PRELIMINARY GEOLOGICAL INVESTIGATION OF OTSEGO LAKE

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INTRODUCTION AND ACKNOWLEDGEMENTS

This report is a synthesis of the contributions of several workers. All of the ecological aspects, underwater sampling, bathymetry as well as some of the geological interpretation are the result of an impressive ten-year research effort by Bill Harman and his students working at the SUCO Biological Field Station. Use of the field station research vessel as well as the logistics for the lake tour and the lake log are also Harman's contribution. Breuninger contributed the sedimentology and Melia the Paleomalacology in two short studies done in 1974. Fleisher contributed material on the glacial geology and the glacial landforms map and accompanied Sales on an initial reconnaissance of the lake perimeter. Sales pulled together most of the general geology, stratigraphy, physiography and structure and did the actual writing of the shore road log, leaning heavily on the interpretations of Fleisher on the glacial geology. While not contributing specifically to this report, the bedrock mapping done by Rickard and Zenger (1964) provides a firm foundation for many of the interpretations. In pulling the paper together and in fitting other workers' concepts to the local situation, Sales may have distorted some of the concepts of the other workers. Much of this contribution represents preliminary ideas that will require further substantiation and modification. Parts of this paper were updated from Sales, et al., 1972.

GENERAL DESCRIPTION OF THE LAKE (LOCATION AND PHYSIOGRAPHY)

Otsego Lake (Figs. 1 & 2) is in northern Otsego County, New York, 57 kilometers (35 miles) southeast of Utica and 89 kilometers (55 miles) west of Albany. The village of Cooperstown is at its south end and the smaller towns of Springfield and Springfield Center lie a few miles north of the lake. It is within the northern part of the Appalachian (Allegheny) Plateau physiographic province in the extreme northeastern part of the Susquehanna watershed. It is considered to be the source for the Susquehanna River although the actual drainage divide separating Susquehanna from Mohawk River drainage lies about 8 kilometers (5 miles) north of the lake. The Plateau Province is a maturely dissected upland with local hill elevations from 550-670 m. (1800-2200 ft.). Valley elevations are in the 300-430 m. (100-1400 ft.) range. Bedrock under the major valleys lies below 30-90 m. (100-300 ft.) of glacial fill (Gieshen, 1974). There is a NNE-SSW topographic grain, possibly basement controlled, that may have been enhanced by glacial erosion so that the area is dominated by over-steepened and over-deepened troughs with intervening subparallel ridges. Otsego Lake lies in one of these troughs, as does its slightly smaller sister lake-Canadarago-just to the west.

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BEDROCK GEOLOGY

The lake is eroded in the Middle Devonian Panther Mountain formation and the subjacent lower members of the Hamilton Group. A prominant dip slope on the Lower Devonian Onondaga Limestone floors the valleys at the north end of the lake and dips gently SSW under the lake surface at a rate of about 90 ft./mile. All other formations in the region also take part in this regional dip (Figs. 1, 3c).

The details of outcrop pattern and lithology are well discussed in Rickard and Zenger's 1964 paper on the Cooperstown and Richfield Springs Quadrangles.

GLACIAL GEOLOGY

Glacial features associated with Otsego Lake and its surroundings are quite diversified and include a well developed moraine and drumlins, as well as hanging deltas, clays and sands representing a previously higher lake stand, here termed Lake Cooperstown (see Glacial contribution by Fleisher for additional detail beyond this summary and for a more regional perspective).

The Cassville-Cooperstown moraine trends southeasterly down Oak Creek valley and crosses the Susquehanna valley 2 miles south of Cooperstown and the Otsego Lake outlet, appearing again in Cherry Valley, the next valley to the east. This moraine completely fills the Susquehanna valley to an elevation of 1250 feet, except for a sharply incised cut at Phoenix Mills, through which the present Susquehanna River flows. This cut provides a logical damming mechanism that could have held Lake Cooperstown elevations at approximately 1250 feet prior to breaching. As a possible alternative, the lake may merely have been graded to the highest terrace level representing graded flood plain at that time. Large terrace remnants at 1250 feet are preserved at Hartwick Seminary and the County Home 2 miles below the moraine.

Several of the deltas along the west (more gentle) side of the lake are not graded to the present lake level, but are strongly incised in their upper areas with smaller present-day deltas below them graded to the present lake and with a noticeable break in slope in between. Upper areas of these deltas (Brockway, Three Mile, Five Mile, Six Mile, and Allen Lake) vary considerably in smoothness and preservation, but seem to be graded to a level of about 1250 feet. An exceptional exposure has been dug in the front of one of these hanging deltas between Five and Six Mile Points on the west side of the lake to accommodate the Lake View Motel and parking lot behind it. This clearly shows very coarse gravels and cobbles with little matrix foreset toward the lake below a nearly level surface at about 1255 ft. elevation. Down the dip of the foresets, sands of similar foreset attitude interfinger with the cobbles. At the top of the coarse foresets there is no sharp transition to horizontal topset strata.

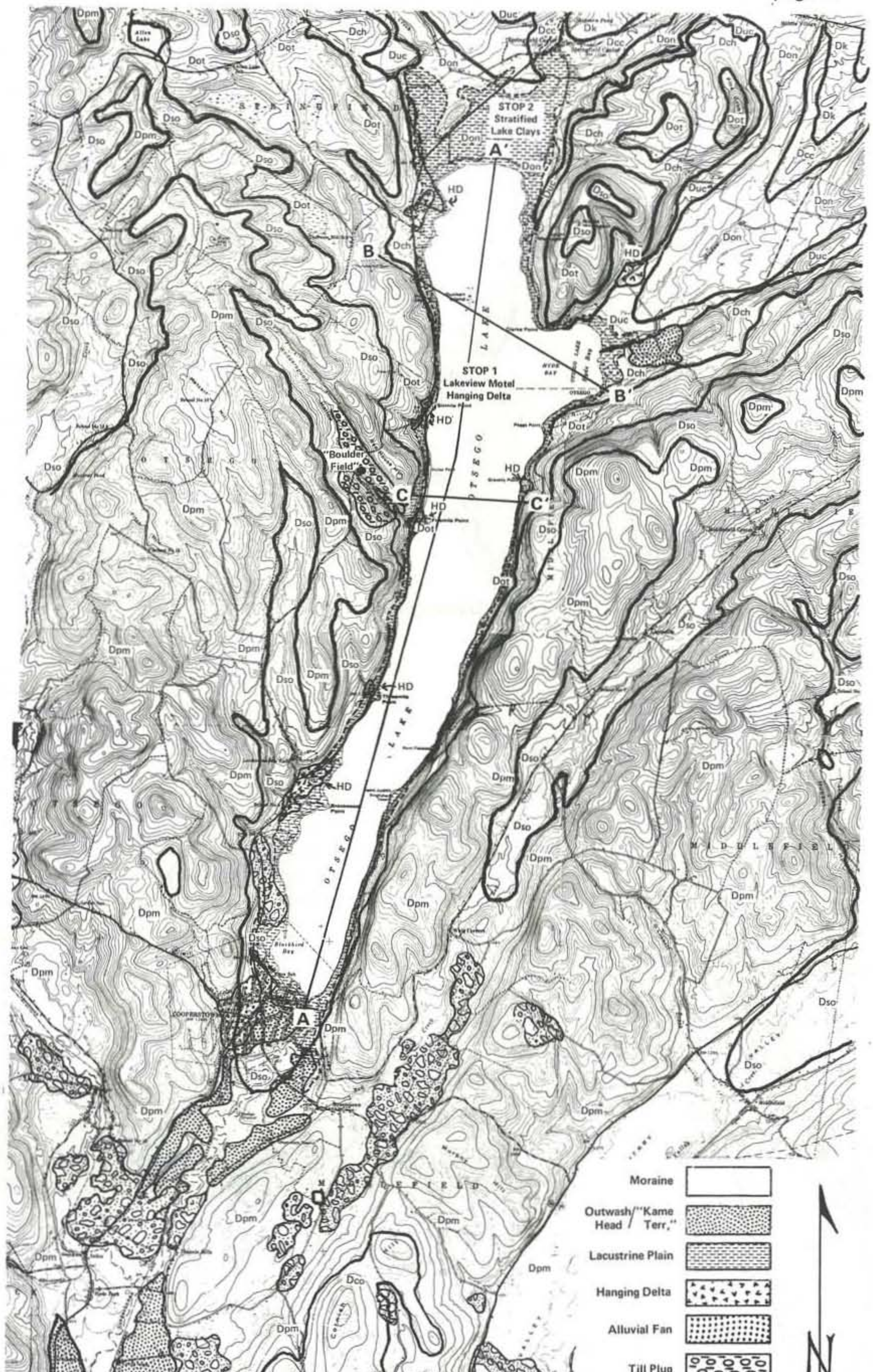


Figure 1. Composite topographic, Glacial Landform and Bedrock Contact Map of Otsego Lake area. Bedrock contacts taken from Rickard and Zenger, 1964. Glacial Geology taken from unpublished Reconnaissance maps by Fleisher and modified from Melia (1975). Mohican Canyon till plug to County Home - Hartwick Seminary terrace area added by Sales during reconnaissance for the road log.

Fig.2

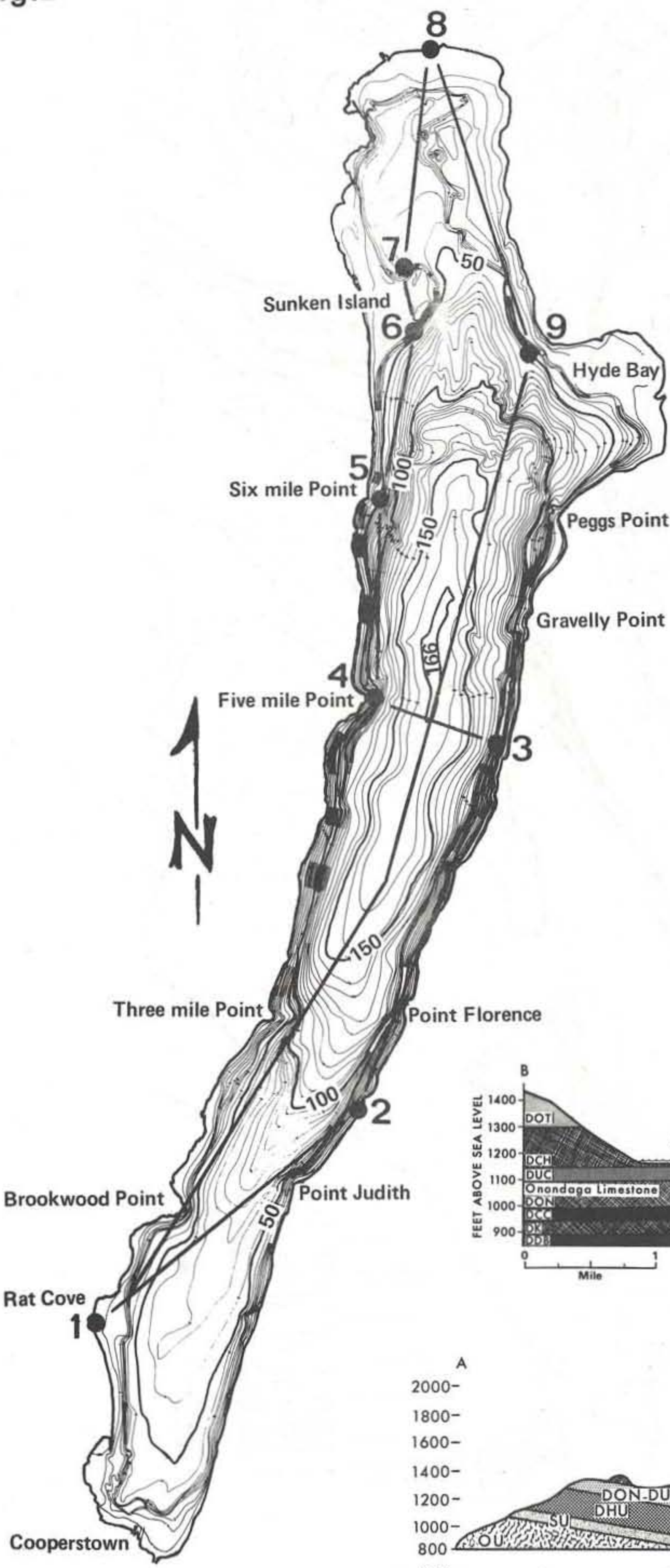
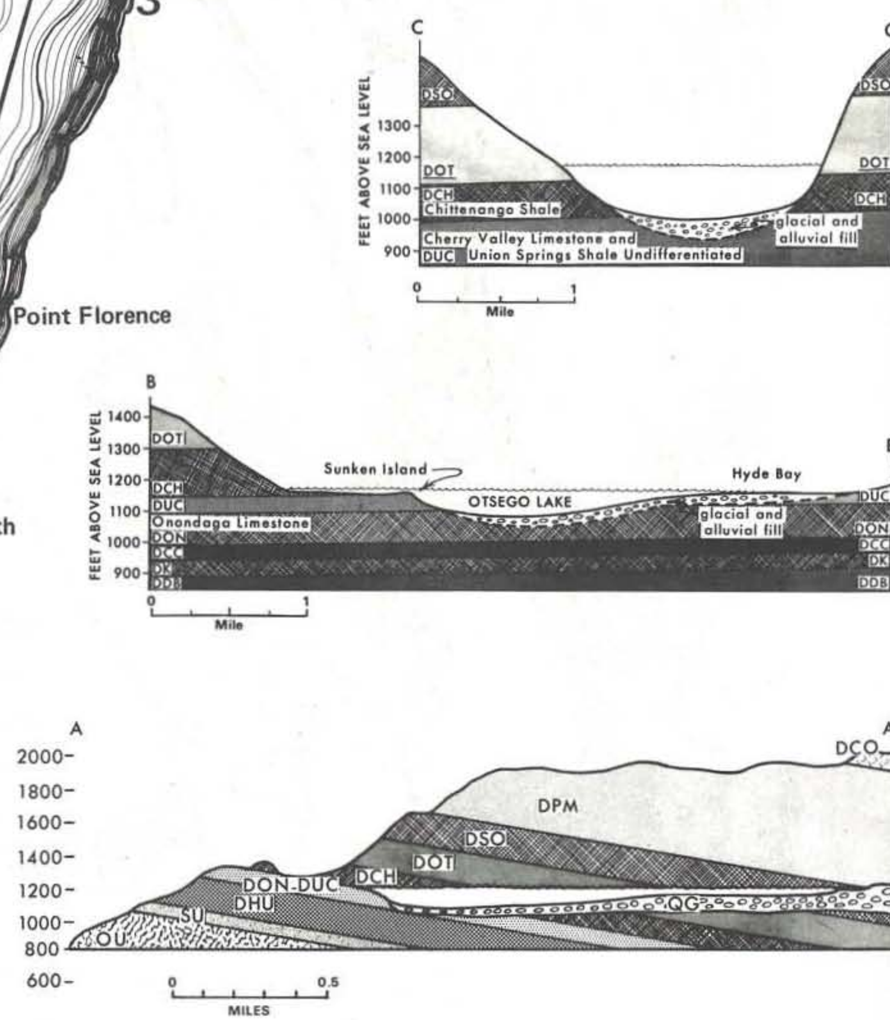


Fig. 3 - Diagrammatic cross sections of Otsego Lake.



Very finely and well-laminated lake clays are exposed at an elevation of 1240 feet at the intersection of Rt. 80 and County Route 53, in the ditch on the SE corner of the intersection approximately 1 mile north of the north end of the lake. These must be lake bottom pelagic clays deposited in quiet, protected water and below wave base under conditions (colder water?) that precluded bioturbation - all recent lake bottom clays and silts taken in cores from the present lake bottom are nearly non-laminated and apparently strongly bioturbated.

It is common that preglacial drainage oriented transverse to ice flow is often partly or completely filled with till during ice advance. Because of its hanging position above the lake trough, and because of incision by the postglacial Mohican Canyon, the till plug exposed there is an interesting and well exposed example. It may also be used indirectly to gain an estimate of amount of glacial down utting in the main valley. The base of the till plug and elevation of the preglacial (interglacial?) valley floor is at about 1320 ft. elevation about one mile from the axis of the trunk valley. If we take the gradient of the former side valley floor as a moderate 100 feet/mile the confluence with the trunk stream should have been at about 1200 feet elevation, which is very close to the present lake level. Paul Gieschen (1974) found an average of 250 feet of fill below the general 1200-1250 ft. level of the present valley floors. Assuming that the same depths to bedrock prevail under Otsego Lake (except that water is substituted for some of the fill) there has been about 250 ft. of glacial downcutting below the preglacial valley bottom. This depth is, of course, much greater if computed at the truncated spurs. The end of Red House Hill at 1600 feet has been also removed in the trunk valley to this same common depth (±950 feet), giving over 600 feet of downcutting by ice at the interfluves.

CAUSES OF THE REGIONAL TOPOGRAPHY

The regional topography is the result of the interplay between: 1) SSW dipping rock units of varying erosional competence, 2) interfingering of hard and soft SSW plunging rock tongues, 3) SSW trending basement faulting seen in the Southern Adirondacks and plunging southward under the area and transmitted subtly to the surface by joint development, 4) Cenozoic through Recent epiorogenic uplift of the entire Appalachian region that provided erosion potential, and 5) Pleistocene continental glaciation which deepened south trending valleys, filled cross trending valleys, and partially filled valleys with a combination of morainal and glacial fluvial debris. The first two of these topics are discussed in detail below.

Stratigraphic Control of the Topography

The Catskill Delta of Devonian age has long been considered a world classic example for the progradation of a clastic apron over the marine deposits of a shallow sea. The net result of this geometry is the upward and westward shift of facies from marine through littoral through continental as the delta grew. The marine facies is dominated by thinly bedded and fine grained shales, especially the Chittenango shale, which are the least resistant to erosion of the rocks in the Plateau. At the other extreme, the continental facies is dominated by well indurated, coarse grained and massively bedded sandstones and conglomerates which by contrast are very competent and slow to erode. The littoral facies is stratigraphically, geographically and in terms of erosive competence, intermediate between the two extremes, being dominated by sandstones and siltstones of moderate bedding thickness.

The regional southward dip in combination with the regional southeastward rise in topography cause the marine facies to outcrop dominantly in the north and west areas of the Plateau, the continental facies to outcrop dominantly to the southeast in the Catskill Mountains, and the littoral facies to outcrop in between. Since, in an area of slow epiorogenic uplift such as the Tertiary Appalachians, erosion and uplift approach a steady state, elevations closely reflect rock resistance. In the Plateau the slow and steady rise of topography southeastward into the Catskills is caused by and is a reflection of rock resistance.

In detail, however, the stratigraphy in the Catskill Delta is famous for its interfingering facies tongues, reflecting a cyclic advance and retreat of environments within the overall westward progradation. The interfingering is locally seen in local stratigraphic sections as a vertical interlayering of sandstone and shale or conglomerate and sandstone or all three. The scale is extremely variable with major tongues being many tens of kilometers long and hundreds to tens of meters thick stratigraphically, with many minor thinner tongues. In general, the ends of these facies tongues should parallel the long axis of the Appalachian Sedimentary Basin, though in detail they must show the same lobate disposition seen in many present day low lying shorelines, reflecting contributions from irregular source areas into irregular depocenters.

This internal geometry of the Catskill Delta in combination with the superimposed regional southward dip dictates several very important geometric relationships: 1) the intertonguing relationships must intersect the surface of the Plateau, 2) since dip is low a geologic map of the Plateau is essentially a vertically exaggerated cross section which, if viewed in a south to southwesterly direction at a low angle, is restored to an undistorted (down structure) cross section, 3) geometry demands that in a situation such as the top of the Panther Mountain tongue more competent sandstone-conglomerate facies, tongues wedge out westward and plunge southward to southwestward. This may be responsible for the tendency for west and north facing valley walls built against these tongues to be slightly steeper, 4) geometry also demands that more incompetent shaly tongues of a more marine facies die out eastward. This in combination with the regional dip requires that valleys cut in these incompetent tongues, in a transgressive situation, when followed eastward or northeastward should rise and blend into the upland surface beveled on the adjacent harder unit where the softer tongues wedge to nothing, 5) cuestas should have the same en echelon arrangement on the Plateau surface that facies tongues have in the classic cross section.

A facies tongue cuesta should grow westward or southwestward above a developing soft tongue valley, turn slightly southward or southeastward as the tongue thins, and plunge under the next soft valley to the south.

It is here suggested that the east walls of the valleys of Canadarago Lake, Fly Creek, Otsego Lake, Red Creek, and Cherry Valley Creek are basically facies tongue cuestas held up by resistant tongues in the Panther Mt. formation and straightened by ice flow. The valleys themselves are cut in shale tongues of the lower Hamilton Group. Valleys of Otego Creek, Fly Creek, and Red Creek rise and blend into the upland, suggesting that they are shale tongue valleys. The valleys of Canadarago Lake, Otsego Lake, and Cherry Valley Creek, however, have been over-deepened by glacial erosion. They have breached the Plateau front and been deepened into through-going troughs. This facies tongue control has to have occurred quite high, at least above any glacial trough downcutting.

LAKE DIMENSIONS AND GEOMETRY

The lake has a normal pool elevation of about 361 m. (1194.5 ft.) controlled by a small dam in the Susquehanna River just downstream from the outlet. According to Palmer (1974) the lake may attain levels .5 feet below and 2 feet above this mean elevation. Sohacki (1974) made a study of discharge within the watershed and from the lake, finding a lake discharge of about 2,400,000 ft.^{3}/24 hours. It is about 13 km. (8 miles) long and averages about 1.5 km. (1 mile) wide, with east-west width increasing from about 0.8 km. (0.5 miles) near the south end of the lake to roughly 2.4 km. (1.5 miles) at Hyde Bay near the north end.

Maximum depth of 50 m. (166 ft.) occurs about two thirds of the way toward the north end of the lake, about N45°E (Fig. 2, Fig. 3c) of Five Mile Point, which is located on the west side of the lake.

There is east-west symmetry below water level. The deepest part of the lake is almost perfectly centered between the east and west shores. This symmetry below water level is noteworthy because there is a pronounced asymmetry both in the Otsego Lake trough above water level and in the adjacent major valleys both to the east (Red Creek and Cherry Valley Creek valleys) and to the west (Fly Creek and Oaks Creek valleys) (compare Figs. 1 and 2). The regional map suggests that the asymmetry is a general feature of the region. In east-west profile the lake basin below water level has the noticeable U shape of glacial troughs. This contrasts with the much flatter bottoms of the valley trains in adjacent glacial valleys. It is not known what proportion of this profile is attributable to erosion and what to deposition.

ORIGIN OF LONGITUDINAL BASIN GEOMETRY

The longitudinal profile of the lake basin is asymmetrical (Fig. 2) with a steeper and more irregular northern or south-facing end and a more gentle southern end, and with the basin deep 2/3 of the way toward the northern end. The northern end, below a prominent shallow bench is both steeper and more irregular than its southern counterpart, suggesting that the same type of plucking that takes place on the lee sides of glaciated bedrock knobs may have been instrumental in removing the resistant Onondaga-Helderberg Limestones on this lee slope. Down-dip projection suggests that those formations should underlies that slope. The prominant gentle slope that floors the northern arm of the lake below the shallow bench is in the correct position to be an extension of the equally prominant dip slopes that occur on the Onondaga north of the lake.

The configuration of the south half of the lake is characterized southward by the flat basin deep, a gentle but very noticeable steeper slope up to about 65 feet depth and then a noticeably flatter area up to about 40 ft. depth, which is the base of the shallow bench.

There are two very different possible interpretations of this south half of the lake: (1) it is dominantly an erosional configuration caused by glacial scour of bedrock units of varying resistance, with only a conforming mantle of glacial fill; (2) it is a depositional configuration due to glacial fill above an essentially flat bedrock floor profile 200-300 ft. below lake level. A bedrock controlled configuration is supported by the fact that the mode of topographic expression of the bedrock units that should intersect the lake floor in this area correlates well with the topographic expression of the same units on the cuesta fronts northeast and northwest of the lake. Thus the basin deep would be etched in the very soft Chittenango shale, the same unit that has been stripped to form the Onondaga bench. The noticeably steeper midslope would correlate with the first subcuesta of the overall Panther Mt. cuesta, or the one held up by the relatively resistant lower Otsego shale. This unit forms the lower first cuesta above the Onondaga bench northwest of the north arm of the lake, and the same unit supports Cape Wykoff, Shankley Mountain, and Piney Cobble northeast and north of the lake, respectively. The higher flat on the lake bottom would correlate well with the line of swales in the upper Otsego shale aligned with Allen Lake northwest of the lake and with the saddles south of Cape Wykoff and Piney Cobble. Arguing against a bedrock carved profile and for a glacial fill profile for the configuration of the southern half of the lake is the fact that Gieschen (1974) has graviametrically computed depths to bedrock through Cooperstown village that suggests 279 feet of fill above bedrock. To honor this and still maintain a bedrock controlled erosional profile for the south half of the lake is nearly impossible, and suggests a more or less flat longitudinal bedrock profile some 100 feet below the bottom of the basin deep, with control of topography caused by amounts of glacial fill over this flat floor. As Gieschen, 1974 (p.44) points out, Fairchild (1924) has already suggested this "drift barrior" as the cause of the lake.

If this second (fill-dam) hypothesis holds true, it supports interesting speculations about the basic cause of the lake - why it is water rather than glacial fill: almost all wasting glacial tongues restricted in a confining valley debauch into a proglacial lake of some extent - it takes time after retreat of a glacier front to fill the glacial trough from its empty condition to a condition in which drainage is over the graded top of the accumulated valley fill. If fill contribution is locally small but previously deposited volume of valley fill downstream is great, a long lake develops. If local availability of fill is more than ample to fill the area immediately in front of the ice with debris up-grade of the outwash plain below, there is no lake at all. Thus there is a dynamic equilibrium at play with rapidity of retreat and build up of the downstream graded profile tending to increase volume of the lake, and sediment supply, especially downstream from the glacier and especially from side-entering tributaries, tending to decrease the volume of the lake. This concept applied to Otsego Lake suggests that as the glacier retreated northward and freed Oak Creek and Red Creek successively, such a large volume of sediment was dumped into the trunk Susquehanna that it was filled to grade, forming a very stable dam at that elevation. Excess material may even have extended the north facing slope of the fill northward to its present position. Contribution from the small clustered west slope streams along the southwest quarter of the lake between Leatherstocking Falls and Cooperstown may have supplied enough material to create the hump in lake bottom at Brockway Point. While the ice was being cleared from the main part of the lake and north along the Onondaga bench, the lake wasn't filled because there weren't enough large tributaries (of the calibre of Red and Oak Creeks) to supply this volume of sediment. Before the volume required could accumulate break-through of a lower outlet along the Mohawk diverted sediment discharge. Interestingly it should have also drastically and immediately cut the discharge of the Susquehanna and shifted the equilibrium from the high level grade, represented by the high terrace with kettles at 1250 feet, toward down cutting and terrace formation which as of today has lowered the river some 50 feet below its previous high stand.

DEVELOPMENT OF THE SHALLOW WATER BENCH

One of the most noticeable features of Lake Otsego bathymetry is the shallow water bench that rims much of the lake. The bench correlates in degree of development with the assumed sediment influx potential as reflected in the on-shore drainage area behind the bench (Sohacki, 1974). Thus it is best developed at the north end of the lake where the Allen Lake, Weaver Lake-Young Lake-Cripple Creek, and Hyden Creek drainages are bounded by divides as much as 9 km. from the lake shore. Its second best development occurs in the Hyde Bay where Shadow Brook also has its source several miles from the lake. Its development at the south end of the lake correlates well with the large subdrainage area provided by Glen Creek and the several creeks which enter the west side of the lakes between Cooperstown and Brookwood Point.

By contrast those areas of the lake basin which have no appreciable drainage area behind them and which show little postglacial dissection are nearly devoid of a bench. This includes the entire east side of the lake northward to Gravelly Point and the middle west side of the lake between the northern limit of the Brookwood Point Delta and the southern limit of the Sunken Island Platform. As a generalization those areas which do not have a wave built bench of soft sediment offshore have a tendency to have a small wave cut terrace developed at lake level.

There is also a good correlation between development of the bench and slope of the lake floor on which it is built. The generalization appears valid that wherever the slope of the floor approaches the average slope of the bench face no bench is present.

The bench appears to be best developed in areas where the shore behind it is both gentle and apparently constructional, being built of either glacial-fluvial or morainal deposits or postglacial alluvial-deltaic aprons. This raises the possibility that the bench is merely the sub-lake extension of the alluvial aprons developed on shore regarded to present wave base. The correlation of the bench lip with the 15 ft. contours suggests a depth control mechanism, but it is not sure whether this is mechanical wave base, a light, or chemical control of the sediment trapping aquatic plants,or some unknown mechanism.

There are areas of special interest with regard to bench development.
1) Sunken Island: Sunken Island near the northern end of the lake represents both one of the most elevated and most lakeward promontories of the shallow water bench. Depths on top of it are less than 2 m. and it is sometimes awash during prolonged dry spells. Among other possibilities, it may owe its origin to (a) an abnormal organic buildup if the general bench is organically built; (b) a high standing bedrock core either of roche moutonnee origin or of possible thickening in the underlying Cherry Valley Limestone due to Devonian reef buildup; (c) a lake-leveled drumlin core. Two somewhat similar features at Canadarago Lake--Deowongo Island and the Sunken Island near the west side of the lake--may have a common origin. Morphologically both of these appear to have a drumlin origin. Deowongo Island has a series of large (up to 2 m. in long dimension) boulders off its south end, visible on the lake floor. These could be a concentration of large erratics, exposed by winnowing out of till. There is some possibility, however, that they are large joint blocks plucked from the lee end of a roche moutonnee which cores that island. Thus the origin of these features and of Sunken Island in Otsego Lake could possibly be resolved by coring and sampling but at present is open to multiple interpretation.

The origin of the very flat area between Sunken Island and the shore likewise is unresolved. If beds in the bench area are of organic origin, the bench may merely represent favorable environment for carbonate secreting charophyte algae. If on the other hand it should be made up dominantly of clastic material, it may represent a "tombolo bar" mechanism with the material derived either from beveling of Sunken Island or from southward longshore drift of clastics winnowed from the Allen Lake Creek Delta front. Harman has pointed out on aerial photographs a noticeable counterclockwise drift in the lake, displayed in sediment plumes eroded off headlands. This is apparently common to most of the Finger Lakes and is usually attributed to Coriolis effect. This may, however, be due to a prevailing southwest wind bypassing the hilly western shore and creating a northward vector of drag along the east shore, with passive return flow south along the relatively sheltered west shore. There is, of course, no reason why the "organic" and "tombolo" mechanisms could not augment each other.

2) <u>The Allen Lake Creek Delta</u>: The Allen Lake Creek Delta at the northwest corner of the lake is unique in that the subaerial delta front extends all the way to the edge of the bench face in an area otherwise dominated by extensive bench development. This raises the dual possibilities that the subaerial delta (a) is merely a raised and perhaps non-beveled but otherwise normal portion of the more extensive underwater bench, (b) is later and physically overlies a normal and genetically different segment of the bench. Brookwood Point Delta seems similar. Coring on the delta might resolve this.

3) <u>Bench segment west of Mt. Wellington</u>: The bench segment west of Mt. Wellington on the east side of the north arm of the lake is interesting on several counts. It is the largest in the lake. It shows a noticeable inner linear depression parallel to the shore and an elevated outer lip. Depths in the inner depression are in the 5-7 m. range while those on the outer lip are in the 3-5 m. range, with an area less than 3 m. deep at the north end. The inner depression is bounded on either end by sharp declivities which appear to be erosional in origin. If these are subaerially eroded canyons, they would prove a previously lower water stand. If they are of submarine origin, they suggest effective cutting by some combination of density and/or longshore drift currents. There is a very sharp isolated high and an associated low at the outer edge of this bench segment which could possibly shed light on the orgin of the general feature. Tentatively they might be: algal buildups, large erratics, preserved kame and kettle topography, or bedrock outliers. Noticeably linear segments of this bench face might be joint controlled if the bench is partially of bedrock origin. If the bench has a constructional origin, the mechanism should be compatible with these straight segments. Some segments of this bench face appear to approach verticality which may enhance the possibility of exposure of the internal makeup of the bench.

SEDIMENTOLOGY

In an attempt to define sedimentological factors in the lake, 3 cores have been taken: one (A-1, 1.5 m. long), just north of the bench face in about 11 m. (30 ft.) of water about 100 m. (300 ft.) out from the town dock in Cooperstown, and two (A-2, 3.5 m.; A-3, 0.97 m.) from the lake deep in 50 m. (166 ft.) of water off Five Mile Point. These latter two cores come from the lake's deepest point as shown on Harman's (1974) bathymetric map (Fig. 2), and as located by sonar.

Two of the three sediment cores obtained in October, 1974 were cut into sections 0.1 m. long and examined petrographically.

Core A-1. During analysis grains larger than 1 mm. were sieved out and identified with a binocular microscope. Abundant aquatic snails, which occur throughout the core, have been described separately under the heading paleomalacology.

The lower section of the core, from 0.3 to 1.5 m. was grayish-white limy silty clay with abundant gastropods and gastropod fragments. At 0.8-0.9 m. in the cores were a few blackened twig fragments; otherwise there were no grains greater than 1 mm. in diameter. This part of the core represents relatively uniform biogenic sedimentation plus clays from suspension.

Sediment in the upper 0.3 m. of the core was limy gravely clay, with abundant snails. In the greater-than-1 mm. sieve fraction, 321 grains (excluding snails) were counted. Of these, 39% were fine grained sandstone and siltstone, brown to black in color; 16% were weakly consolidated brown silty clay clasts, 14% were twigs, seed hulls and other plant fragments; 8% were slag, presumably from railroads or the steam ferryboat which used to ply the lake; 2% were chert; and 1% were quartz and metamorphic rock fragments. The sandstone and siltstone grains were derived from the marine Devonian formations which crop out in the hills on either side of the lake. The chert grains probably came from limestones of the Onondaga and Helderberg Groups exposed along the Mohawk Escarpment to the north of the lake. The metamorphic rock fragments most probably come (via glacial transport) from the Adirondack Mountains.

Manmade slag first appeared in the core at exactly the same stratigraphic level as did non-manmade, natural grains such as sandstone, siltstone, chert, and quartz. This suggests that all, not just the slag, were recently introduced into the lake by man, rather than by completely natural sedimentary processes. (Plant remains such as twigs, however, occur both above and below 0.3 m.)

Core A-2. This core was cut into 10 cm.-long sections which were examined with a binocular microscope. The entire core consists of noncalcareous silty clay, olive black (5y 6/1) to olive gray (5y 4/1) in color, with less than 1% sand. The clay has a poor horizontal parting. There are slight changes in sediment color and in amount of decomposed black organic material (mostly bits of wood and leaves) which might allow lithologic subdivision of future cores into correlatable units. Colors cited are of moist, not dry, sediment, and follow the terminology of the Rock-Color Chart published by the Geological Society of America, New York (1963).

PALEOMALACOLOGY OF CORE A-1

Laboratory Procedures and Fossil Identification

This short (1.5 m.) core contained an abundance of aquatic pulmonate and prosobranch snails as well as much fragmental shell material. The core was sectioned into lengths which were placed in polypropylene vials and covered with 50% ethanol to prevent the sediment from drying out and to combat the growth of molds.

All intact snails and clamshells recovered from the core were counted and identified to species. Where possible shells were extracted by washing through a nest of sieves (2 and 1 mm.). Between 40 and 200 (the average being 100) shells were counted for each 0.1 m. interval and the results were incorporated into a general mollusk diagram (Fig. 4). Most shells smaller than 1 mm. in diameter were immature, hence the lower sieve size in the nest was 1 mm. For the identification of the mollusks the key by Harman and Berg (1971) was used.

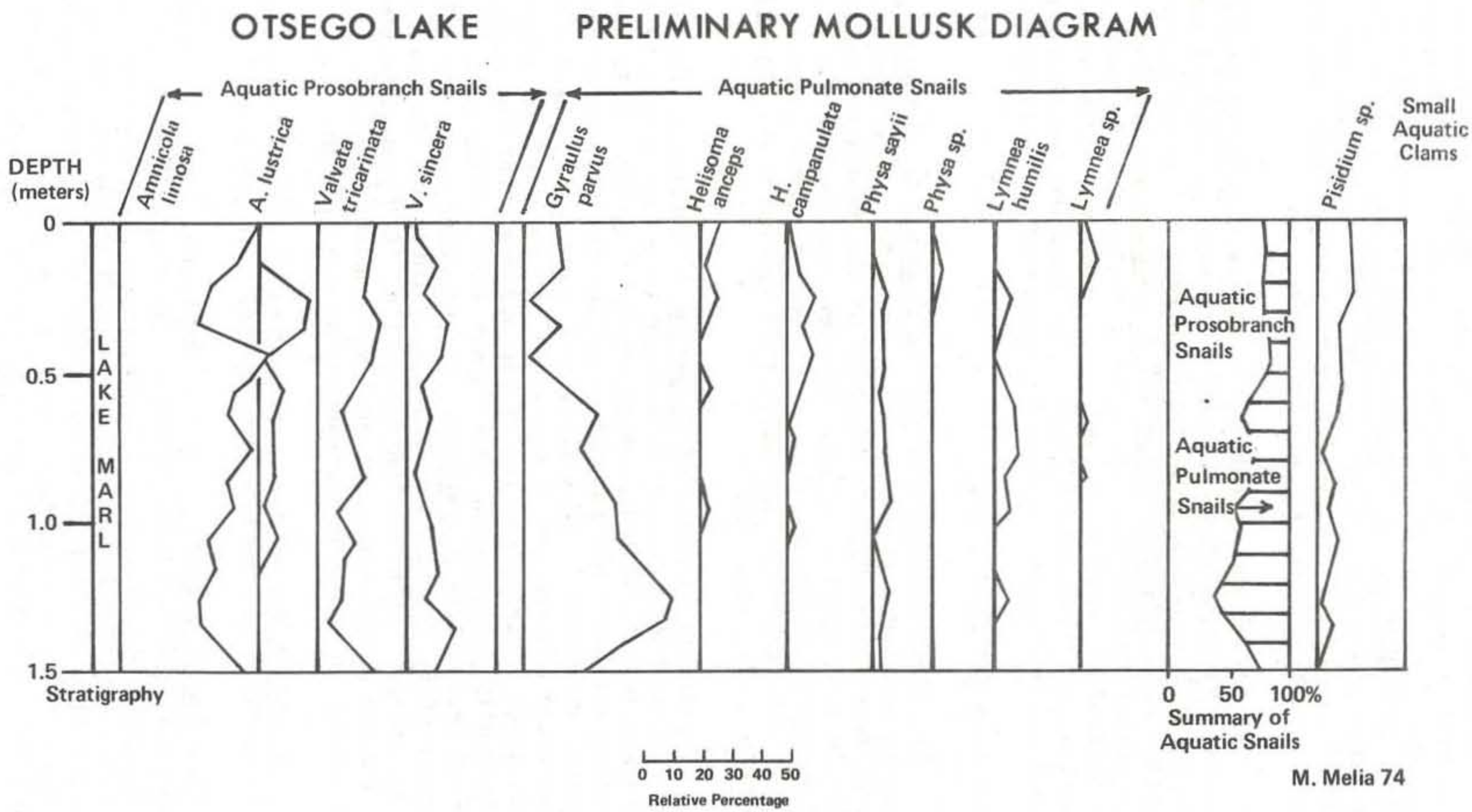


Figure 4. Preliminary Mollusk Diagram of Otsego Lake from Sales, et al., 1974.

Mollusk Stratigraphy

Prosobranch species were by far the most abundant mollusks in the core, and generally showed an increase in relative percentage upwards to the top of the core. Here they accounted for 70% of the total mollusks present. Amnicola limosa was by far the most numerous of these and accounted for at least 30% of all mollusks present (see Fig. 4). Similar observations were noted by Watts and Bright (1968) in a core from Pickerel Lake, South Dakota.

The most abundant pulmonate snail was Gyraulus parvus. This species, however, showed a marked decrease in relative numbers toward the surface from a maximum (51%) between 1.2 m. and 1.3 m. in core depth. Both Helisoma anceps and H. campanulata increased in relative percentage towards the top of the core, as did the small clam Pisidium sp. No terrestrial pulmonate snails were observed in the core. The mollusks only reported to genus were immature specimens whose species could not be determined with any degree of reliability.

Tentative Interpretations.

The great abundance of Amnicola limosa and Gyraulus parvus in the core is not surprising since they are both common species in the littoral zone where they are 'typical of the autochthonous organic matter association' (Harman, 1972). However, the decrease in relative numbers of G. parvus to the surface may reflect a recent decrease in the amount of bottom vegetation upon which this species lives (Harman, 1975, personal communication).

The greater numbers of G. parvus in the lower part of the core may reflect their greater resistance to being crushed by increased lithostatic load with increased depth of burial. This species is pseudoplanispiral and generally smaller than the other conispiral species in the core, therefore, a G. parvus shell with a small surface area would undergo less compression and consequently less crushing with depth. During sieving it was observed that the larger shells (especially Helisoma sp. broke apart more readily than the smaller shells (especially G. parvus). On the other hand, the relative numbers of G. parvus do decrease near bottom of the core and approach a percentage similar to that above 1 m. A 'Gyraulus maximum', then, related to environmental or ecologic conditions in the lake during the recent past may be represented on the diagram.

G. parvus may be over-represented in the core because of an overabundance of immature specimens of this species.

An Amnicola lustrica maximum between 0.2 m. and 0.4 m. in core depth may reflect recent interspecific competition on the parts of A. lustrica and A. limosa. Bottom vegetation, and hence snail populations, may have been disturbed by soft-sediment slumping or by the introduction of coarse sand and gravel of terrigenous origin, as noted in the section on sedimentology, this report. A. lustrica is less dependent on vegetation than is A. limosa, and thus would better maintain its population with changes in the substrate. At this point no positive explanation can be given for the demise of A. lustrica; it is still an inhabitant of the lake today (Harman, 1972).

Suggestions for Further Study

Clearly more information must be gathered before any firm conclusions about post-glacial changes of the mollusk population in Otsego Lake can be drawn. From a single 1.5 m. core which at best only spans a few centuries, a good reconstruction of the paleomalacology can not be gained. With more cores for correlation and perhaps some C-14 dates on the organic matter within the cores, a better picture might be perceived.

If pollen stratigraphy of the future cores is also obtained, the cores may be fit into the postglacial time framework where C-14 dates are not available.

Geochemical data must be obtained from the pore waters of the sediments in the lake in order to gain insight into the paleolimnological conditions and the influence of lake waters on the chemical solutions of shells. (Most shells in the present study were heavily pitted but were not abraded to any appreciable extent.)

Studies of the recent changes in the diatom populations of the lake should also provide paleoenvironmental information. Recent work by Del Prete (1972) has shown that diatom death assemblages may provide information about the postglacial depositional environments in lakes. Correlations between the diatom frequencies and geochemical analyses of the lake cores may also shed light on past lake conditions. Such a study was recently completed for Utah Lake, Utah (Bolland, 1974).

OTSEGO LAKE: CONTEMPORARY ECOLOGY

This contribution was written to provide background materials so that a better understanding of observable features noted in the log of the research vessel ANODONTOIDES can be understood from a biological point of view, and to explain, in a simplistic way how the results of processes now at work in Otsego Lake can confuse the characterization of ancient lakes.

It should be obvious that a lake is more than a hole in the ground filled with water. Aside from its morphology, every lake has its characteristic color, transparency, temperature regimes, combination of chemical compounds in solution, and not the least important, plant and animal populations. All of these (and more) interact in various complex ways to make each lake a unique environmental entity.

The distribution and abundance of living organisms drastically effects lake characteristics. For example; they modify oxygen levels, which in turn alter water chemistry which is extremely important in the building or degredation of sediments. Another example;

the reduction of the molar action of waves on shorelines and the concomittant trapping of silt and detritus in shallow areas for extended periods before it slumps into the deeper parts of the basin. Another, the precipitation of carbonates or silicates in the presence of various organisms directly forming sedimentary compounds.

Living things are dependent on inorganic nutrients (e.g.,phosphorus and nitrogen) in proper combinations and amounts to maintain viable populations. These nutrients cycle through ecosystems,often becoming trapped for extended periods and therefore unavailable for use. Their availability to organisms is affected not only by their presence in parent rocks, but by a lake's chemistry, morphology, and climate (and importantly in these times, populations of organisms living in the watershed). Therefore, we have come full circle. Initial action and resultant interaction cannot be distinguished.

Contemporary biologists spend much time discussing the potential productivity (the amount of protoplasm that can be grown there) of lakes. They call this the lakes trophic (energy) status. Bodies of water that are typified by great populations of algae and rooted macrophytes, turbid waters, and deep anaerobic organic sediments are considered very productive (eutrophic). Those with few plants, clear waters, and rocky bottoms are not productive at all (oligotrophic). Natural changes over time tend to turn oligotrophic lakes into eutrophic lakes because nutrients leached from parent rock are used by organisms, and recycled again and again, while more and more continue to be extracted from the bedrock (organic pollution is simply the result of the addition of "excess" nutrients from other ecosystems speeding up these natural changes).

However, lakes like Otsego are often called chemically eutrophic and morphometrically oligotrophic. Typical lakes in this climate (like Canadarago just to the west) with nutrient inputs similar to Otsego's are much shallower. When vast populations of algae in Canadarago die they fall to the sediments and are decomposed, during that process all of the oxygen in the lower waters is removed forming anaerobic sediments that release the nutrients for reuse by more algae when fall overturn (the breakup of thermal stratification) occurs. This results in greater populations of algae the next year and chronically reducing sediments.

Otsego is much deeper with a much greater volume of hypolimnion to surface area than Canadarago. The same amounts of nutrients entering would be used by algae (if not immediately lost into deep water). The algae would die and fall to the bottom, but since the volume of oxygenated water is so much greater, the oxygen is not completely used, sediments remain aerobic, and during fall overturn most nutrients remain chemically bound and are not returned to the surface organisms. This results in the maintenance of only small algae populations. Therefore in Otsego the greatest part of the lake appears oligotrophic but shallow isolated bays have superficially eutrophic characteristics.

A geologist 10,000 years from now coring Otsego Lake sediments could be extremely confused by taking a few cores scattered randomly throughout the basin. He could find fine and coarse grained anaerobic and aerobic sediments. Areas of $CaCO_3$ precipitates, and those where carbonates had been dissolved away. He could find fossils of organisms typical of eutrophic and those typical of oligotrophic waters. In order to determine the actual lake's characteristic, a knowledge of the distribution and abundance of those organisms present and a thorough knowledge of their ecological requirements (and restrictions) would be invaluable. Further, and I expect of more interest to geologists, the observations and analysis of sediments now being deposited in the presence of various biotic communities should be undertaken to use for comparison with their older counterparts.

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BOAT LOG - RESEARCH VESSEL ANODONTOIDES

Time from last point	Time Underway	(estimated at a research vessel cruising speed of approximately 2.5 miles/hour)
0:00	0:00	Biological Field Station, Rat Cove (Station 1). Shallow protected bay exhibiting surficial sediments of decomposing organic matter and precipitating $CaCO_3$ associated with *Chara vulgaris* and the rooted macrophytes. Surficial substrates oxidized and exposed to high (23°C) summer temperatures. Sediments and included subfossils illustrate population distribution of rooted plants according to their compensation points. Complexity of plant community and large standing crop is indicative of high potential productivity (eutrophy) and late stages in limnological succession.
0:05	0:05	Leaving the littoral area of Rat Cove. After the depth has exceeded the compensation point of *Potamogeton crispus* no more aquatic benthic plants can exist (profundal zone). Sonar indicates a rapid drop into the main basin which is practically flat bottomed as is typical of overdeepened glacial valleys. Note possible slump feature.
0:10	0:15	Deepest area long this transect. Must be underlain by 100 to 150 feet of fill above bedrock.
0:10	0:25	Kingfisher Tower. Bottom appears highly irregular as minor undulations are traversed parallel to the eastern shore.
0:05	0:30	Wave cut terraces derived from exposed bedrock (Station 2). No building possible because of sheer drop into basin.

Time from last point	Time Underway	
0:10	0:40	Wave built terraces. Stones sorted to size can be observed along entire terrace.
0:05	0:45	Pathfinder camp (Station 3). Start of transect across deepest point in lake (166 feet).
0:05	0:50	Center of basin.
0:05	0:55	Five mile point (Station 4). Contemporary delta. Angle of repose about 50°.
0:10	1:05	Lakeview Motel (Station 5). Walk to view delta formed in glacial Lake Cooperstown.
0:10	1:15	Sunken Island (South) (Station 6). Assorted boulders on lee of glacial advance. Formation may be a drumlin or a solid block of Cherry Valley limestone.
0:01	1:16	Sunken Island (North (Station 7). $CaCO_3$ nodules in association with blue-green algae. It's not known whether the algae are affecting the precipitation or if they are simply living in an inorganic precipitate.
0:14	1:30	Eel and associated "Islands". Possible blocks of limestone plucked from bedrock to the east.
0:10	1:40	North Shore (Station 8). Eroding sand beach. Illustrating effects of fetch of 8-9 miles from the south on a substrate similar to Rat Cove's over glacial till and/or coarse lacustrine deposits.
0:20	2:00	Clarke Point (Station 9). Eroding glacial till from the flanks of Mt. Wellington. In the spring, during ice break up, ice has been observed pushed up the shore to a height of 20 feet.
0:30	2:30	Ekman dredge sample from deepest point in the lake (166 feet). Essentially anaerobic silts covered with aerobic surficial sediments with tremendous amounts of organic oils and trapped nutrients. Constant 4-6°C temperatures year around.
0:30	3:00	Return to Rat Cove (Station 1).

ROAD LOG - OTSEGO LAKE

Road log starts from the Museum parking lot on the east side of Rt. 80 at entrance to Biological Field Station about 1/2 mile north of the Fenimore House and Farmer's Museum. It then proceeds north up the west side of Otsego Lake on Rt. 80. General bedrock geology covered in Rickard and Zenger, 1964.

Miles from last point	Cumulative Miles	
0.0	0.0	This entire area seems to be built on an undulating surface of low relief that averages 50 feet above lake level. Because of degree of undulation it is classified as moraine. There is some possibility that it may be a poorly developed distributive hanging delta into the shallow end of the lake from the several streams entering this general area of the lake. Bedrock rise across the road is a ledge of Solsville sandstone which is well exposed a few hundred feet to the south.
0.9	0.9	Road entering from the left passes close by Leatherstocking Falls of James Fenimore Cooper fame. A pullout 0.2 mile up this road affords a good view of the falls when water is high and leaves are off. The falls are, however, hard to see in summer. Leatherstocking Falls is caused by the same resistant ledge of upper Solsville sandstone seen on the golf course at mileage 0. Large open field on the right side of the road represents the undulating top of the Brockway Point hanging delta. This undulating top may possibly indicate continued growth and regrading during periods of water level fluctuation.
0.1	1.0	Bench mark on bridge over Leatherstocking Creek at 1251 ft. elevation can be seen to be approximately level with the top of the hanging delta.
0.35	1.35	Tennis court next to the lake is on the modern Leatherstocking Creek delta graded to the present lake level. Between here and the previous stop the creek can be seen to be incised below the older delta level. More or less continuous exposures of the lower Solsville shales on the west side of the road for the next several hundred feet. (Fossil list contained in Rickard and Zenger, 1964, p. 78.)

Miles from last point	Cumulative Miles	
0.65	2.0	Entrance to Three Mile Point. If open, this point affords one of the best views of the lake. The over steepened eastern wall of the glacial trough is very apparent and, if lighting is right, the consistent southward regional dip (approximately 100 feet/mile) can be seen in the foliage pattern, reflecting the ledges and benches and changing chemistry of the various rock units. The contact of the Solsville shales over the Otsego shales is about at road level on both sides of the lake and passes under lake level a few hundred feet to the south. Kingfisher Tower, a well known scenic landmark can be seen slightly to the south and across the lake at the water's edge. On the west side of the road the large house sits on what appears to be the top of the Three Mile Point hanging delta. Leveling up from the benchmark in the wall near the road suggests this elevation again to be very close to 1250 feet.
0.8	2.8	Terrace Motel for reference.
0.1	2.9	Exposure of bouldery till on west side of road. Nearly all of the large erratics are from the several resistant limestones which crop out along the Onondaga-Helderberg escarpment several miles to the north, with almost no contribution from the local bedrock which, being Otsego shale, can only be pulverized and contribute to the clay matrix.
0.1	3.0	Discontinuous outcrops of the Devonian Otsego shale on the west side of the road.
0.1	3.1	Wide open views of the lake but no good pull offs. Five Mile Point visible northward up west shore. Max. depth (166 feet) occurs in the center of the lake just off this point.
0.55	3.65	Crossing Five Mile Point delta contributed by Wedderspoon Hollow Creek via Mohican Canyon. A new delta graded to present lake level forms the point, with older elevated delta remnants up at road level at about 1250 feet. The stream is still incised into bedrock on the east side of the road so the area of the delta is rather small, perhaps because it is built on a very steep area of the glacial trough wall.

Miles from last point	Cumulative Miles	
		The delta front falls off very steeply to the lake deep and according to Harman who has dived along the front is made up of very coarse cobbles with abundant coarse plant debris.
		This intersection is the start of Auxiliary side trip up Mohican Canyon on County Rt. 28. Main log continues north on Rt. 80 - readjust your mileage if you take this side trip.
0.75	4.40	Lakeview Motel. Obtain permission to drive up behind motel to an excellent exposure of a cross section of a hanging delta. This shows coarse cobbles (apparently similar to those being deposited today on the front of Five Mile Point delta) foreset toward the lake and grading and interfingering with sands deposited lower on the delta front. While the top of the delta is very level there is no sharp contact internally between horizontal topset cobbles and the inclined foreset cobbles, but rather a blending. Leveling up from the water suggests an elevation of about 1255 feet for the upper level surface. This is the most significant exposure proving the former high lake stand.
1.0	5.40	Remains of Sunken Island sign. From here Sunken Island (of James Fenimore Cooper fame and awash with 3-6 feet of water)is located nearly half way across the north arm of the lake and slightly to the north of a line to Clarke Point which separates the north arm from Hyde Bay. See Lake Log for considerable additional detail.
1.1	6.50	Bridge over Allen Lake Creek. Benchmark in the middle of east bridge wall (1253 feet) provides excellent control for leveling the noticeably flat surface of the elevated delta just to the south of the bridge.
0.4	6.90	Clark Pond-Cripple Creek bridge.
0.4	7.30	Well defined NE-SW trending drumlin on west side of road upon which the Episcopal Conference Center is built.

Miles from last point	Cumulative Miles	
		This is one of the southern most representatives of the well known field of east-west trending drumlins that sits on the Onondage bench to the north. It was deposited by ice moving westward up the Mohawk Valley. Flow lines of the drumlins suggests that ice flow curved smoothly southward into the Otsego Lake trough.
0.5	7.80	Turn east on County Rt. 53 and stop. Lake clays of the former high lake stand preserved in drainage ditch on the southeast corner of the intersection. These are very well laminated (varved?) and are at an elevation of 1240 feet. At the 1250-55 ft. lake stand these should have been well out from shore and just below wave base on this very flat area of the Onondaga bench. It is interesting that all modern sediments taken from the lake, while equally fine grained, are strongly bioturbated and non-laminated.
0.4	8.20	Excellent view south over former flat lake bottom, presumably underlain by the high-stand lake clays, south into the Otsego Lake trough. Mt. Wellington, the "sleeping lion", at two o'clock rises from the Onondaga bench and is capped by the Solsville formation.
1.0	9.20	Near top of pass at north end of Mt. Wellington (Wow! - sounds like the Canadian Rockies) stop and look back. Good view of the topographic break between the drumlin covered Onondaga bench to the north and the ledgy cuestas of the Panther Mountain-Solsville escarpment to the south. Rum Hill (Mt. Otsego), 2100 ft. and the highest point on the escarpment is directly in line with the road.
0.6	9.80	Intersection with Griggs Road. Overview of Shadow Brook valley. Piny cobble at 10 o'clock. If light is right several drumlins can be seen along and parallel to the base of the Panther Mtn. escarpment that forms the southeast side of the valley. They may have been shaped from the underlying Chittenango shale outcrop along the base of that escarpment. This soft shale may have provided the clay rich matrix material for the till. Foreground flat is not true valley bottom, but a southerly extension of a well-developed dip slope cut on the upper contact of the resistant Onondaga limestone as the Union Spring-Chittenango shales were stripped off.

Miles from last point	Cumulative Miles	
0.2	10.00	Intersection with Continental Road. Continue straight across bench, around sharp curves and off edge of Onondaga bench.
0.7	10.70	Bridge over Shadow Brook running on bedding in Onondaga. Notice that while the very low dip is typical, the strike here (North 85°East) is atypical, since in general regional strikes are very consistent at about North 70°West.
0.3	11.00	Well at yellow house logged a thickness of lake sands that may require some further down cutting below the levels exposed in the stream, although the anomolous strike and dip should help accommodate this depth of fill.
0.2	11.20	Turn south onto County Rt. 31 and return to Cooperstown via east side of lake.

Summary of East Shore Geology (No mileage or specific stops.) The extreme steepness of the east side of the lake in combination with its very forested nature make the geology less diversified and harder to see. While mostly hidden in the trees, some of the resistant bedrock members form prominent cliffs and ledges on the hillside. One of these contains Natty Bumpo's cave of James Fenimore Cooper fame. The upper Solsville (C) sandstone creates some high waterfalls in some of the very sharp and steep gorges draining this glacially over-steepened slope. The best, easily accessible bedrock exposure is along the first side road branching to the right as you drive north out of Cooperstown up the east side of the lake. A large but over grown quarry on the right several hundred feet up this road provides good exposures of the Panther Mountain lithologies (best exposures are way to the right as you enter the quarry and hidden around a corner). Bedrock is well exposed intermittently at lake level, where a small wave cut bench can sometimes be seen at present lake level with prominent underwater cliffs outward from the bench (see lake log). Driving the road one gets the impression that it may be partially built on a similar wave cut bench related to the former high water stand, especially just north of Kingfisher Tower, but this may be just a case of a bedrock ledge intersecting road level at this point.

Optional Side Trip
Mohican Canyon-Wedderspoon Hollow

Zero speedometer at intersection Rt. 80 and County Rt. 28

Miles from last point	Cumulative Miles	
0.0	0.0	Start Auxiliary Log.
0.0	0.0	Continuous exposure of the upper beds of the Otsego shale. Better and more picturesque exposure available at stream level, including a 10 ft. water fall.
0.15	0.15	Contact of Otsego shale and upper Mohican Canyon till plug exposed on both sides of road cut at an estimated elevation of 1320 feet.
0.2	0.35	Road and stream lower sharply in gradient at approximately 1330 feet onto the floor of the Wedderspoon preglacial valley. All exposures in the walls of Mohican Canyon above this elevation appear to be lodgement till. Subtracting this 1320 ft. elevation from the noticeably gentle surface at an elevation of ±1500 feet at the top of Mohigan Canyon suggests a 180 ft. thick till plug.
0.32	0.67	Large turn out on south side of road. Bedrock till plug contact exposed at stream level below turn out but with considerable slumping of till into stream.
0.45	1.12	Good exposure of clay-rich lodgement till with 6 foot limestone erratic. More or less continuous exposure of till on high side of road for the rest of the way up the canyon.
0.52	1.64	Cross culvert over creek. Immediately across the creek is the "Piorstown Boulder field", an area of solid erratics with no matrix covering an area about 50 feet square. Most of the rocks exceed two feet and some are as large as 4 feet in diameter.
		About 90% of the field including the largest and best rounded erratics are Adirondack crystallines. Less than 10% are limestone (averaging smaller and less well rounded) with only a very small <5% contribution of smaller cobbles from the local bedrock.

Miles from last point	Cumulative Miles	
		Size of the erratics suggest that this may be a natural winnowing process. It may, however, have been dumped there in clearing the large flat field that defines the top of the till plug above the boulders. In either case, it is an excellent sample of erratics characterizing the till plug.
0.05	1.69	Intersection of Rt. 28 and Wedderspoon Hollow Road at the top of till plug exposure.

Options from Intersection

1.) Return directly to Rt. 80 via same route.
2.) Small quarries in the upper Solsville (C) Ledge forming sandstone are exposed 0.3, 0.5, 1.5 miles south of this intersection (left turn).
3.) A right turn at intersection plus another right turn on a dirt road 0.1 miles after that takes you over Red House Hill and back down to Rt. 80 with a high scenic view of the north end of the lake from the crest of the hill.