

RELATION OF SHORE AND NEARSHORE BOTTOM FEATURES TO ROCK STRUCTURE ALONG LAKE ERIE

ROBERT P. HARTLEY

Ohio Department of Natural Resources, Division of Geological Survey, Sandusky, Ohio

The shorelines of Lake Erie tend to parallel the strike of the bedrock, indicating an overall relation of shape to rock structure. This has been shown by Carman (1946) in his explanation of the relief features of the Erie basin. The south shore of the lake from the city of Huron eastward parallels the strike of the south-eastward-dipping Upper Devonian shales.

The headlands and island chain of Point Pelee, Ontario, Pelee Island, Middle Island, Gull Island, Kelleys Island, Marblehead Peninsula, and Johnson's Island lie along the outcrop of the eastward-dipping Columbus limestone. Catawba Island, the three Bass Islands, East Sister Island, and Middle Sister Island lie on the outcrop of the Upper Bass Island dolomite group, following a curved pattern induced by the northward plunge of the Cincinnati Arch. The west end and

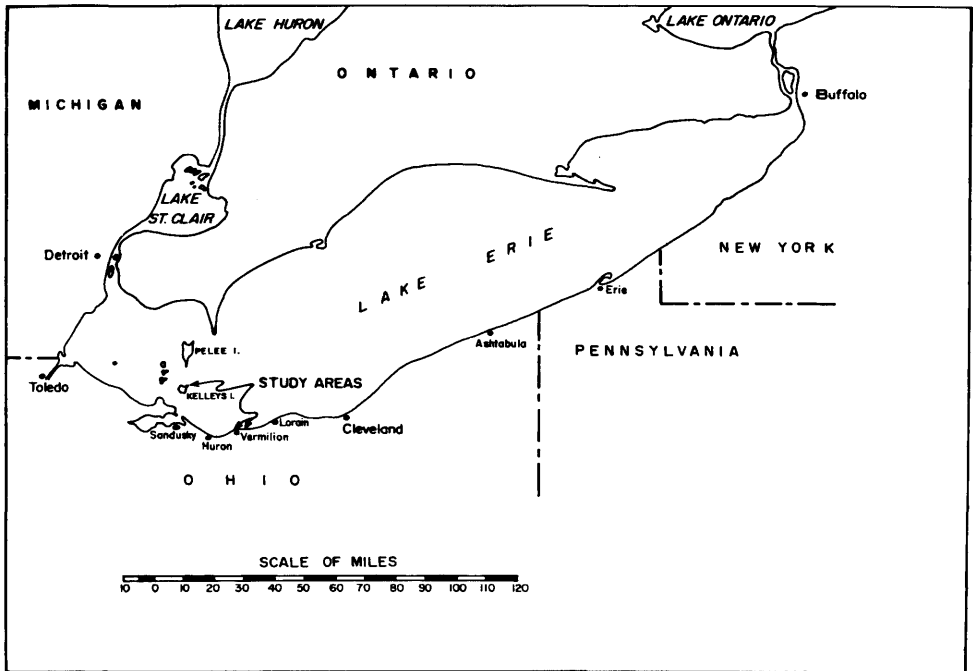


FIGURE 1. Locality map of study area.

northwest corner of Lake Erie parallel the same outcrop line. The eastern half of the north shore of Lake Erie is probably sub-parallel to the strike of southward-dipping Upper Devonian limestones.

Small scale structural forms lead to variety in shoreline configuration. The following discussion deals with the forms found on Kelleys Island and those found along a two-mile stretch of shore just east of Vermilion, Ohio (fig. 1). Kelleys Island has been affected mainly by jointing of the Columbus limestone while the area east of Vermilion exhibits jointing, thrust faulting, normal faulting, and folding in the Ohio shales.

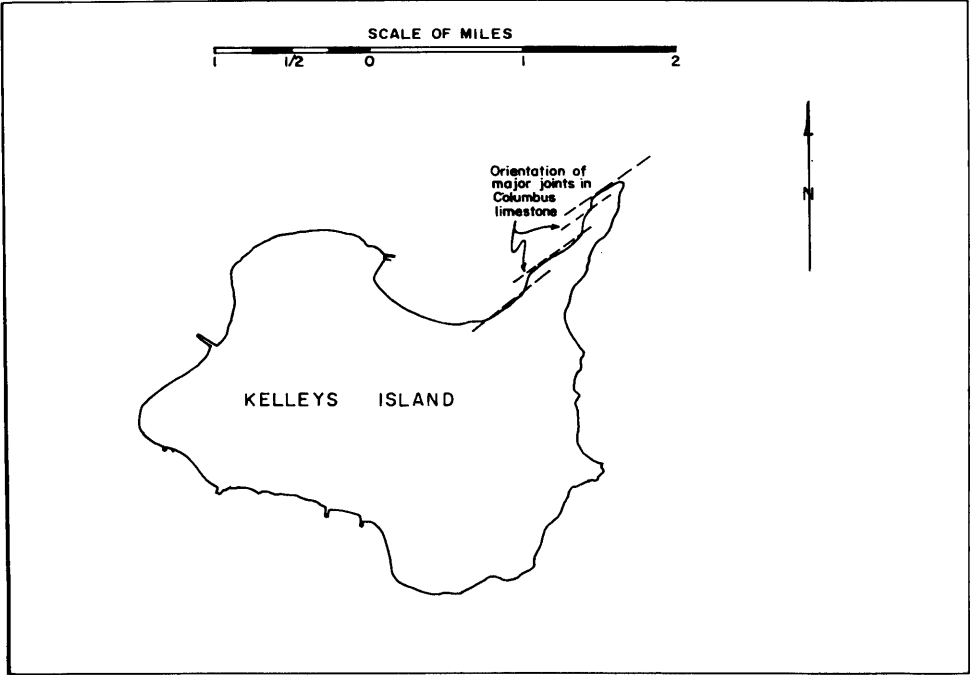


FIGURE 2. Relations of jointing to shoreline configuration on Long Point, Kelleys Island.

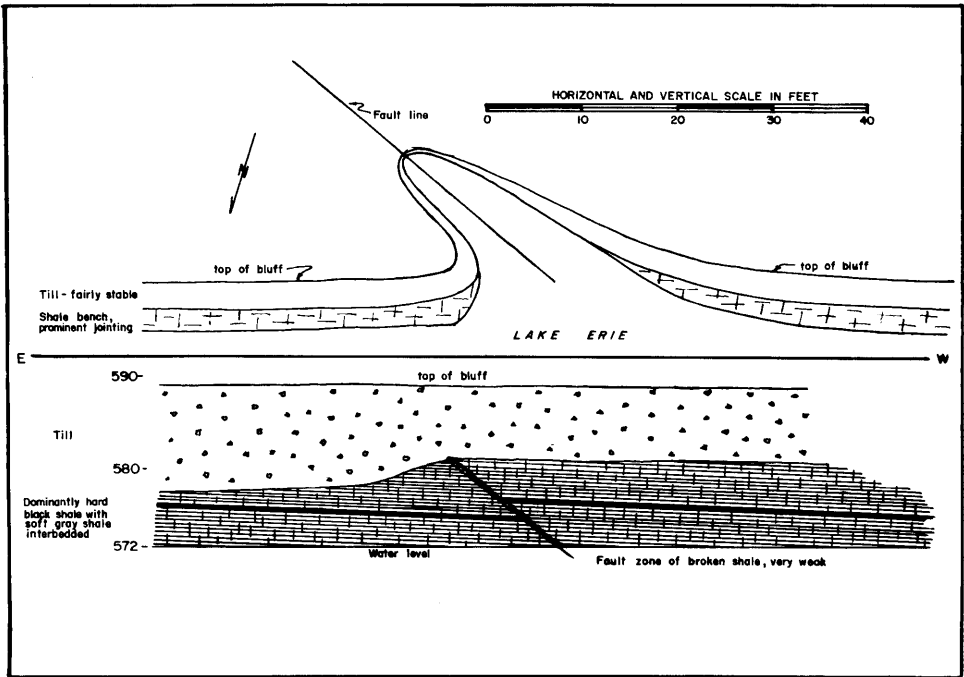


FIGURE 3. Shoreline form resulting from wave-cutting and frost action in fault zone. Note maximum retreat occurs along fault line in weak, broken beds. Collapse occurs slowly but continuously, exceeding that of general bluff face. General bluff line parallels joint planes.

JOINTING

Vertical joint systems in the Columbus limestone at Kelleys Island have resulted in a pronounced parallel alinement of bluff faces on the west side of Long Point (fig. 2). The remainder of the Kelleys Island shore does not show the joint control for two reasons: (1) the Columbus limestone surface rock dips eastward so that the east side of the island presents a surface (paralleling the strike) nearly at water level, there being no bluff to break along the joints, and (2) the remainder of the island generally displays the underlying Lucas dolomite at water level which shows, at best, less distinct jointing. It is suspected that many of the shores of the other islands show the same relations to jointing.

Vertical jointing in the Ohio shale, if in undisturbed horizontal beds, results in linear shorelines. The bluff face may be vertical and appear to follow a single joint plane for several hundred feet. Where indentations occur, they are sharply

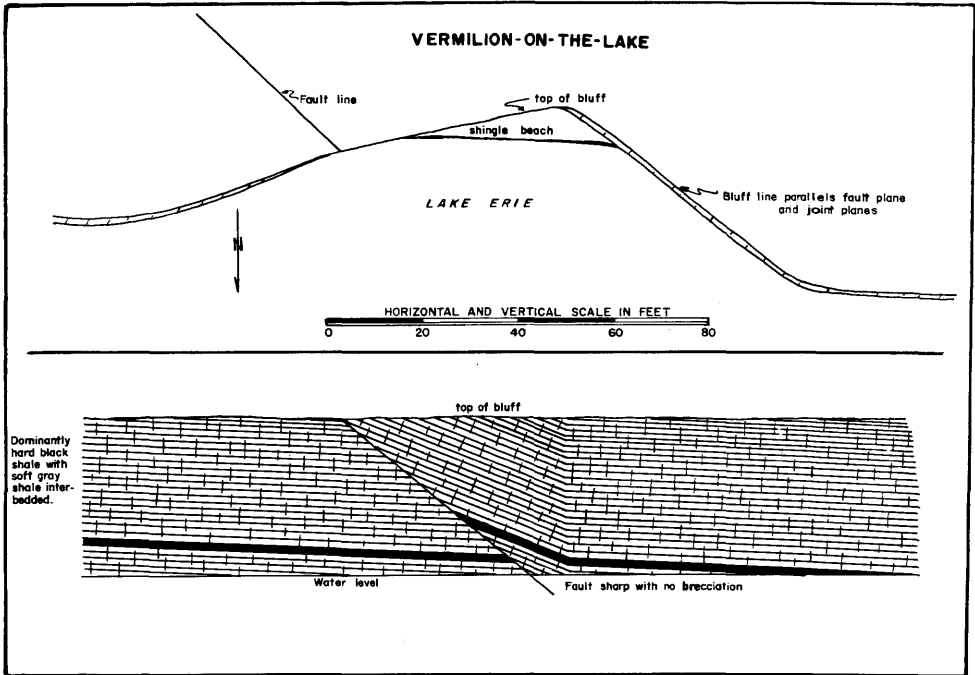


FIGURE 4. Shoreline form resulting from wave-cutting and frost action in fault zone. Note maximum retreat occurs where beds are bent at sharp angles. Collapse occurs suddenly.

angular, tending to follow a major transversing joint surface. However, these indentations are never deep, rarely exceeding 20 ft. Shorelines controlled by jointing alone are fairly stable in the shale areas. Failure occurs by ice wedging along joint surfaces, loosening rectangular blocks.

Shoreline configurations in the shale area east of Vermilion are usually not controlled by jointing alone. Faulting and folding combine with jointing to induce intricate shapes.

FAULTING

Thrust faulting leads to comparatively deep embayments (fig. 3), especially if there is much crushing along the fault surface. The axis of such an embayment

follows the strike of the fault. Apparently the head of the embayment retreats more rapidly than the flanking shoreline until a stable form is attained. Subsequently the head of the embayment will retreat at the same gradual rate as the flanking shoreline. Beaches in the embayments are ephemeral and can be entirely removed by a single storm.

Another type of thrust fault is shown in figure 4. The same beds east and west of the fault zone lie in the same planes but near the fault, on the upthrust side, the beds are broken or bent sharply along a vertical plane. Between this plane and the fault surface the beds rise steeply but are not bent. Slippage has occurred along bedding planes in this zone. The strata have been weakened by the slippage, by the faulting, and by the vertical breakage. The zone of most

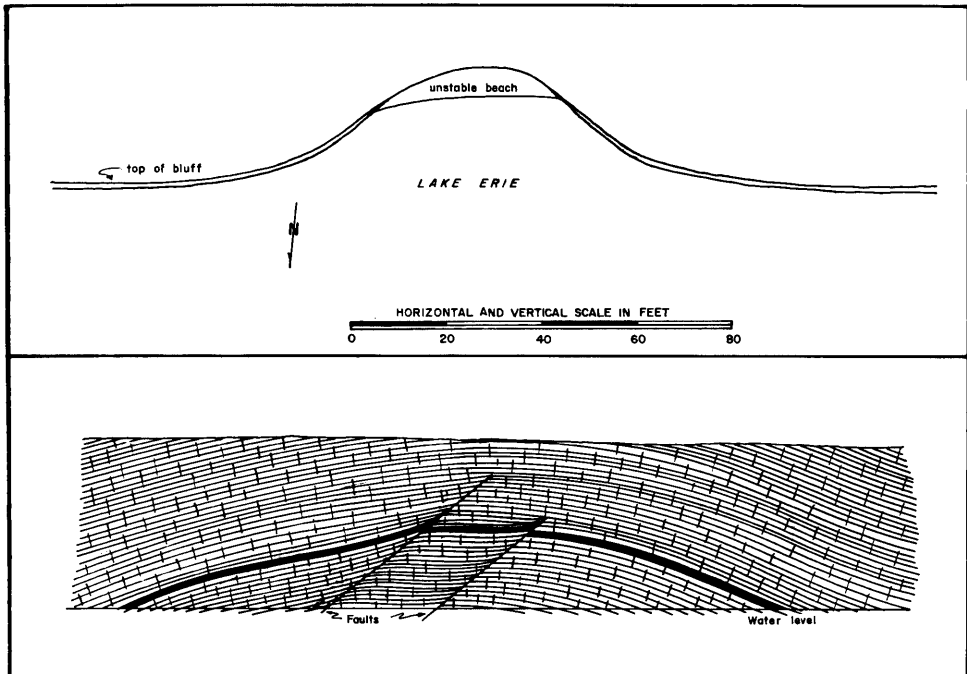


FIGURE 5. Shoreline form resulting from wave and frost action in faulted zone at apex of anticline. Beds broken and joints open. Cave is formed and collapse occurs suddenly. Retreat in faulted zone exceeds general shore retreat.

rapid retreat in this case is not along the fault plane but along the vertical breakage zone. Here the bluff at present retreats more rapidly than the flanking bluffs. Wave cutting in this area, and probably frost action, cause collapse. The collapse is not gradual but occurs as sudden falls.

Faulting near the apex of an anticline is illustrated in figure 5. Here the beds are weakened by the faulting and by the opening of joints. The weakest zone is between the faults and a cave is created by wave action. Sudden collapse of the strata occurs after the bluff is undercut some unpredictable amount. Here again the head of the embayment retreats more rapidly than the flanking bluffs.

FOLDING

Long, curving shorelines have been created in areas of gentle warping which are otherwise undisturbed. They result simply from the rising or lowering, in

elevation, of resistant and non-resistant beds within the zone of wave action. Depending upon the direction of warping, either embayments or headlands may be formed. Ordinarily, but certainly not always, anticlines result in broad headlands and synclines result in indentations along the shale bluffs east of Vermilion.

Shore profiles also show relations to structure. Caves, always associated with less resistant gray shale beds, tend to form at the apices of anticlines and along horizontal beds (fig. 6a). Rarely do they form on the limbs of folds. They appear to be formed by the grinding action of sand and gravel in localized pockets as it is thrown about by wave action. The cave becomes very deep compared to its cross dimensions. Caves of this sort apparently have little or no effect on the general retreat of the shoreline. Very deep caves may exist along a straight shoreline.

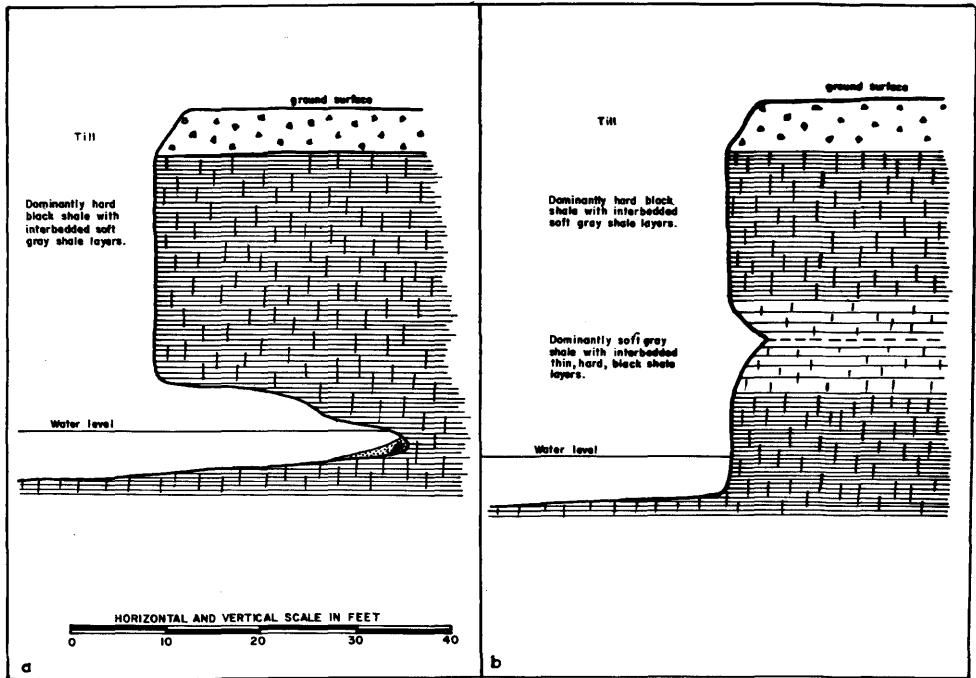


FIGURE 6a. Cave formed by waves armored by local pocket of sand and gravel. Stable bluff above; collapse does not occur if overlying beds are unbroken.

FIGURE 6b. Indentation formed in bluff by wave action probably augmented by frost action. Thin, black shale layer along dotted line. Stable bluff above indentation.

Caves are far less prevalent along the limbs of folds apparently because the wave uprush is deflected along shore in the direction of rising strata and because the softer gray beds in which they form are present at the zone of attack only very locally.

Extensive wave undercutting in the Ohio shale in the same area east of Vermilion is not significant in undisturbed strata. It does occur however and is characterized by the profile shown in figure 6b. This profile is peculiar in that it is V-shaped with a very sharply defined line of maximum indentation. The explanation for this type of undercutting probably can be found in the varying degrees of induration within the softer gray beds of the shale.

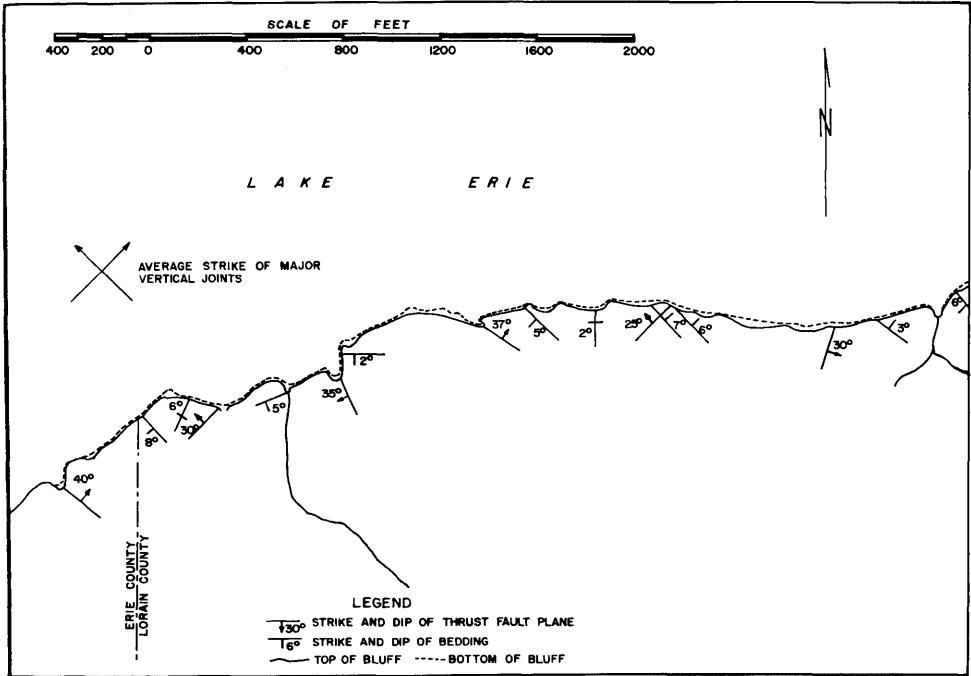


FIGURE 7. Shoreline configuration and some structural features near Vermilion, Ohio.

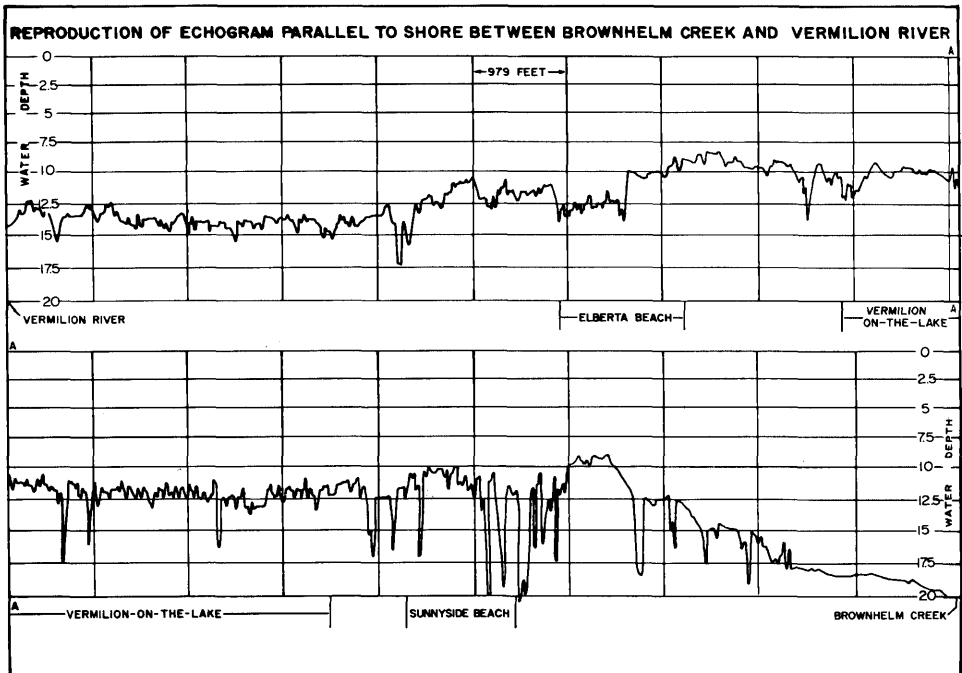


FIGURE 8. Profile taken from echogram made with Bendix DR8A depth recorder. Run made approximately 1000 ft from shore, September 22, 1955. Not reduced to low-water datum.

The dip of shale strata is reflected in general in the steepness of the bluff profile. Flat or shoreward-dipping beds tend to have vertical profiles whereas lakeward-dipping beds have less steep profiles. One explanation for this may be that gravity and ground-water lubrication play more important roles in removal of material from lakeward-dipping beds. Blocks loosened by weathering and frost action would tend to slide down the bedding surfaces toward the lake.

STRUCTURE COMBINATIONS

Combinations of structural features in the Ohio shale exposed along the lake shore result in intricate shapes of shorelines. Figure 7 shows a segment of shoreline just east of Vermilion, Ohio where some of the most complex structure along the shore of Lake Erie is found. The shoreline is very irregular and is not being straightened as one would think it should. As long as such structure presents itself in the bluffs and remains in the zone of wave action, it seems that irregularity will persist.

LAKE BOTTOM FEATURES

Profiles made on the nearshore shale bottom near Vermilion indicate that bottom topography may also be related to rock structure. The bottom in this area has not been visually inspected, but in profile it is unlike any of the shale bottoms elsewhere. Miniature subaqueous canyons occur normal to and parallel to the shore (fig. 8). They have relief up to 10 or 12 ft, widths as narrow as 75 to 100 ft, and vertical walls. The bottom is otherwise relatively flat. It seems more than a coincidence that these depressions occur only in the area where deformation has been observed. The greatest irregularity occurs off Sunnyside Beach (fig. 8) and it is at this point on the shore that maximum deformation has taken place. It is suspected that the canyons have resulted from concentrations of water forces in zones weakened by faulting or opened joint systems. There remains the possibility that the depressions are extensions of stream valleys on land. However, they do not seem to fit the drainage pattern on shore and, since unbroken shale areas to the east do not show these depressions, stream origin is tentatively discounted.

SUMMARY

Structure of the bedrock has had definite effects on the shoreline configuration of Lake Erie. Shoreline trends follow the general strike of the bedrock. On a smaller scale, jointing leads to angular or blocky irregularities. Faulting results in narrow inlets and bays. Flexures lead to gently curving shorelines. Caves form at the apices of anticlines and in horizontal, less resistant beds. All these features combine to produce diverse irregularities with no apparent areal pattern in shoreline configuration. On the lake bottom, if not covered by sediment, they apparently result in deeply serrate profiles.

ACKNOWLEDGMENTS

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LITERATURE CITED

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