constant while the bulk of glacially eroded debris suddenly became available for transport. The Mad River and other major drainage channels rapidly became overcharged with sediment at this time and began to backfill. The base level of all tributary channels also began to rise, and they too became choked with debris. With continued ice retreat, streams flowing over valley train deposits remained fully charged with sediment, continued to agrade, and continued to raise the base level of tributaries. Ultimately, the presently misfit channels backfilled until little, if any, of the original channel remained.

The stages of depression development are shown in figure 2. A closed deciduous forest developed over the new poorly defined valleys. The stream deposits filling these valleys would be much more permeable than glacial till. Since Miami lobe outwash is generally about 80%

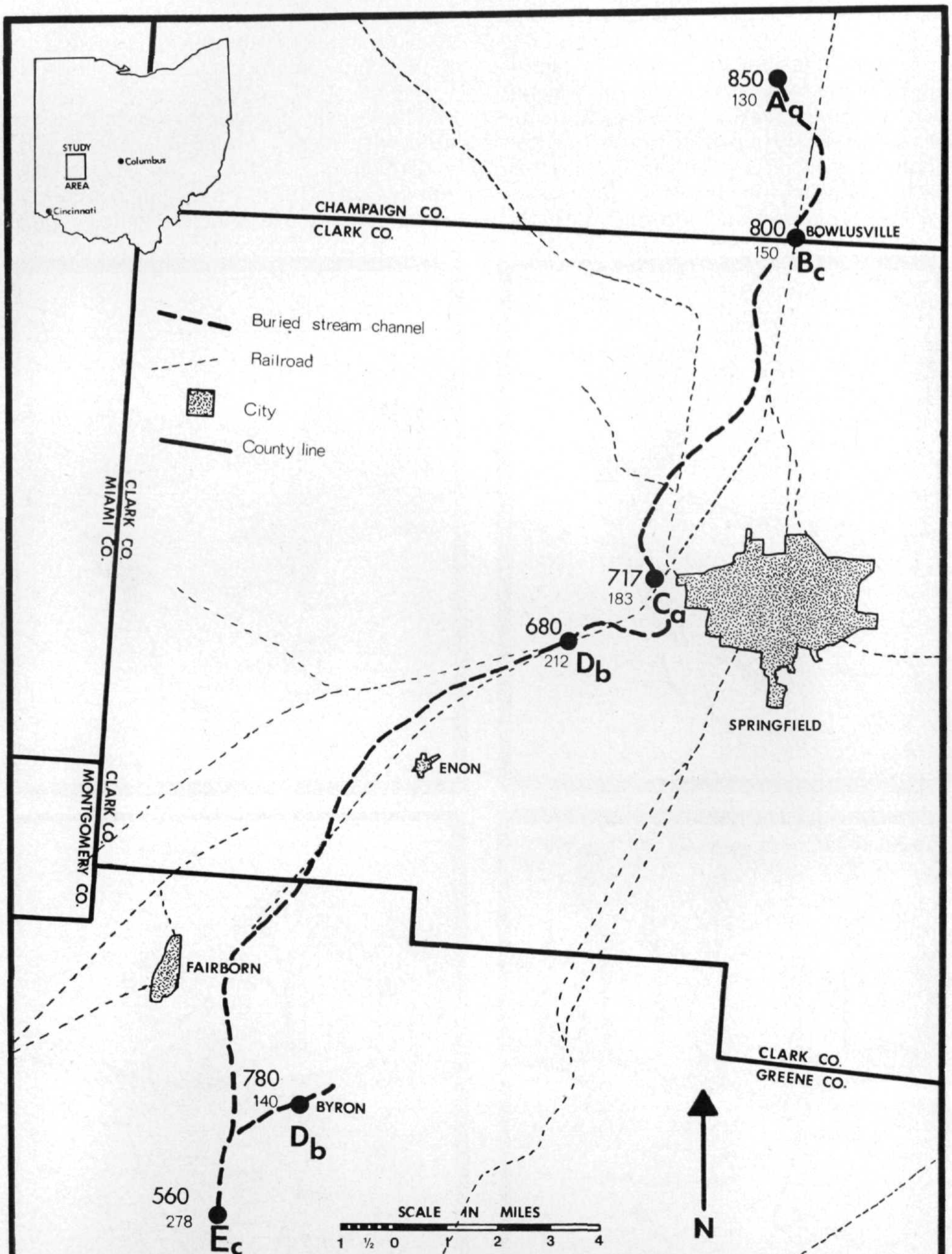

FIGURE 1. Map showing proposed buried stream channel and data sources. Elevation of buried stream channel is shown in bold face numbers and depth of buried channel below surface in smaller numbers. Sources of data are shown as: **a** = from well logs; **b** = from seismic data; **c** = from combined gravity, seismic data and well logs. The basic reference sources for the data are: **A** = Norris, S. E. and Spicer, C. H. (1958); **B** = Contrino, C. T. (1973); **C** = Alvord, Burdick and Howson (1952); **D** = Richard (1975); **E** = Massar (1975).

limestone and dolomite, much of the sand and gravel in backfilled channels has been available for solution. Groundwater flow through these conduits would be more rapid than elsewhere, allowing for rapid recharging of groundwater and enhanced solutioning of the carbonates. If this process occurs, the depression would be enlarged and lowered until the lowest parts intercepted the water table. At this time, perennial stream development would begin.

The cause of climatic changes associated with recent glacial episodes is still a controversial subject. One author (Bryson *et al*, 1971) has suggested that recent continental glaciers were triggered

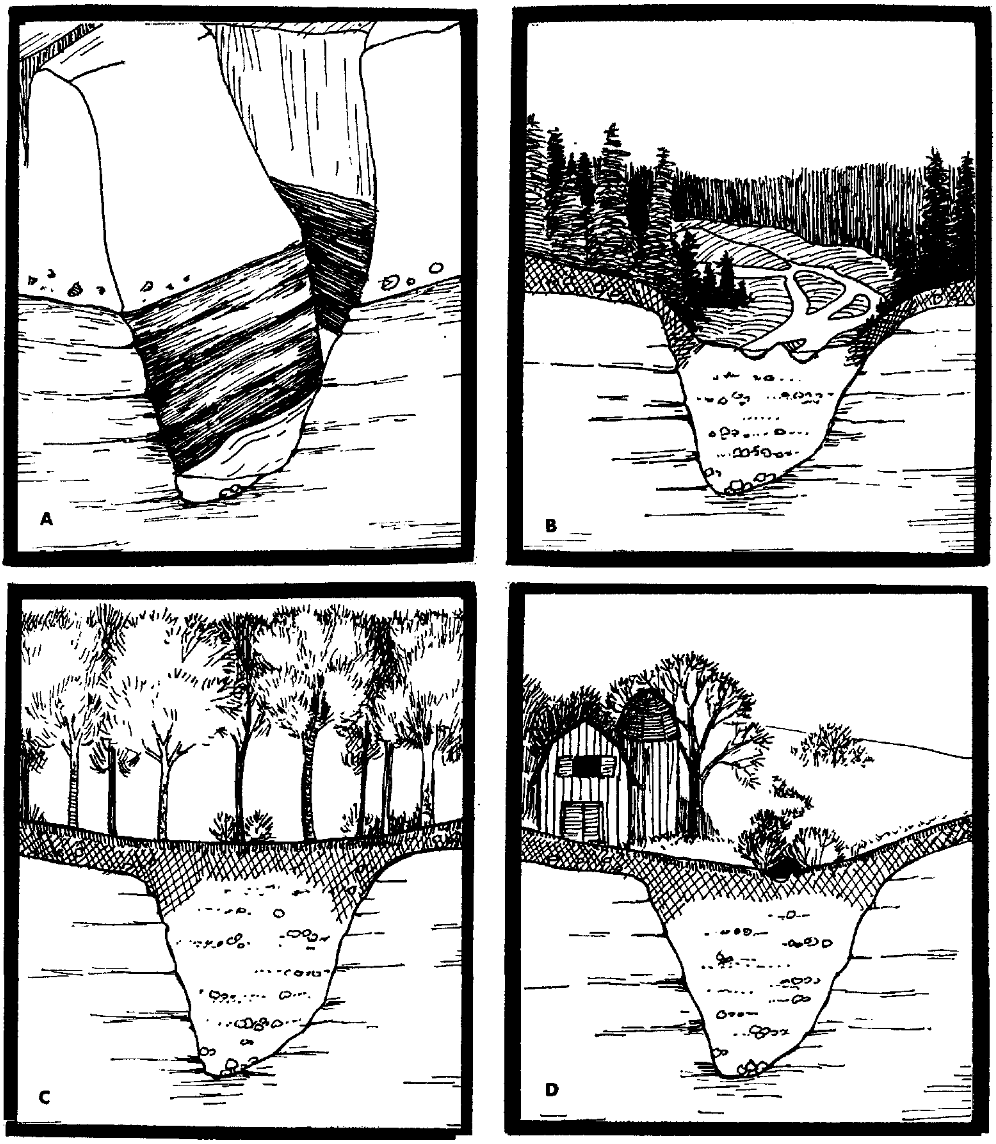

FIGURE 2. Development stages of misfit streams. A) dendritic drainage system develops in waning ice sheet; B) dendritic channels backfill with stream sorted debris; C) climate ameliorates and soil develops over poorly defined depressions; D) misfit valleys appear as groundwater flow dissolves carbonates.

by the abrupt (within less than a century) change of the quasi-steady synoptic scale eddy patterns which dominate mid-latitude climates. Others (Sellers, 1969; Budyko, 1969) have used crude global radiation balance models to show that a decrease of 1% to 3% in the solar constant (well below the present error in measuring this quantity) could produce massive glaciation. Still other theories are related to changes in the earth's orbit.

MISFIT STREAM NEAR BYRON, OHIO

Near the town of Byron (Bath Township, Green County, Ohio) there is a depression with water flowing in it only near the valley train deposit (See fig. 1 for exact location and references). The depth to bedrock in the center of this depression has been seismically determined to be 140 feet below the present surface. Bedrock adjacent to the depression is about 20 feet below ground level, indicating bedrock surface relief 120 feet greater than that of the current surface depression. Extrapolation back to headwaters indicates that this particular stream had a gradient of about 400 feet per mile when the erosion into bedrock ceased. The stream was also a minor tributary of Beaver Creek, which appears to occupy one of the major back-filled meltwater channels cited above. About one mile south of where the stream joins the main creek bedrock lies about 278 feet beneath Beaver Creek representing the probable base level for the misfit stream, and this is about 220 feet below the bedrock elevation of the stream near Byron (fig. 1).

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