ANOMALOUS DRAINAGE PATTERN AND CRUSTAL TILTING IN OTTAWA COUNTY AND VICINITY, OHIO[1]

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ABSTRACT

Ottawa County, Ohio, is situated near the western end of Lake Erie on a flat glacial-lake plain that is interrupted by bedrock highs only at the western and eastern ends of the county. The drainage pattern on the lake plain is anomalous in that the courses of the major streams do not trend directly down the present slope normal to its strike. The entire region has apparently experienced tilting down to the north about an axis trending approximately east-west, producing an increased gradient to the north and resulting in considerable stream piracy. The tilting involved differential movement on the order of 2.8 feet per mile and is believed to be related to isostatic adjustment during and following the last stages of Pleistocene glaciation.

INTRODUCTION

Ottawa County is located in northwestern Ohio, in part along the Lake Erie shore (fig. 1). The purpose of this paper is to describe the major physiographic features of the county and surrounding area and to point out an anomalous condition reflected by the drainage pattern. This anomaly is interpreted as being the result of crustal tilting in the western end of the Lake Erie basin.

PHYSIOGRAPHIC ELEMENTS

The surficial material over most of Ottawa County consists of glacial-lake sediments and till, forming an extremely flat surface. This surface is interrupted by three prominent bedrock highs. The westernmost of these is formed by the massive Lockport Dolomite, of Middle Silurian age, which crops out along the axis of the Findlay Arch. The upper part of this dolomite has been referred to as "Guelph" by some workers, but this term—originally used to designate a zone—has never been defined as a rock-stratigraphic unit in Ohio. The writer

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(Sparling, 1965) prefers the term Lockport, as originally defined by Hall (1839), for strata immediately beneath the Upper Silurian series.

In the eastern end of the county are two dissected cuestas formed by resistant strata dipping very gently to the east. These cuestas were described in detail by Carman (1946). The westernmost is formed by dolomites of the upper part of the Bass Islands Formation of Upper Silurian age. The Bass Islands cuesta extends across the middle of the peninsular portion of the county and through the Bass Islands, but is not recognized south of Sandusky Bay. The easternmost cuesta is formed by the Columbus and Delaware Limestones of Middle Devonian age. It trends discontinuously from south of Sandusky Bay across the eastern end of Ottawa County (Marblehead Peninsula) to Kelleys Island and Pelee Island.

Another bedrock high (also held up by dolomite) rises close to the surface in the north-central part of the county, causing a slight bulge in the shoreline (fig. 1); but it produces only a minor interruption to the flatness of this area.

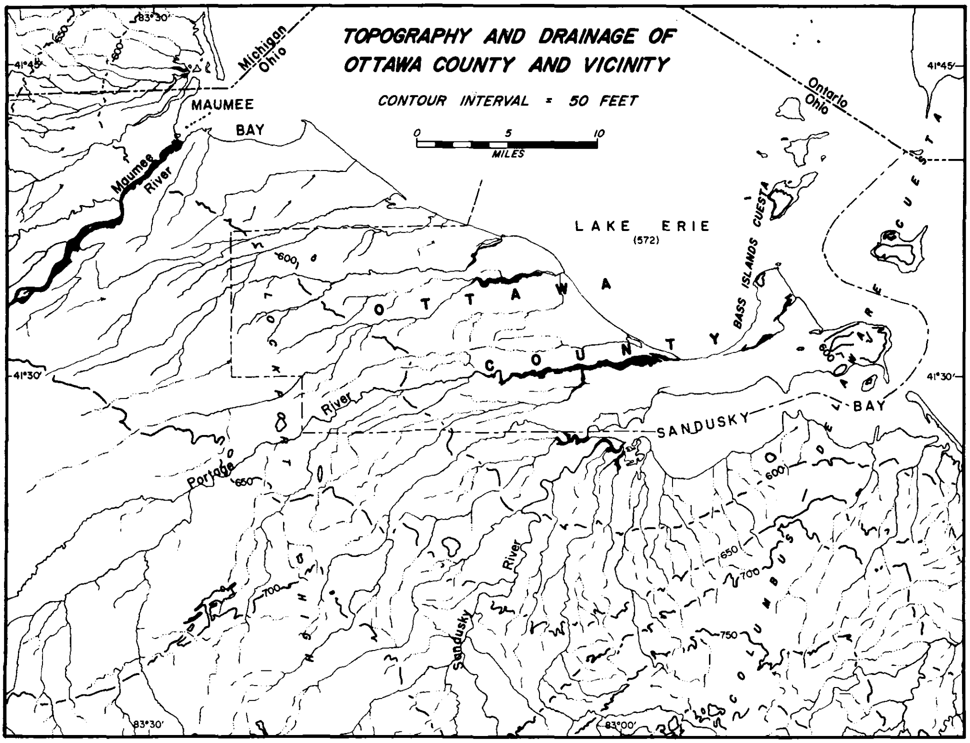

FIGURE 1. Topography and drainage of Ottawa County and vicinity. Contours are shown only in interstream areas.

ANOMALOUS DRAINAGE AND CRUSTAL TILTING

Except for the outcrops of Lockport Dolomite, the surface in central and western Ottawa County and adjacent regions is a glacial-lake plain on which topographic contours trend about N49°W to N54°W. The slope ranges from about 2.5 to 3.7 feet per mile. The drainage pattern of this area is anomalous in that the major streams do not flow directly down this slope, normal to its strike. Instead there are long straight stream segments which trend about N73°E to N87°E. It follows that the consequent slope on which they formed must have had a strike ranging from about N17°W to N3°W. As seen in figure 2, the stream segments flowing normal to the initial strike are aligned in such a way as to indicate that they are fragments of original consequent streams whose courses have been interrupted at various points through stream piracy by northerly flowing tributaries. Another anomalous situation is the fact that tributaries entering the present streams from the north are almost completely lacking.

All of these factors indicate that the entire region was tilted down to the north following the initial subaerial erosion of the glacial-lake plain. As a result, initial tributary streams that flowed southward, if there were any, suffered loss of gradient and disappeared. North-flowing tributaries, on the other hand, experienced an increase in gradient that allowed them to capture segments of the original major east-flowing consequent streams.

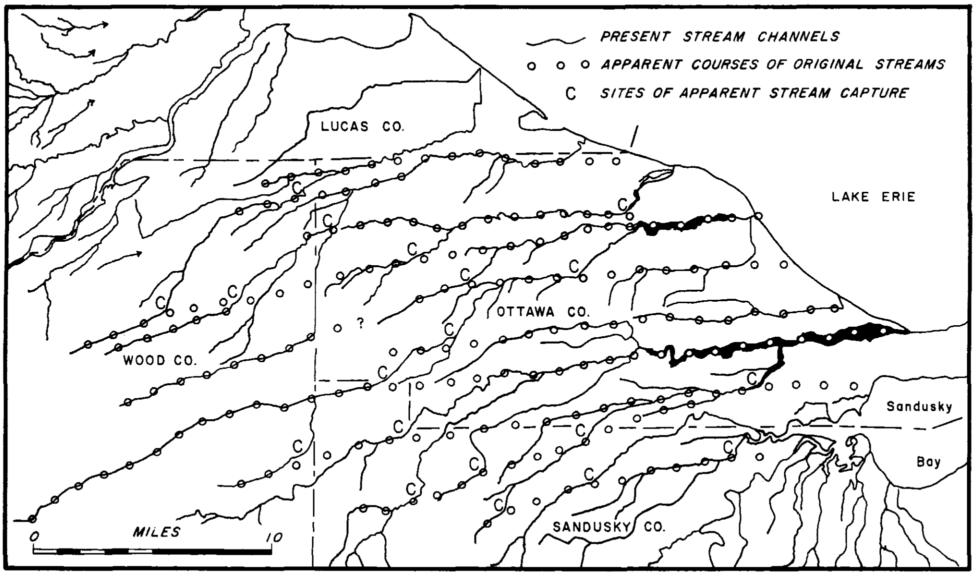

FIGURE 2. Present stream channels and apparent courses of original consequent streams that have been interrupted by stream capture.

An approximation of the magnitude of tilting and the gradient of the original slope can be determined as illustrated in figure 3. The points chosen for the derivation of these values are so placed as to avoid the influence of any bedrock highs and, assuming that the tilting took place about an east-west axis, values of 2.9 feet per mile and 2 feet per mile are indicated for the northward tilting and for the gradient of the initial slope, respectively. Derivation of the magnitude of tilting based on other points yields a range of about 2.1 to 3.3 feet per mile, with an average of about 2.8 feet per mile. Additional calculations of the gradient of the initial surface indicate that 2 feet per mile is a reasonable average.

It should be pointed out that the tilt axis did not necessarily trend exactly east-west, nor was the direction and magnitude of tilting necessarily consistent throughout the entire region. Nevertheless, it seems clear that the magnitude of tilting exceeded the initial gradient of the surface, and therefore exceeded the gradients of the initial major consequent streams. Widespread stream capture was thus inevitable.

The initial slope on which the major consequent streams developed must have existed immediately following the retreat of the last glacial lake that covered this region. The last such lake for which there is evidence would be Lake Lundy (Forsyth, 1959). During early post-Lundy time, the western end of the Lake Erie basin must have been higher, with respect to the region to the south, than it is at present. This western Lake Erie area may have been upwarped in response to crustal depression farther north by the late Pleistocene ice sheet, and may have been downwarped as the area to the north rebounded following complete deglaciation. This is a very tentative hypothesis for which the writer can offer no supporting evidence, but it does seem reasonable to assume that differential movement in the area is in some way related to isostatic adjustment during and following the retreat of the ice sheet.

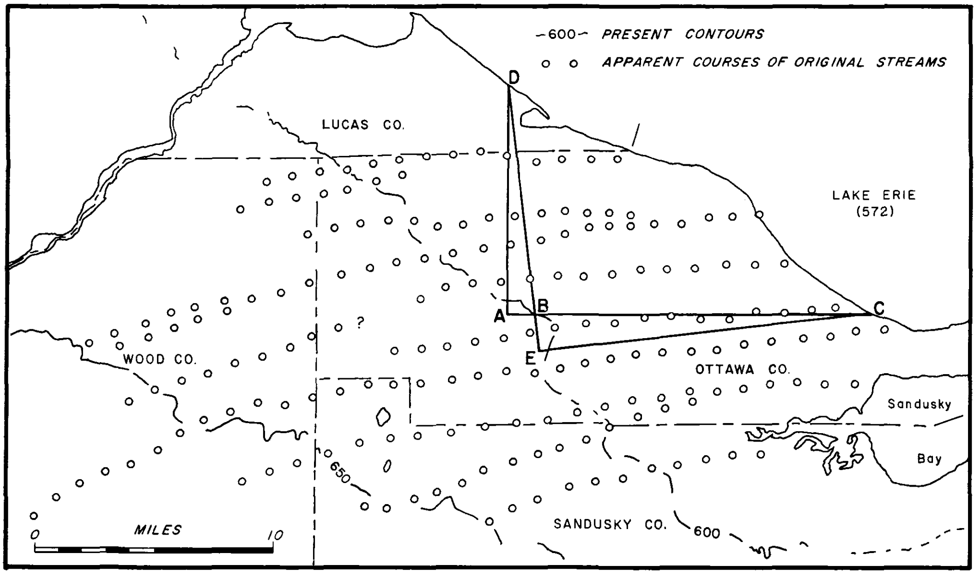

FIGURE 3. Determination of magnitude of crustal tilting and gradient of the initial slope, assuming an east-west tilt axis. Line ABC trends parallel to the assumed tilt axis, and line DBE, approximately perpendicular to the apparent courses of original streams, represents the average strike of the initial surface. Point D was initially at approximately the same elevation as point B, but is presently 28 feet lower (572 vs. 600 feet). It follows that downward tilting to the north is 28 feet over the distance AD (9.7 miles), since this line is normal to the assumed tilt axis; the magnitude of differential tilting is thus about 2.9 feet per mile. Point C is also 28 feet lower than point B, a relationship that would not have been altered by the tilting; since point E lies on an extension of the original strike through point B, point C would initially have been 28 feet lower than point E. Line EC, normal to DBE, represents the trend of the initial slope, which had a gradient equivalent to 28 feet over the distance EC (14 miles), or 2 feet per mile.

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