Deformation Structures in Lower Paleozoic Rocks, Northwestern New York

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INTRODUCTION

This field trip is concerned with the nature and origin of some deformation structures within Lower Paleozoic cover to Precambrian basement in the vicinity of Theresa, New York (Fig. 1). Many of the structures suggest localized mobility within the basement that generated instability within the cover rocks - both during and at some time following their deposition.

All of the main stops will be within the Potsdam Sandstone (Upper Cambrian) and the Theresa Formation (Lower Ordovician). A cursory examination of some of the Precambrian gneisses also will be made.

The Potsdam Sandstone in the Theresa area lies with marked angular unconformity on a Precambrian sequence of marble and quartzofeldspathic gneisses. The sub-Potsdam surface in places is rugged with a relief in excess of 70 ft although some of this relief may be due to penecontemporaneous faulting during sedimentation (Stops 2 and 3). The relict topography in part may be due to differential erosion of alternating zones of marble and quartzofeldspathic gneisses because in some areas the marble underlies marked topographic depressions. Where observed, the lowermost Potsdam occurs above an approximately 3-ft thick weathered zone of the basement rocks (Barber, 1977). The Potsdam Sandstone in this area typically consists of a buff to light-gray, thin-bedded to massive, silica-cemented, medium- to fine-grained orthoquartzite; minor amounts of detrital feldspar, mica, and tourmaline occur but rarely exceed 3 percent of the mode. It lacks the pink coloration of the lower parts of the formation in the north (Kirchgasser and Theokritoff, 1971; Selleck, 1978).

The irregular topography on the Precambrian profoundly influenced Potsdam sedimentation. Lowermost Potsdam rocks occur in depressions of the basement surface and these areas are characterized by syndepositional deformation structures. Rapid and large changes in thickness, breccia slides, and minor faulting suggest active faulting during deposition (Stops 2, 3 and 5). At least one of these areas is on strike with NE-trending faults within the basement to the north (R.V. Guzowski, 1977, pers. comm.; Barber, 1977; Buddington, 1934).

The overlying Lower Ordovician Theresa Formation ranges in composition between dolomitic limestone to quartz sandstone, the latter being concentrated in the lower 5 to 10 ft of the formation (Stop 1). Calcite sandstones locally occur within the succession. Typically, the Theresa is thinly bedded and light gray. Convolute lamination is a locally abundant feature.

In the central part of the area (Fig. 1), Theresa limestones outcrop as outliers capping elongate low-amplitude domal folds. These are best

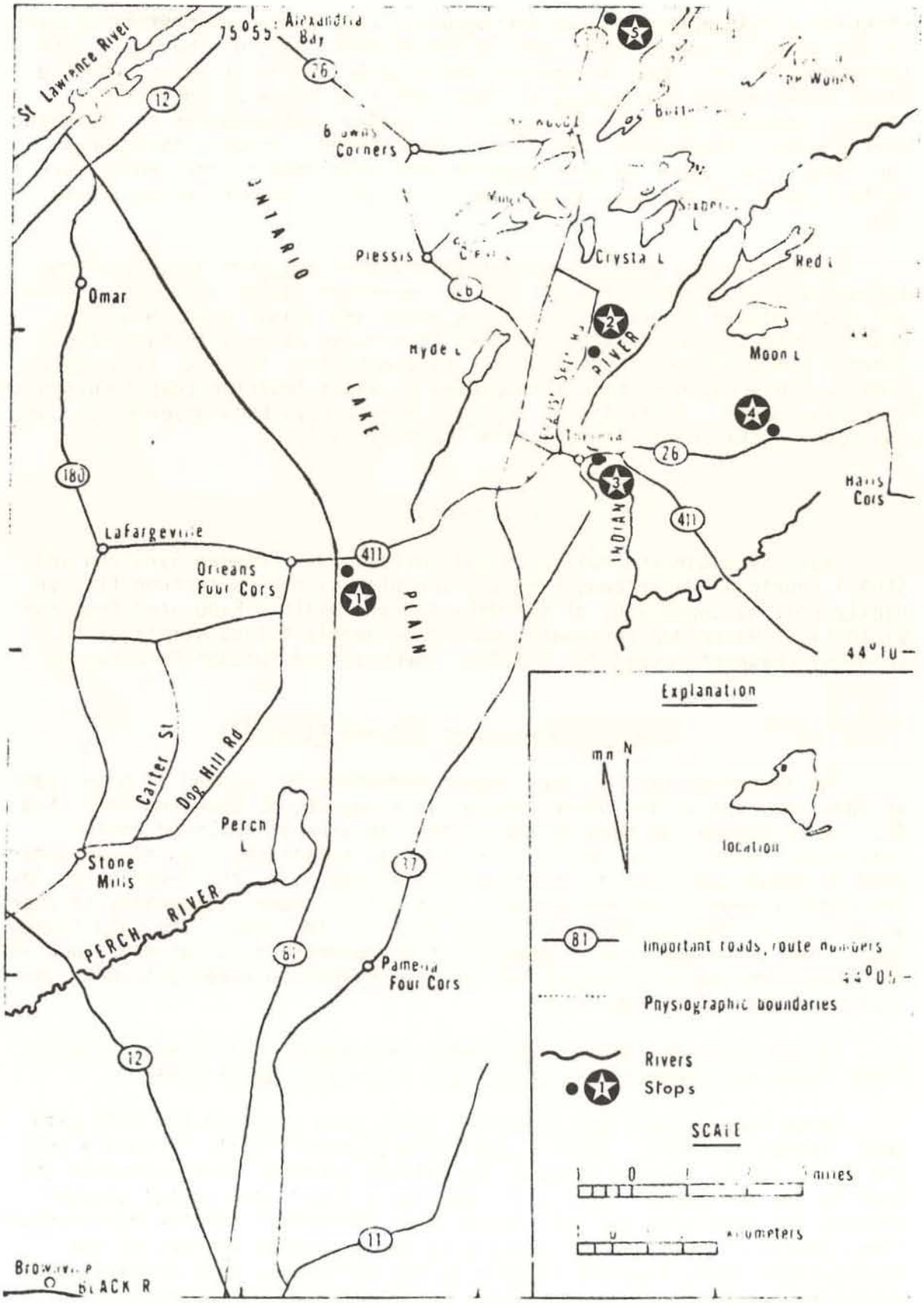

Figure 1. Locality map for Theresa area.

observed within a 3-5 mi wide NNE-trending zone extending from Perch Lake in the south to Butterfield Lake in the northern part of the area. The boundaries of this zone are marked imprecisely by NNE-striking probable fault zones within the basement. The effect of these on the Potsdam-Theresa sequence is seen as instability during sedimentation in the east (see previous discussion) and in post-depositional folding throughout the zone. The latter is particularly well developed in the central and western parts of the zone within the structurally higher Theresa Formation.

Fold-producing post-Ordovician deformation has been described from the succession to the north, in the St. Lawrence Valley (Chadwick, 1915) and post-Potsdam mineralization along veins and joints throughout the region close to the contact with the Precambrian attests to Phanerozoic thermal reactivation of parts of the basement (B.W. Selleck, 1978, pers. comm.). This may have been accompanied by major faulting that deformed the overlying cover. No faults of regional extent have been observed to cut the cover rocks in the Theresa area (Barber, 1977).

FIELD GUIDE

Leave Syracuse and follow US I81 northwards. Between Syracuse and Stop 1 (north of Watertown, Fig. 2), the highway passes through flat or gently rolling topography of the Ontario Lake Plain. Exposures from the vicinity of Watertown northward consist of gently folded strata of the Trenton, Chaumont, Lowville, Pamelia, Theresa, and Potsdam Formations.

Stop 1. Junction Rt I81 and Rt NY 411

The lowermost part of the Theresa Formation is exposed on both sides of this road cut in the hinge zone of an elongate, NE-trending dome (Fig. 2). It is typical of many of the upright to steeply inclined gentle anticlinal folds in the region that occur as relatively high ground separated by broad synclinal or undeformed rock underlying the intervening low and usually poorly drained ground. This 'first order' topography is characteristic of the western and central parts of the area. The fold trends N33°E, and the hinge line plunges NE at approximately 12° at this locality. The interlimb angle is around 160 and no measurable layer thickness variation occurs across the fold.

To the south the hinge-zone widens and extends for at least a mile. Minor folds are present in a relatively flat-lying axial zone.

Three recognizable but dispersed joint sets traverse the fold with mean trends of N74°E, N46°E , and N50°W (Barber, 1977). Probably only the N46°E set is related directly to folding because on rotation of the beds to the horizontal their poles develop a tight zero plunge cluster whereas the remaining two sets become more dispersed. On the northwestern limb, joints of this set dip steeply to the southeast whereas on the southeastern limb, dips are steeply to the northwest; they probably are extensional 'ab' fractures developed during the folding process. The

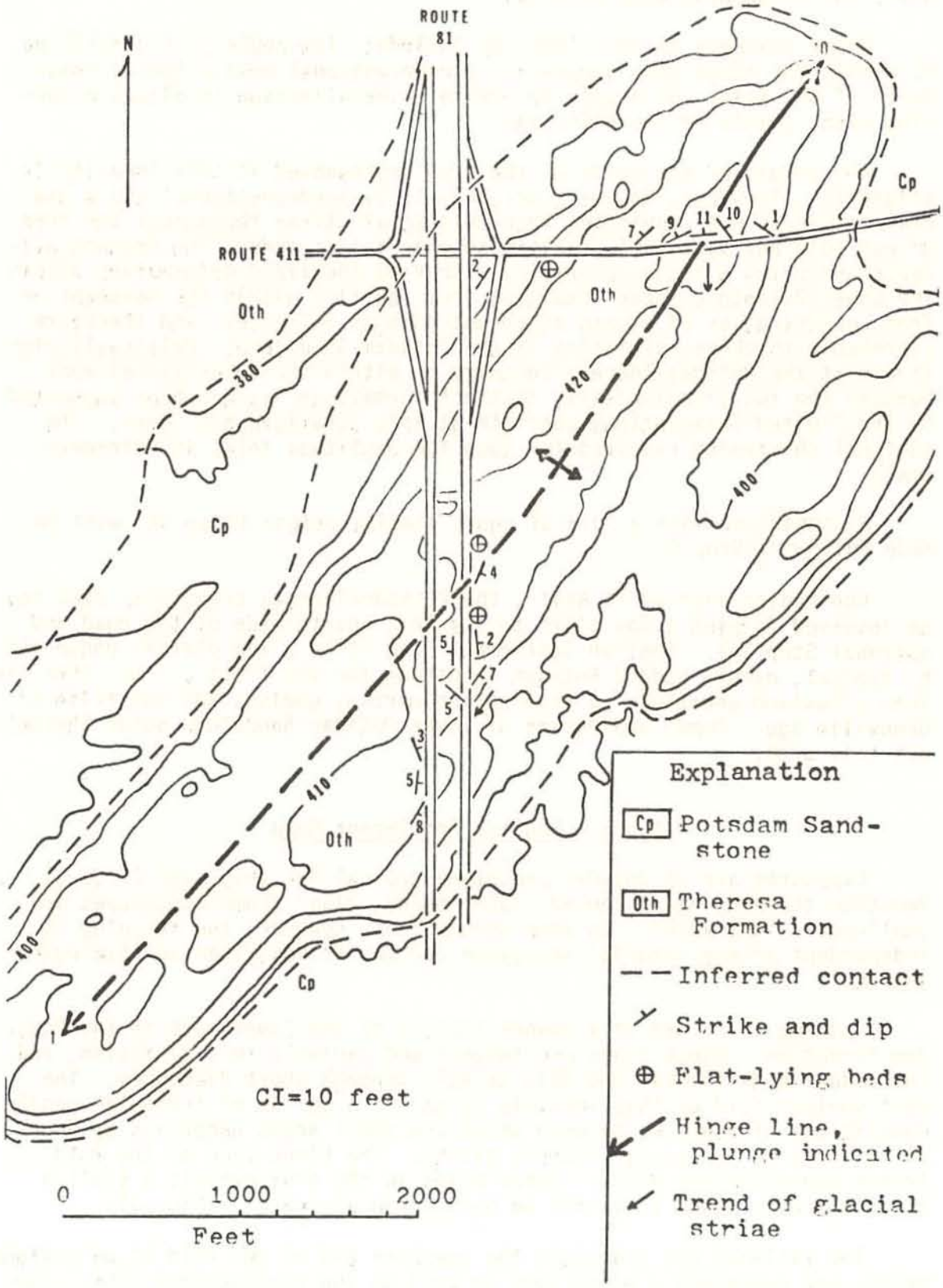

Figure 2. Stop 1 - Generalized structural map.

N74°E and N50°W post-date folding.

Other features at this locality include: low-angle joints striking NE within the hinge zone suggesting a compressional origin for at least parts of the fold; and a calcite-pyrite mineralization in places occurring along joints of the N74°E set.

The origin of the folds of the type represented at this locality is enigmatic. They are, however, unlikely to be syndepositional and a glacial origin is not convincing because glacial striae throughout the area do not hold any systematic relationship to fold trends. The present evidence indicates a tectonic origin, either as localized deformation within the Lower Paleozoic rocks resulting from faulting within the basement or from concentration of strain at abrupt changes in relief, and therefore a probable thickness variation in the Potsdam Sandstone. Relatively high strain at the Potsdam-Theresa boundary or within the transitional zone between the two lithologically distinct formations has not been supported by the limited observations possible at this stratigraphic level. The regional shortening required for such low-amplitude folds is extremely small.

A comparison with a fold of known glacial origin (Stop 5A) will be made following Stop 5.

Continuing east on Rt NY411, the Potsdam-Theresa transition beds may be observed forming a low cliff to the left (north side of the road and optional Stop 1A). English Settlement Road is on a low plateau underlain by typical, evenly bedded Potsdam Sandstone for the first 1.5 mi, then dips into a lowland underlain by alternating marble, gneiss, and quartzite of Grenville age. Domes and basins of lower Potsdam Sandstone occur throughout this area.

Stop 2. English Settlement Road

Exposures are of Potsdam Sandstone typical for this area (Fig. 3). Hematite staining has accented crossbedding, minor slump structures and small-scale lamination. In some occurrences, however, the staining is independent of any internal structure and may be described as 'liesegang banding'.

Bedding is folded in a manner typical of the lower part of the Potsdam Formation. Hinge lines are tenuous and variable in orientation, and individual beds thicken and thin greatly through short distances. The most obvious fold at this locality is one of a series of irregular gentle undulations of bedrock, between which are small areas underlain by Grenville rocks or horizontal Potsdam strata. The hinge-line of the fold trends approxiamtely N40°E. Other folds in the area exhibit a similar trend wherever hinge lines can be determined accurately (Fig. 3).

The railroad cut transects the southern end of the fold at an oblique angle, and expresses a hinge-zone as well as the northwestern limb. The central part of the fold is comprised of horizontally bedded Potsdam and

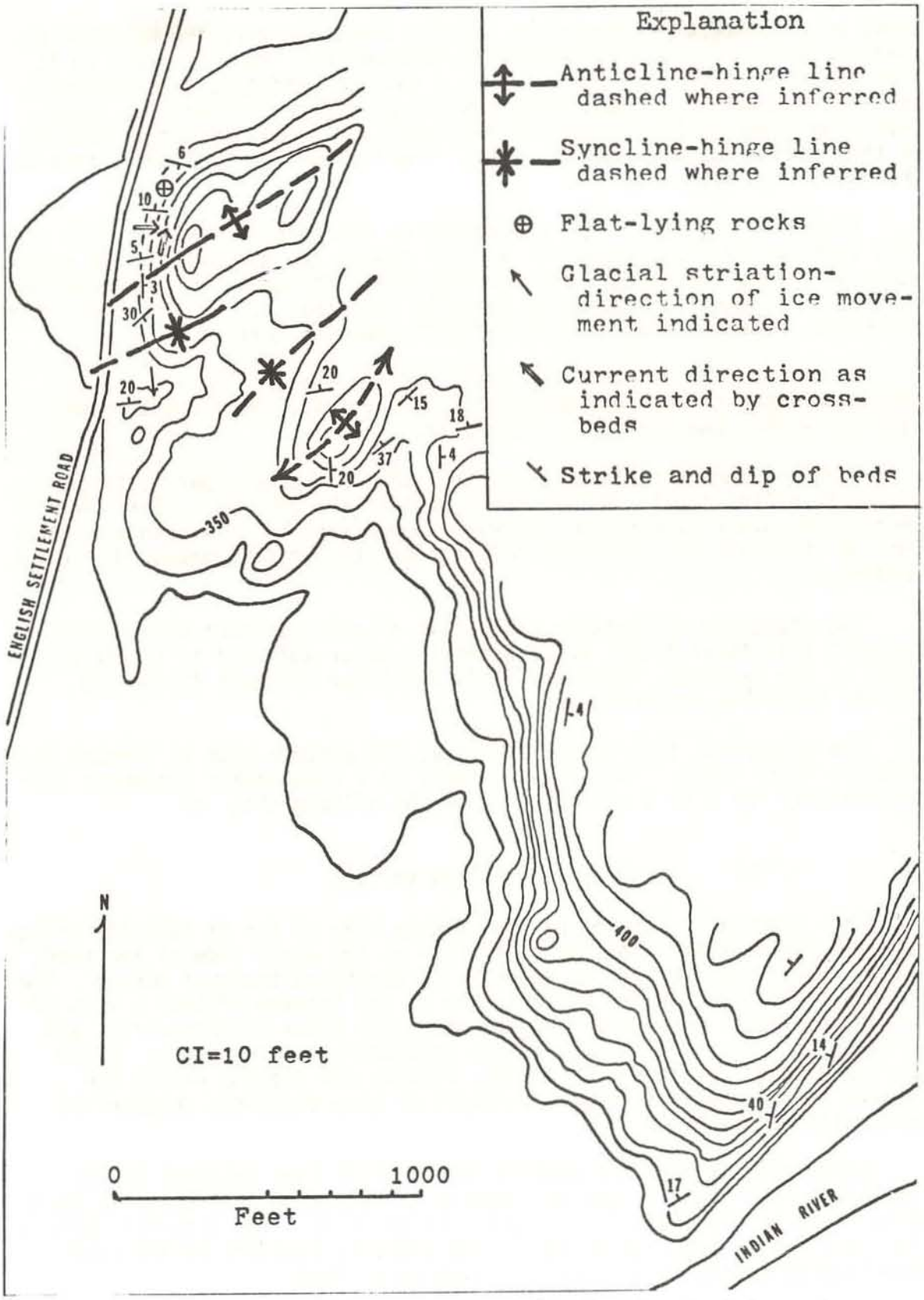

Figure 3. Stop 2 - Structures within Potsdam Sandstone at English Settlement Road.

shows no evidence of deformation. On the limb, however, are a number of features indicative of pre-induration deformation. Approximately 10 ft from the northern end of the outcrop, a massive sandstone layer abruptly deflects downwards and terminates against an adjacent underlying layer. Overlying layers exhibit annealed fractures and lumpy, contorted bedding as they form a flexure over the zone. The flexure has been propagated to the top of the exposure.

Strata to the south, for a distance of approximately 65 ft, form the fold limb, which dips between 5° and 10° toward the northwest. The sandstone is cut by fractures, some of which are differentially weathered normal faults of small displacement (usually less than 0.5 in) that dip to the northwest. Some of these are filled with granular quartz.

On the limb, beds pinch and swell and may change from massive to shaly character through distances of 10 ft or less. Most crossbedded layers are thin and crossbeds are planar.

A major slump structure occurs near the fold crest (partially obscured by a pine tree). At the lower part of the outcrop, a portion of a large slump block is exposed. Poorly layered sandstones within and adjacent to the block are separated by a narrow zone of homogeneous disturbed sandstone.

The abundance of features indicative of soft-sediment deformation suggests that these folds, which generally occur adjacent to topographic highs of the basement, formed by rapid downslope movement during and closely following sedimentation.

The escarpment that crosses NY411 at the western edge of Theresa is a possible fault scarp. This fault extends as a topographic lineament discontinuously for 2 or 3 mi northeast of the village (Fig. 4).

Stop 3. Theresa Village

This outcrop is located on the Theresa side of the Rt NY26-411 bridge over the Indian River. At the cliff face on the south side of the road, Potsdam Sandstone overlies an exposure of weathered basement gneiss. The effects of initial dip are evident here as the Potsdam offlaps a knob of Precambrian rock. Irregular bedding, numerous minor unconformities and evidence of soft-sediment deformation characterize the outcrop. Where the Precambrian core has been eroded, ripples are exposed within the Potsdam that probably formed as a result of slow downslope movement of unconsolidated sediment.

Large slump blocks are exposed in the cliff face adjacent to the sidewalk. Each block is set in a matrix of sandstone that exhibits small-scale contorted laminae or is accented by hematite. The interface between block and matrix tends to be sharp, and suggests slumping of partially consolidated sediments in areas of steep paleoslope.

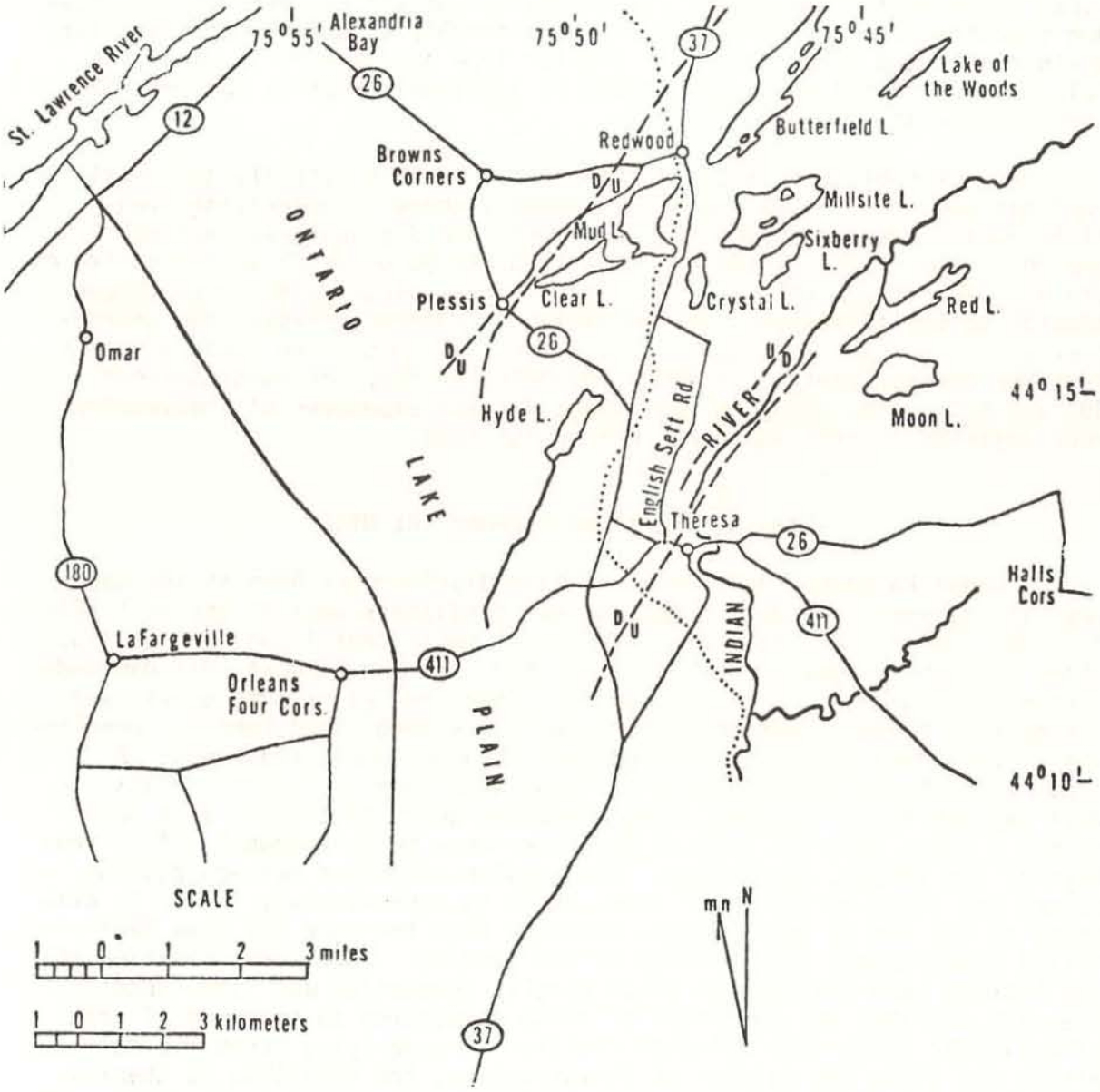

Figure 4. Inferred position of basement faults.

Stop 4. Ritchie's Farm

The high ground behind the farm buildings is comprised of variably bedded, buff-colored, lower Potsdam Sandstone that forms a broad structural basin toward the north. It is typical of all the outliers of Potsdam Sandstone in the region and its relationship to underlying Grenville. Whether this and other basins of similar type are primary is uncertain. Calculations of thickness variations in individual beds is not possible through lack of exposure.

The dominant joint sets in the Potsdam at this locality are nearly vertical and trend N42°W and N81°E, whereas those in underlying Grenville gneiss trend between N42°E and N66°E and dip southeast between 57° and 70°. The strike of these joints tends to be parallel to the strike of the main foliation, whereas dip of these same joints tends to be perpendicular to the foliation. The foliation in coarsely crystalline quartz-biotite-plagioclase (?oligoclase) gneisses, visible a few yards downhill from the Potsdam contact, strikes N68-84°E and dips northwest between 39° and 43°. This trend is consistent for all exposures of Precambrian rock adjacent to this and other nearby outcrops.

Stop 5. North of Redwood, Rt NY37

A major basement fault with relative displacement down to the northwest is inferred to underlie the valley immediately west of the hill (Fig. 4). The hill is comprised of a structural basin containing Potsdam Sandstone similar to that at the previous stop. At the roadcut, Potsdam beds strike N41°E and dip gently southeast. They consist of both evenly and irregularly bedded sandstone containing 'liesegang''type banding, conglomeratic zones and numerous soft sediment deformational structures. A large cone-shaped concretion of the type described by Dietrich (1953) is well exposed in the outcrop. The structure seems to consist of a cone within a cone, with the axis of the inner cone being somewhat offset from that of the larger, outer cone. The angular relations between bedding planes and sides of the outer cone, which is approximately 7-8 ft in diameter at the top of the outcrop, indicate that the cone may have been tilted concurrently with tilting of the bedding. Therefore, rotation of the Potsdam beds followed at least partial compaction and lithification. Dietrich ascribed the formation of these structures to slumping of semi-consolidated sands into solution cavities in underlying Grenville marble. Within and along the margins of the structure, the sandstone is chaotically bedded, and contains numerous healed fractures and small slump blocks. These conical or cylindrical structures occur elsewhere in the area, and although they suggest the importance of soft-sediment deformation, this is the only one that occurs in tilted strata.

Optional Stops (time permitting)

1A Potsdam-Theresa transition beds east of Stop 1.
5A Bedrock deformation of glacial origin. Rt NY12.

Return to Syracuse

REFERENCES

Barber, B.G., 1977, Origin of folding in Paleozoic rocks near Theresa, New York: unpubl. masters thesis, Syracuse Univ., 170 p.

Buddington, A.F., 1934, Geology and mineral resources of the Hammond, Antwerp, and Lowville quadrangles: New York State Mus. Bull. 296, 251 p.

Chadwick, G.H., 1915, Post-Ordovician deformation in the St. Lawrence Valley, New York: Geol. Soc. America Bull., v. 26, p. 287-294.

Dietrich, R.V., 1953, Conical and cylindrical structures in the Potsdam Sandstone, Redwood, New York: New York State Mus. Circ. 34, 19 p.

Kirchgasser, W.T., and Theokritoff, G., 1971, Precambrian and Lower Paleozoic stratigraphy, northwest St. Lawrence and north Jefferson counties, New York: New York State Geol. Assoc., 43rd Ann. Meeting, Field Trip Guidebook, p. B-0 to B-24.

Selleck, B.W., 1978, Paleoenvironments of the Potsdam Sandstone and Theresa Formation, northwestern New York: New York State Geol. Assoc., 50th Ann. Meeting, Field Trip Guidebook, this volume.