DEVONIAN STRATA AND PALEOENVIRONMENTS: CHAUTAUQUA COUNTY REGION: NEW YORK STATE

GORDON C. BAIRD and GARY G. LASH
Department of Geosciences
State University of New York College at Fredonia
Fredonia, New York 14063

INTRODUCTION

The history of the study of the Paleozoic stratigraphic divisions in New York State spans, at least, two centuries, and it records the early development of important concepts centrally germane to the study of sedimentary basins worldwide (see Tesmer, 1989). The works of James Hall, John Clarke, Henry S. Williams, Joseph Barrell, and George Chadwick are well known to most sedimentary workers, as are those of numerous subsequent workers. In particular, the sedimentary sequences of the Allegheny Plateau Region ("Southern Tier" region) served as important sources of information for refinement of the facies concept and for the widespread recognition of the westwardly prograding Catskill Delta Complex which is the primary Paleozoic story recorded in Southern Tier bedrock deposits (see Chadwick, 1924, 1933; Cooper, *et al*., 1942; Caster, 1934; Woodrow, 1985).

The first significant geologic work relating to the Chautauqua County region was presented in James Hall's (1843) *Survey of the Fourth Geologic District*. Subsequent stratigraphic studies in this area include Clarke (1903), Chadwick (1923, 1924), Caster (1934), Pepper and de Witt (1950, 1951) and de Witt and Colton (1953). In northwest Pennsylvania, significant synthetic contributions include I.C. White (1881), Butts (1906-1908), Chadwick (1925), Caster (1934), Pepper et *al*. (1954). In Ohio, deposits equivalent to parts of the New York and Pennsylvania Upper Devonian section (Chagrin Shale) have been the subject of recent paleoenvironmental studies (see Weidner and Feldmann, 1983; Schwimmer and Feldmann, 1990). The present authors particularly build from the comprehensive work of Tesmer (1963) and the subsequent work of Murphy (1973) and Burrier (1977).

Both prior- and ongoing studies of the present authors are directed to the Canadaway-Chadakoin succession exposed on the Lake Erie lowland plain and adjacent escarpment. One of us (Baird) is currently tracing Chadakoin strata from Ohio northeastward along the escarpment to the vicinity of Fredonia, and he is also examining eastward (upslope) facies changes associated with the base of the Dunkirk Shale Member. Lash is currently working on the origins of interbedded siltstone-shale deposits and massive siltstone units (Laona and Shumla members) within the Canadaway Formation.

Despite the earlier regional mapping syntheses of White, Butts, Caster, and Tesmer, the Devonian bedrock geology of the western Southern Tier and northwest Pennsylvania region is not as well known as the classic Middle Devonian and lower Upper Devonian (Frasnian) succession to the north. One reason for this is the apparent paucity of widespread mappable event-beds and discontinuities in the thick high Devonian (Famennian) succession; this problem, coupled with the sparsely fossiliferous nature of many of the thickest units may have discouraged many from attempting to map or study these deposits. A second problem is the relative scarcity of long, clean, continuous stratigraphic sections in the Allegheny Plateau region southeast of the Erie Lake escarpment.

During this field trip we hope to dispel any impressions that this region is a geological "Empty Quarter"-that these deposits are "monotonous" and "unmappable;" we intend to show that, through preliminary mapping of certain units within the Late Devonian (Famennian) Canadaway and Chadakoin formations, we have already found additional mappable key beds, critical to refinement of the existing stratigraphy. In addition, reconnaissance examination of creek and Lake Erie shore sections has turned up both sedimentological and paleontological surprises.

In the present paper we examine more closely beds and facies associated with the boundary between the Hanover and Dunkirk members; in particular we document the occurrence of a black shale-roofed discontinuity near the base of the Dunkirk and its complex eastward passage to extinction. Higher in the Canadaway Formation we examine a distinctive basinal facies ("zebra-facies") characterized by thin repeating alternations of minimally bioturbated black and green shale beds. We report the distinctive and problemmatic occurrence of pyritic microspheres and partial microspheres which occur at hundreds of levels within the Canadaway Formation and which display evidence of exhumation and hydraulic concentration at many stratigraphic levels. In addition, we discuss the biota and distinctive preservation of pyritic fossils in the Corell's Point Goniatite Bed within the Gowanda Shale Member. Moreover, we will discuss the inferred depositional history of massive Canadaway siltstone units, particularly exemplified by the Laona Siltstone (see Stops 1 and 4), which are important thin stratigraphic markers in Chautauqua County. Discussion of the basal Dunkirk-, Corell's Point Bed-, pyritic microsphere-, and Laona Siltstone-problems are respectively complemented by field trip stops 1 to 4.

The stratigraphy and facies gradients within the Chadakoin Formation are described and discussed with respect to refined mapping of the Foerstia (Protosalvinia) zone across northwest Pennsylvania and western Chautauqua County; discovery of a thin zone of concentrated Foerstia, sp. (probable reproductive structure of an extinct fucoid alga) in Twentymile, Chautauqua, and Prendergast creeks, allows more precise matching of the New York and Pennsylvania Chadakoin sections and it has led to the recognition of mappable key beds and intervals particularly within the Ellicott Shale Member.

Finally, we will examine and discuss the coarse, nearshore facies of the Cattaraugus Formation. In particular, we will discuss the anomalously thick lentils of the Panama and other similar "white pebble" conglomerate units in the New York Cattaraugus section as to their inferred depositional setting and transport history. Stops 6 and 8 are respectively directed to the examination of the interval of concentrated Foerstia within the Ellicott Shale and to examination of the Panama Conglomerate within the Cattaraugus Formation at Panama Rocks near Panama, Chautauqua County.

LATE DEVONIAN PALEOGEOGRAPHIC, PALEOENVIRONMENTAL, AND TECTONIC SETTING

Using the Late Devonian reconstruction of Scotese et al., 1985, the western New York study area was positioned at about 3° to 5° South latitude in what must have been a tropical climatic regime which was moist, or, at least seasonally moist (Fig. 1). A broad epicontinental sea covered the study area, but a prograding shoreline existed to the immediate southeast of the Cattaraugus-Chautauqua county region. A rising collisional overthrust complex, the "Acadian Mountains" was present in the eastern Appalachian region; this uplift apparently was a response to convergence of the Armorican Plate or Avalon terranes with Laurussia and it involved diachronous northeast-to- southwest oblique collision with extensive strike-slip and transpressive tectonic activity (see Ettensohn et al. 1988).

Uplift of the Acadian Mountains was accompanied by the formation of a large foreland basin to the west and northwest of the overthrust belts (in the present directional sense); erosion of the tectonic uplands resulted in gradual filling of the trough with terrigenous deposits to form the Catskill Delta Complex (Fig. 2). The first evidence of major orogeny-related basin-filling is recorded in the Lower-Middle Devonian (Uppermost Eifelian-Lower Givetian-age) Marcellus Formation in eastern New York; by the time maximal basin-filling and coastal progradation were affecting westernmost New York during the latest Devonian (Famennian) the Catskill Delta had prograded hundreds of kilometers to the west and southwest (Ettensohn, 1985; Woodrow, 1985). By the lower Mississippian, basin-filling was largely complete in New York State, but epicontinental marine conditions persisted in northwest Pennsylvania and Ohio (Fig. 2).

The Devonian epicontinental sea was apparently deepest to the west and southwest of the prograding delta complex and the water column was typically stratified in the basin center during the Late Devonian with prominent and periodic development of salinity- and/or temperature-related density layers (pycnoclines) in deeper areas. Tropical upwelling, influxes of fresh water from deltas, and thrust load-related deepening of the foreland basin are all factors which may have caused the basin stratification (Thayer, 1974; Byers, 1977; Ettensohn, 1985; Woodrow, 1985) anoxic conditions in the basin with the consequent deposition of organic-rich, laminated muds below the pycnocline. Transgressive rises of the pycnocline apparently produced, in ascending order, the Oatka Creek, Geneseo, Middlesex, Rhinestreet,

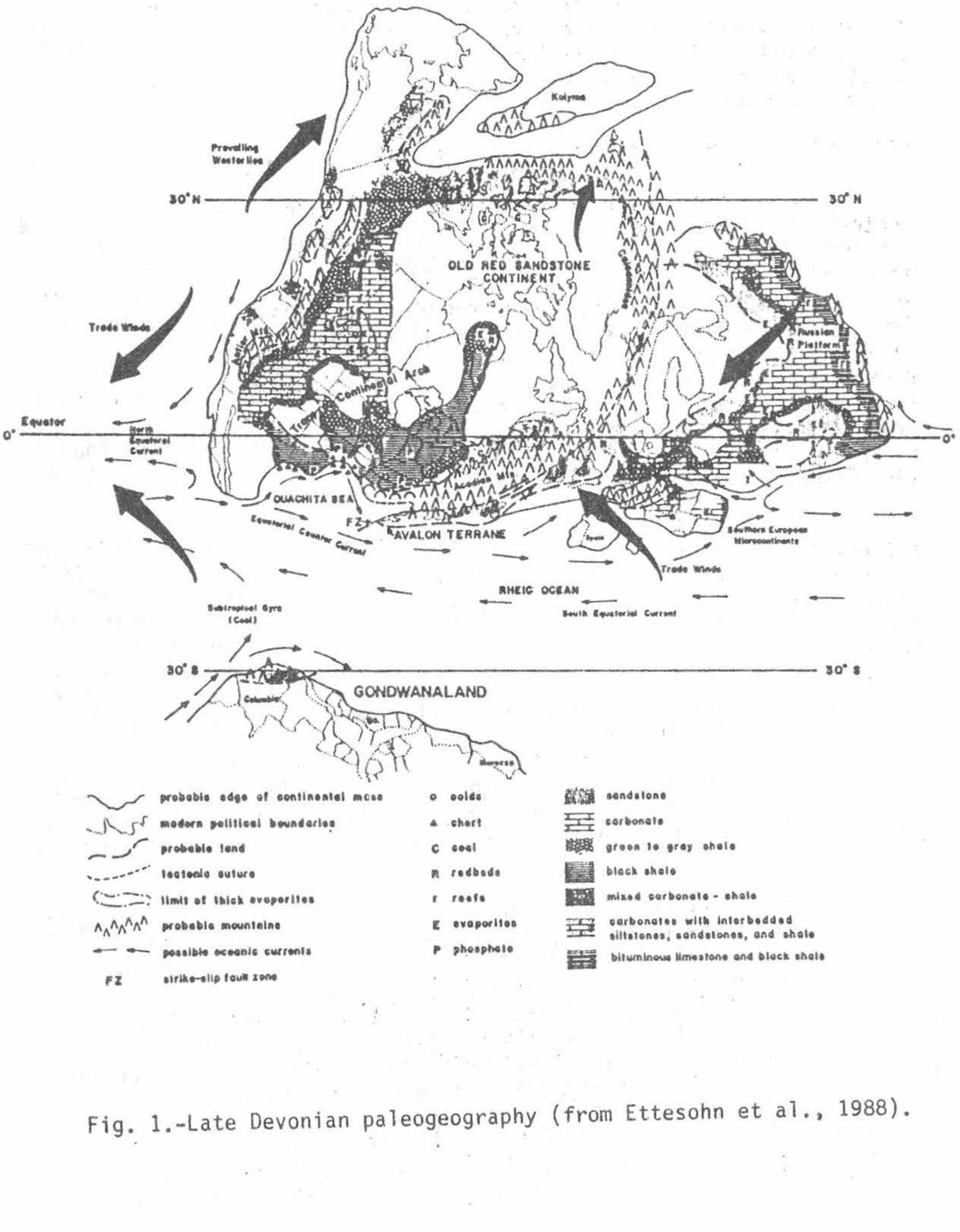

Fig. 1.-Late Devonian paleogeography (from Ettesohn et al., 1988).

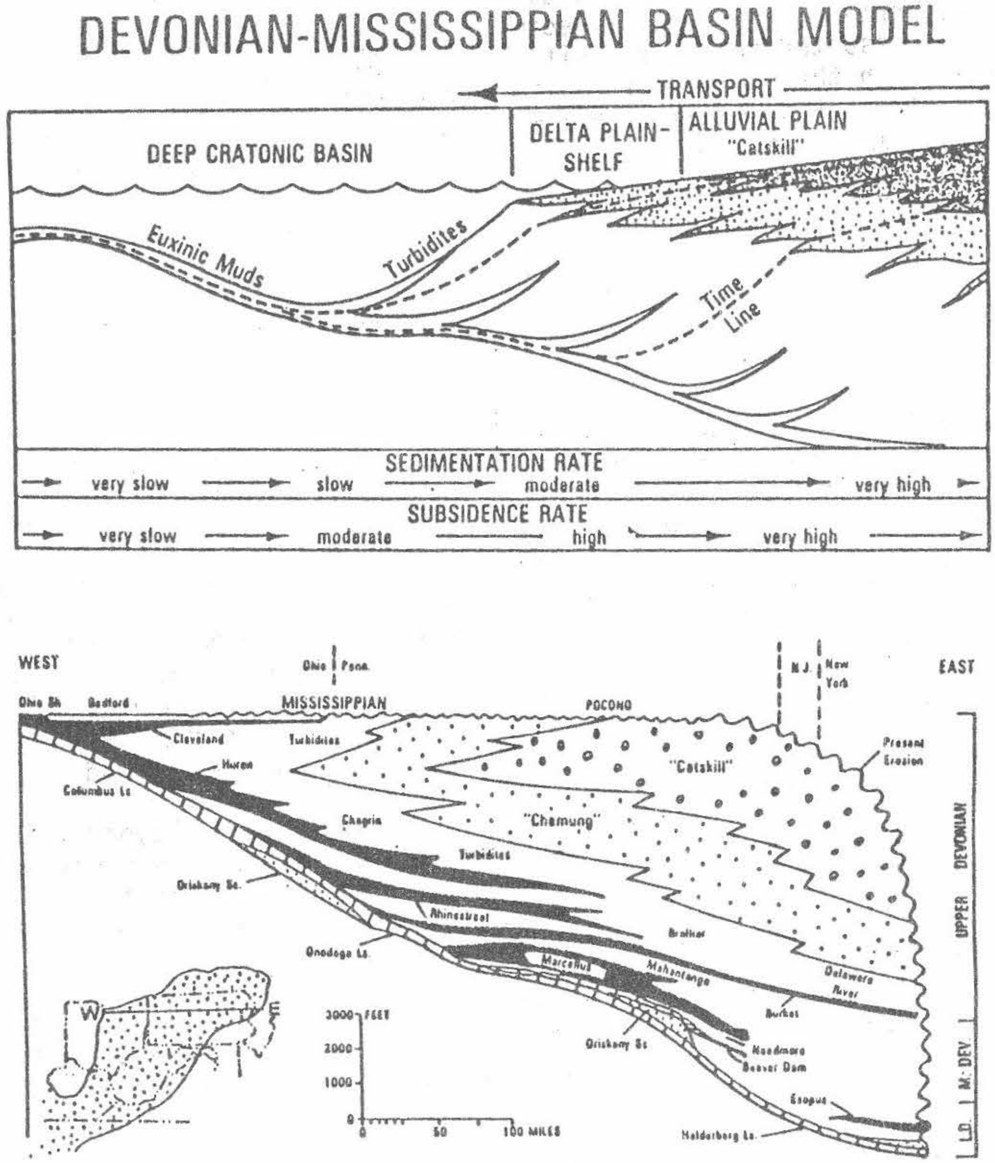

Fig. 2. Idealized east-west cross-section through Catskill Delta Complex: depositional model (top) and simplified stratigraphy (bottom). From Broadhead et al., (1982).

Pipe Creek, and Dunkirk black shales as well as many thinner unnamed black shale units. During times of relative sea level fall large areas of the epicontinental seafloor became variably oxygenated; such conditions resulted in the deposition of green-grey, bioturbated muds, sometimes with the shell debris of various bottom organisms. The vertical alternation of major black and grey-green shale unit in the Upper Devonian prodelta and basin deposits in western New York probably records temporal, cyclic changes in sea-level and paleoclimatic conditions which are superimposed on longer-term tectonic and progradational processes.

STRATIGRAPHIC FRAMEWORK AND FACIES UNITS

Stratigraphy

Upper Devonian (Famennian) deposits in the Chautauqua County - northern Erie Co., Pennsylvania region include approximately 600 meters (1,900 ft.) of marine, nearshore marine, and nonmarine deposits (see Fig. 3). We will examine only a small fraction of this overall succession at eight field stops; the lowest level we will visit is the Hanover Shale-Dunkirk Shale contact near the Frasnian - Famennian stage boundary and the youngest unit will be the Panama Conglomerate within the Cattaraugus Formation. Generally the stratigraphic sequence becomes coarser from the base upwards and there is an overall regressive lithologic transition from basinal black shale facies at the base, through a long prodeltaic succession of interbedded siltstone and bioturbated grey mudstone layers, to siltstone- and sandstone - dominated, shell-rich delta platform deposits at the top. Beyond the reach of our day-long field trip venue are red bed tongues in eastern Chautauqua, Cattaraugus and Allegheny counties which approximate the western limit of nonmarine conditions at the time the Cattaraugus Formation was deposited (Tesmer, 1963). In principle, most of the layers within the Famennian sequence individually grade eastward-southeastward ("upslope") into coarser, shoreward equivalent deposits, and westward-northwestward ("downslope") into finer basinal facies reflecting the generalized Waltherian facies pattern of this part of the Catskill Delta (Fig. 2).

The Famennian stratigraphic succession in Chautauqua County includes three formations (Fig. 3), using the nomenclature of Tesmer, 1963; Buehler and Tesmer, 1963; Tesmer, 1974, 1975; these include in ascending order the Canadaway, Chadakoin and Cattaraugus formations which are unconformably overlain by the Mississippian Knapp Conglomerate in New York, (Tesmer, 1963, 1975). There are still younger Devonian divisions in Ohio; the black Cleveland Shale and still higher basal strata of the grey Bedford Shale yield Devonian clymeniid goniatites (see House, et al, 1986).

The Canadaway Formation is composed mainly of fissile, organic-rich black shales, usually interbedded with green bioturbated or non-bioturbated mudstone and siltstones. With the exception of the Corell's Point Goniatite Bed and a few other, similar pyrite-rich,

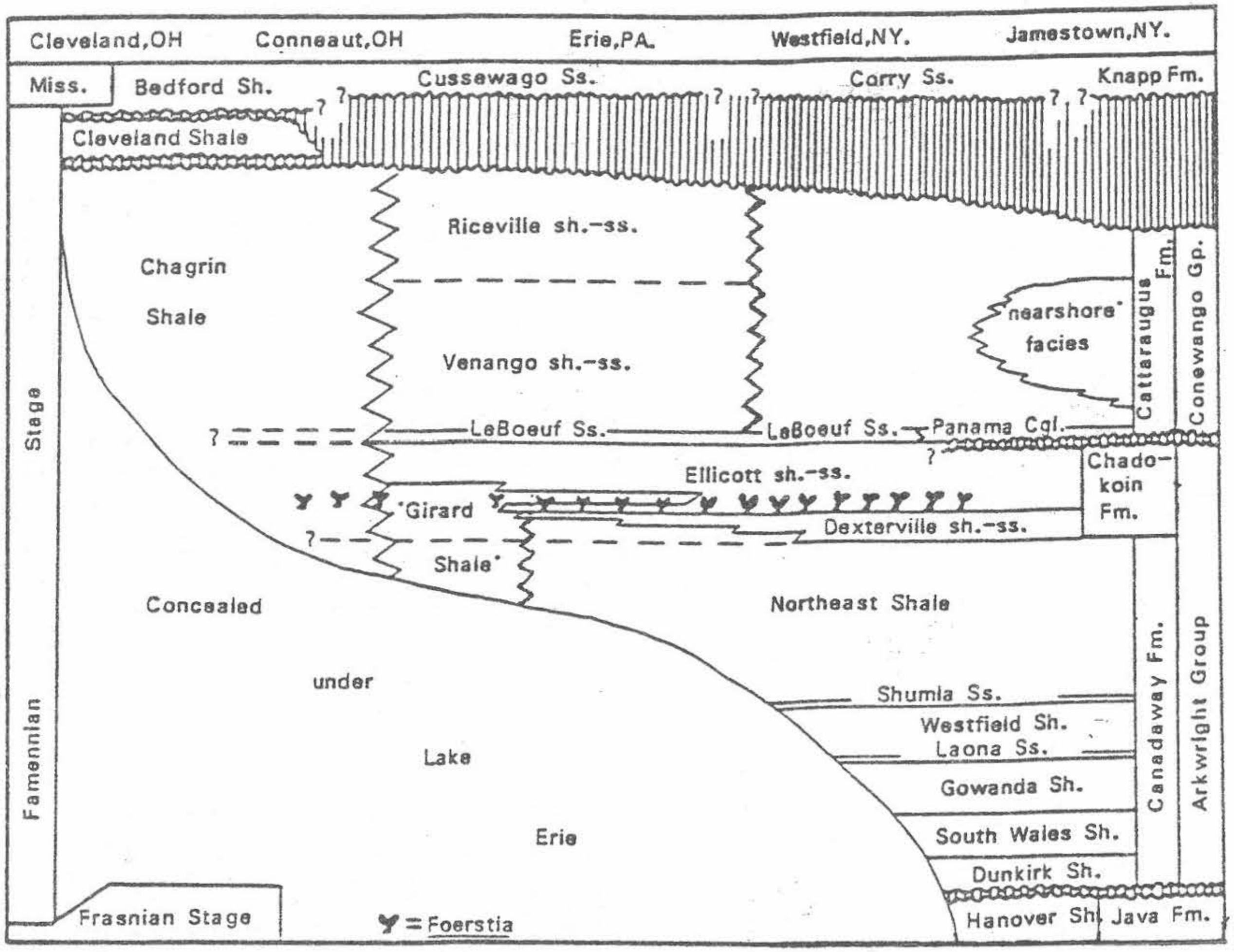

Fig. 3. Chronostratigraphic cross-section of Famennian deposits in Lake Erie region Modified from Rickard (1975), to include equivalent Devonian units in northwest Pennsylvania and Ohio.

concretion-bearing green mudstone units, this 300 meter (1,000 ft.)-thick interval contains few shelly fossils. Some green mudstone and siltstone-rich intervals, however contain numerous trace fossils, some of which are undescribed. Significant fossils include zonally-important goniatitic cephalopods (see Stop 3), rare fish fossils (see Stop 2), and hexactinellid ("glass") sponges which are reported from the Northeast Shale Member (Tesmer, 1963).

The Chadakoin Formation, including the Dexterville and Ellicott members, is distinctly siltier and richer in shelly fossils; this 120 meter (375 ft.)-thick division is the lowest unit composed of the silty, fossiliferous "Chemung" magnafacies (sensu Rickard, 1975) which represents well oxygenated, storm-influenced bottom conditions on the uppermost prodelta slope and platform (see Sutton, et al. 1974; Thayer, 1974; Sutton and McGhee, 1985; Burrier, 1977). Spiriferid, productid, and rhynchonellid brachiopods, bryozoans, bivalves, and diverse trace fossils are conspicuous componants, particularly in the upper two thirds of the formation. Significant fossils include glass sponges, horseshoe crab body-and trace fossils, plus diverse echinoderms, including inadunate crinoids, undescribed archaeocidaroid echinoids and stelleroids, as well as the algal fossil Foerstia (see Stop 6). Swaley siltstones, siltstone para-ripples, gutter casts, and abundant tempestitic siltstone beds and coquinites attest to frequent storm-wave impingement on the substrate (Burrier, 1977; this paper).

In Chautauqua County, the 215 meter (650 ft.)-thick Cattaraugus Formation begins with the first beds of quartz-pebble (orthoquartzitic) conglomerate or thick-bedded white sandstone which appear above Chadakoin mudstones and siltstones. Tesmer, 1963, indicates that the basal Cattaraugus quartz-pebble-rich sandstones corresponds to the level of the Panama Conglomerate, a unit of highly variable thickness within the county (see Stop 8). Recent mapping by Baird in western Chautauqua County suggests that the Panama Conglomerate correlates to a thinner, white (quartz-rich) sandstone (LeBoeuf Member) which can be observed near Sherman and Summerdale (Fig. 3). Post-Panama Cattaraugus deposits are, on average, siltier and sandier than those within the Chadakoin and additional, higher conglomeratic units are reported, particularly in eastern Chautauqua County and in Cattaraugus County (Tesmer, 1963, 1975). Cattaraugus deposits are usually very fossiliferous; moldic spiriferid, productid, and rhynchonellid brachiopods, bryozoans, bivalves, and crinoid stem debris are commonly observed at the numerous, small weathered outcrops which dot the upland parts of the county. A very large, triangular spiriferid brachiopod, Sphenospira alta, characterized by an extremely broad interarea (see Schwimmer and Feldmann, 1990) can be found in Cattaraugus siltstone beds in creeks south of Sherman. Cattaraugus fossils include many species different from those in the underlying Chadakoin Formation suggesting a significant period of erosion and nondeposition preceding Cattaraugus deposition (see Caster, 1934). Again, numerous features such as hummocky cross-stratification and tempestitic beds attest to strong storm-wave influence in Cattaraugus platform settings.

Facies Units

Five key types of spectral magnafacies occur within the regressive sequence of the Catskill Delta (see Rickard, 1975); the divisions relevant to this report include: in respective shoreward-order: "Marcellus", "Portage," "Chemung," and "Cattaraugus." (The nonmarine "Catskill" (Red bed) magnafacies is exposed east and southeast of the region we will visit). The Marcellus magnafacies, also called "Cleveland" magnafacies by Caster (1934) includes the well known organic-rich ("black") shale units; these deposits include laminated, black shales, exemplified by the Dunkirk Member, which contain no benthic organisms, or, at least, extremely few benthos. Anoxic bottom conditions are believed to explain the lack of bottom organisms and the lack of benthos. Most workers attribute the pervasive water stratification to maximal inferred water depths for these deposits; depth estimates for this facies usually are pegged in the "lower infralittoral" range (50 to 200 meters) for black shales in the Appalachian Basin (Bowen et al., 1974,; Thayer, 1974; Broadhead, et al. 1982). Bowen, et al, 1974, describe this facies as representing nondeltaic outer slope and basin conditions.

The Portage magnafacies includes mudstone, siltstone, and fine sandstone deposits which typically lack benthic shelled organisms or yield only low diversity assemblages of benthic and pelagic organisms (Rickard, 1975). Deposits of this type represent dysoxic (poorly oxygenated) bottom conditions which could only support soft-bodied or thin-shelled bottom organisms (see Rhoads and Morse, 1971; Savrda and Bottjer, 1987; Wignall, 1990). Typically thin siltstone or sandstone beds with sole marks often characterized by groove- or flute casts, alternate with bioturbated grey mudstone, non-bioturbated grey mudstone, and discrete thin black shale beds. Relative proportions of these various lithologies vary with stratigraphic level between the Dunkirk Shale and the base of the Chadakoin Formation, but there is an overall regressive stratigraphic trend from black shale-dominated sections at the base to bioturbated silty mudstone and siltstone-dominated sections at the top.

Siltstone beds in this magnafacies include gravity-flow deposits that appear to have a turbiditic appearance but there are many beds which have complex internal bedding which may reflect deep storm-wave impingement or other bottom-current processes (see discussion: Stops 1, 3, 5). This magnafacies is believed to record sedimentation along the lower-to-middle prodelta slope and the proximal part of the offshore shelf near the delta. (Sutton, et al., 1974; Thayer, 1974).

Fossiliferous mudstone, siltstone, and sandstone deposits within the Catskill Delta complex are largely grouped under the magnafacies designation "Chemung" (see Rickard, 1975); these deposits yield abundant and sometimes diverse communities of filter-feeding and deposit-feeding benthic organisms. Coquinitic storm deposits are abundant as are soft-sediment deformation features such as ball-and pillow structures, and there is abundant evidence of bottom smothering of organisms (see Stops 6,7). The entire Chadakoin Formation and much of the Cattaraugus Formation in western Chautauqua County and equivalent Venango Formation in Erie County, Pennsylvania fall within this magnafacies.

Nearshore deposits are referred to the "Cattaraugus" magnafacies by Rickard (1975); in such sequences red beds alternate with grey mudstone and sandstone intervals representing nearshore marine or brackish-water settings. This magnafacies usually contains low diversity fossil assemblages, and such features as flat-pebble conglomerates, ball-and-pillow deformation, and locally abundant plant debris are frequently observed. River-influenced nearshore shelf, estuarine-marine, and intertidal marsh-mudflat conditions are believed to be recorded by such sediments. Nearshore marine Cattaraugus deposits accumulated only a short distance west of the floodplain-fluvial channel paleoenvironments recorded in the Catskill magnafacies (Rickard, 1975). The Cattaraugus magnafacies is well developed within the Cattaraugus Formation in the upland regions south of Randolph, in the Alleghany State Park, and around Olean (see discussions in Caster, 1934; Tesmer, 1974; Rickard, 1975).

STRATIGRAPHIC UNITS

Member divisions:

Descriptions of component members of the upper Java, Canadaway, Chadakoin, and Cattaraugus formations are included below in order of stratigraphic succession. Descriptions are brief for units not examined and/or not visited on the field trip.

Java Formation:

Hanover Shale Member (See Figs. 4, 5; Stop 2). The Hanover Member, which is the uppermost unit containing fossils of the Frasnian Stage, was originally described by Hartnagel (1912) for exposures which occur near Silver Creek in Hanover Township. This 28 meter (90 ft.)-thick unit is composed primarily of green-grey mudstone with accessory discrete thin black shale beds and zones of small calcareous, phosphatic and pyritic nodules. The Hanover yields few shelly fossils, but is usually intensely bioturbated to the degree that some grey mudstone intervals have a massive, weakly-bedded appearance. It is distinctive in lacking many discrete siltstone beds which is the normal condition for late Devonian Portage-type magnafacies. The Hanover changes eastward into siltier, upslope deposits (Wiscoy Member) southeast of the type section at Java Village. Hanover outcrops are numerous and good in the region between Dunkirk Harbor and Warsaw, Wyoming County.

Hanover fossils include a mixture of benthic and pelagic fossils; goniatites and carbonized driftwood fragments are common at Silver Creek. Small rugose corals and crinoid ossiclesoccur in the nodular beds at numerous levels. The Frasnian-Famennian stage boundary position of the end-Frasnian extinction event has been tentatively pegged several meters below the top of this unit (Kirchgasser, pers. comm. 1989).

Canadaway Formation:

Dunkirk Shale Member (See Figs. 4, 5; Stop 2). The Dunkirk Member, named by Clarke (1903) for exposures at Dunkirk Harbor (see Stop 1), is a hard, radioactive, black shale unit which is about 12.5 meters (40 ft.)-thick in the Dunkirk area (Tesmer, 1963). This unit is southwestwardly correlative with the basal Huron Shale in Ohio (Woodrow, et al., 1988), and tongues of black Dunkirk can be traced eastward to the vicinity of Hornell, Steuben County (Pepper and de Witt, 1951).

The Dunkirk is a hard, prominently-jointed black shale which contains large (1-5 foot-diam.) septarial limestone concretions and numerous amoebiform pyrite nodules. Usually this unit is laminated, but close examination reveals the presence of small-scale bioturbation at some levels which suggest that low levels of bottom oxygenation occurred during some of the time of black mud accumulation. Benthic taxa include the linguloid brachioped Barroisella. Pelagic organisms and transported debris include: conodonts, algal spores, fish fossils and carbonized driftwood.

At Point Gratiot (Stop 1) the 17 cm (6.5 in.)-thick basal bed of Dunkirk, separated from the main overlying continuous black shale sequence by a 13.5 cm (4.5 in.)-thick bioturbated grey mudstone unit, yields abundant carbonized plant debris plus the remains of both articulated and disarticulated large armored fish (Fig. 4A). The top of the 17 cm grey band marks a submarine discontinuity which contains a lag bed of detrital pyrite, small fish bones, wood debris and conodonts (Baird and Brett, 1986).

As this discontinuity is traced northeastward to the vicinity of Java Village, Wyoming County, more and more beds progressively appear beneath it such that this break passes essentially to extinction (Fig. 5). Several black shale beds alternating with bioturbated and non-bioturbated grey-green mudstone make up an intervening sequence several meters-thick (Fig. 5). Most of the thin black shales, however, display minor diastemic basal contacts with the grey-green beds marked by minor detrital pyrite. Collectively, these diastems truncate underlying units as they are traced southwestward such that higher diastems apparently downcut through lower ones until only the single 13.5 cm grey-green bed remains at this locality (Figs. 4, 5). This illustrates the pervasiveness of submarine erosion associated with the transgression grey-to-black facies change beneath even very thin black

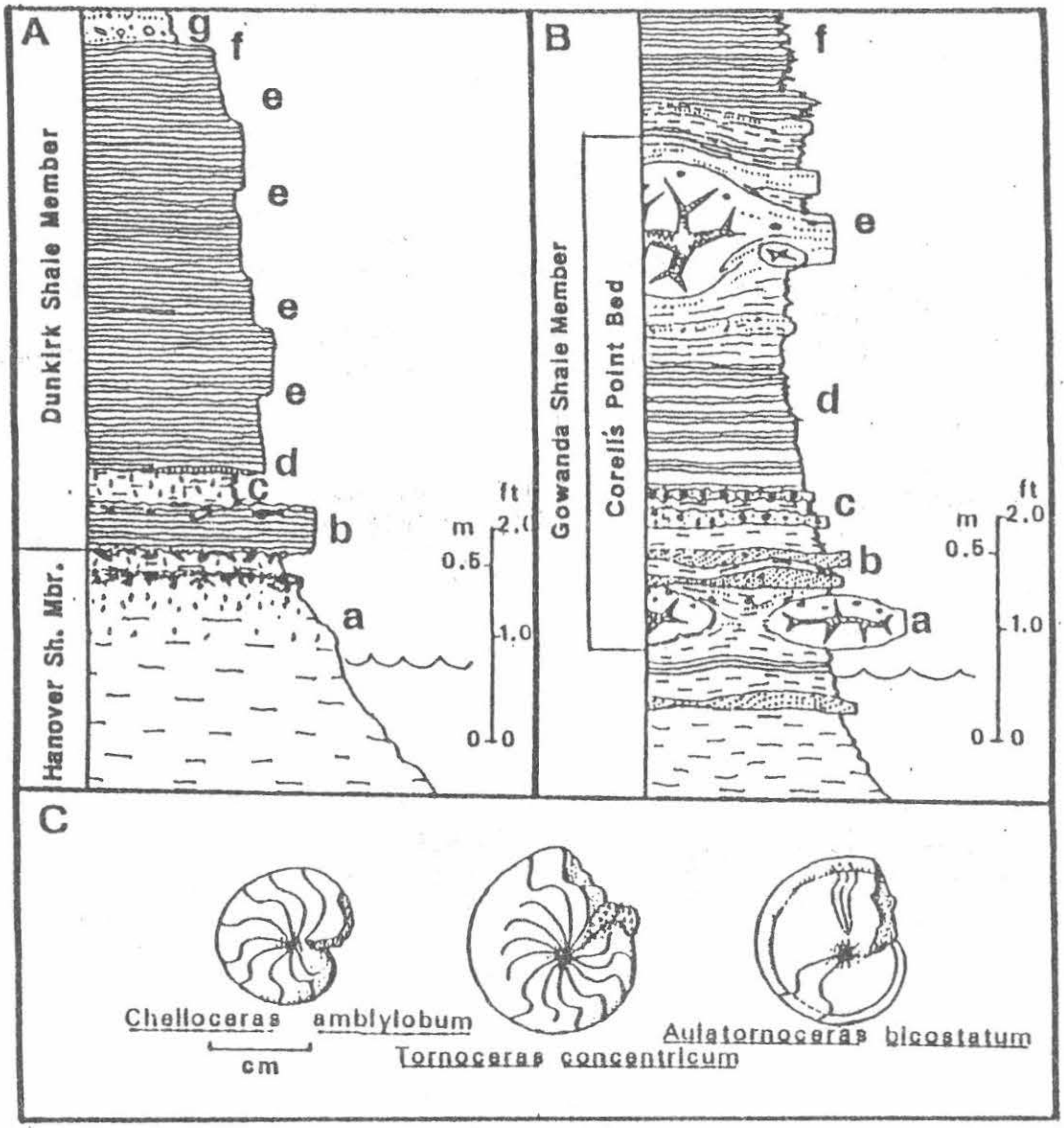

Fig. 4. Stratigraphic sections for the Point Gratiot and Corell's Point lake shore localities and key goniatite fossils from the Corell's Point Bed. A) Section at Point Gratiot (STOP 2). Lettered units include: a) intensely bioturbated grey-green mudstone; b) wood-and bone-bearing black shale bed; c) bioturbated grey-green mudstone bed; d) detrital pyrite lens along black shale-roofed discontinuity; e) laminated black shale; f) striated glacial scour contact; g) bedded glacial "till"; B) Section at Corell's Point (STOP 3). Lettered units include: a) septarian concretions containing fossiliferous pyritic steinkerns; b) siltstone beds containing unfossiliferous pyrite nodules, c) bioturbated siltstone beds yielding numerous pyrite nodules, pyritic fossil steinkerns and non-pyritic fossils; d) interbedded black and grey-green shale ("zebra" facies); e) large septarian concretions with occasional pyritic steinkerns and abundant auloporid corals; f) black shale; C) Key zonal goniatites from Corell's Point Bed (After House, 1962, 1965; Kirchgasser, 1974).

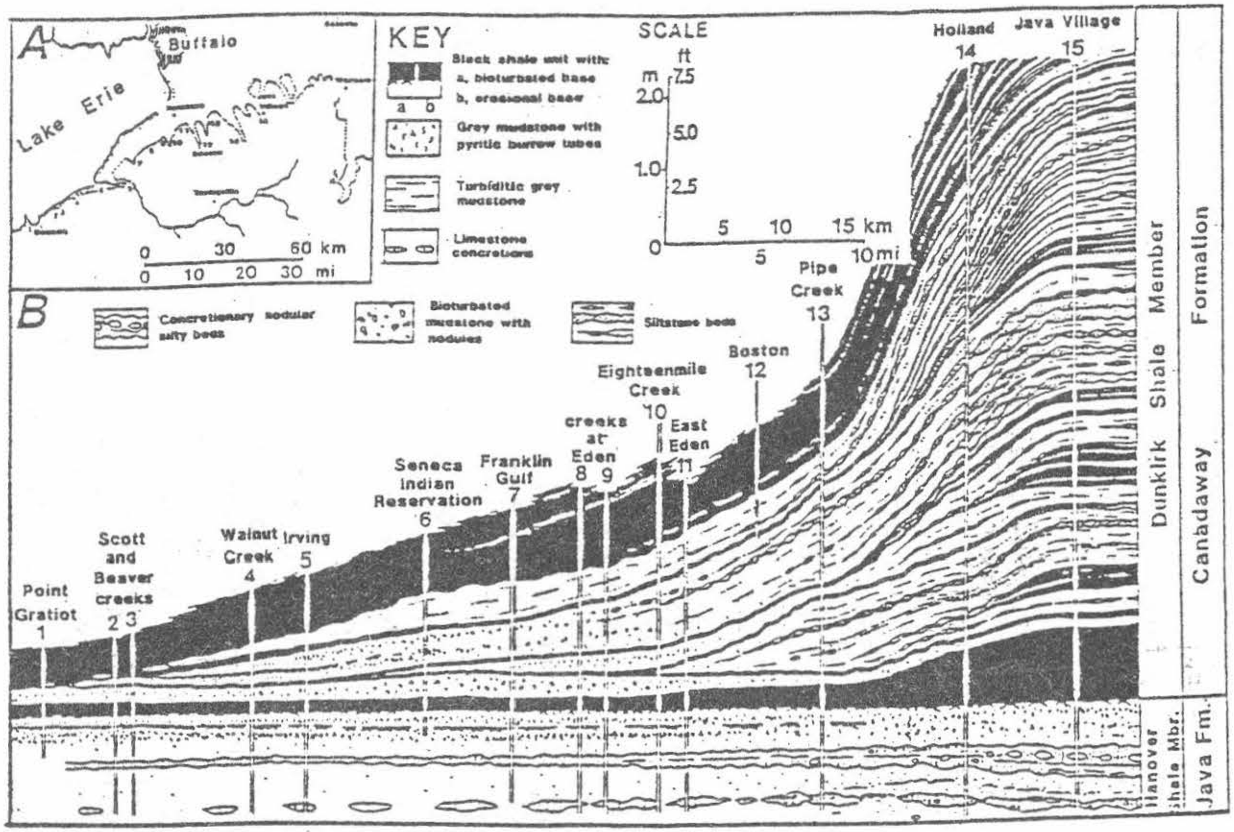

Fig. 5. Stratigraphic transect of basal Famennian strata (uppermost Hanover Shale Member and lowermost Dunkirk Shale Member) between Point Gratiot, Chautauqua County (STOP 2) and Java Village, Wyoming County. Note conspicuous northeastward thickening of basal Dunkirk as turbiditic grey mudstone facies appears within section. Many black shale beds in expanded (splayed) northeastern Dunkirk deposits have erosional bases. Southwestward convergence of these black shale beds involves, in part, the apparent downcutting by one or more of these beds into lower strata such that only one remaining grey mudstone bed is visible within the Dunkirk at the Lake Erie shore (see STOP 2).

shale units. It also illustrates the distinctive character of condensed sedimentary deposits involving alternations between dysoxic and anoxic facies.

South Wales Shale Member. Above the Dunkirk Member is an 18 to 25 meter (60-80 ft.)-thick interval of interbedded black and dark grey shale, grey-green mudstone and occasional flaggy siltstone beds designated the South Wales Member by Pepper and de Witt, 1951, for exposures in a small tributory to the east branch of Cazenovia Creek, three miles south of South Wales in southern Erie County. Large septarian concretions are associated with horizons of grey-green bioturbated mudstone. Macrofossils are rare but carbonized wood and rare fish fragments can be collected from this unit.

Gowanda Shale Member (See Figs. 4B, C, 6, 7; Stops 1, 3, 4). Above the South Wales Member is a 37-72 meter (120-230 ft.)-thick interval of interbedded black shale, marginally black shale, grey mudstone, and siltstone beds, designated by Hartnagel (1912), for exposures near Gowanda, Cattaraugus County. This unit is dominated by black shale in the lower half and contains numerous siltstone beds in the upper third. Thin intervals of bioturbated grey mudstone with both large and small calcareous concretions occur at several levels; these yield auloporid corals, bivalves, cephalopods and driftwood.

The best known of the fossil-bearing levels is the regionally mappable Corell's Point Bed (see House, 1966, 1968; Kirchgasser, 1974; Tesmer, 1974), which is, in reality, two-closely spaced pyrite nodule-and concretion-rich beds which yield uncrushed pyritic steinkerns of goniatites and orthoconic nautiloids (see Fig. 4B, C; Stop 2). The Corell's Point Bed is believed to be traceable as far to the northeast as Holland, Erie County and the south branch of Cattaraugus Creek east of Dayton (House, 1966, 1968); at the latter locality it occurs at an elevation of 965 feet which is anomolously high suggesting the possibility of significant structural upwarping of beds southeast of Gowanda. This Corell's Point Bed locality has yet to be examined by the present authors.

The upper Gowanda is characterized by finely interbedded discrete beds and laminae of black shale, non-bioturbated grey mudstone, bioturbated grey mudstone, and both lenticular and evenly-bedded siltstone (Fig. 6). Contacts are usually sharp between these divisions due to minimal bioturbation and these deposits have a striking banded appearance particularly along clean lake sections (see Stops 1, 3, 4). This type of deposit is herein designated by an informal name, "zebra facies," for economy of description; it is characteristic of parts of the Gowanda, Westfield, and Northeast shale members.

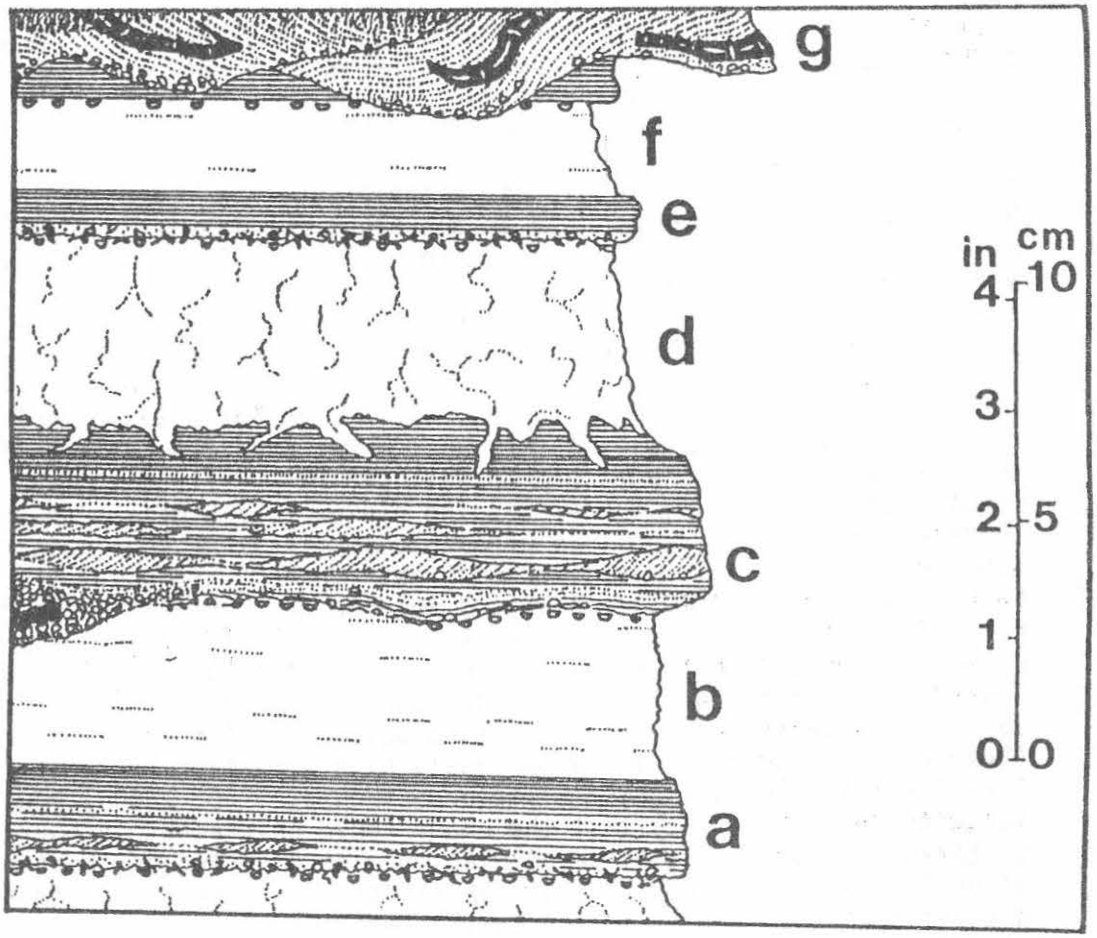

Fig. 6. Association of sediment-types and bedding relationships in finely interbedded grey mudstone-, black shale, and thin siltstone deposits ("zebra facies") typical of the lower and middle parts of the Canadaway Formation (see text; STOPS 1, 3, 4). Units shown include: a) black shale bed with in-situ partial, pyritic microspheres below the base and exhumed and reoriented microspheres at the base; b) turbiditic grey-green mudstone bed with in-situ partial microspheres below top; c) silty black shale bed with minor erosional contact at base. Both whole and partial reworked microspheres fill a scour depression on the erosion surface; d) bioturbated grey-green mudstone layer. Burrowers have penetrated the underlying black mud layer and have piped grey mud down into this bed; e) thin black shale bed similar to a; f) turbiditic mudstone layer similar to b; g) thicker siltstone bed recording significant bottom erosion by non-turbiditic currents prior to sediment accumulation. An underlying black shale layer is partly-to completely removed by erosion and both detrital pyritic microspheres and wood debris are concentrated within this siltstone bed.

The zebra facies records a complex succession of depositional events in an anoxic to lower dysoxic slope-to-basin setting. Although many of the grey-green mudstone and siltstone beds appear to be of turbiditic origin, some beds may have formed as a result of bottom current processes (see Stanley, 1987). Most unusual are the frequent occurrences of sand-sized pyritic microspheres at or near the bases of the thin black shale beds (Figs. 6, 7). These microspheres and partial microspheres may be the result of bacterial sulfate reduction within gas bubbles which were trapped beneath the black mud layers or under bacterial mats (Fig. 7). Reorientation of geopetal partial microspheres within many black shales due to current scour or bioturbation suggests that these black shales were deposited rapidly and that some black mud substrates could support burrowing organisms (see discussion; Stop 4).

Laona Siltstone Member (See Stops 1, 4). Above the Gowanda Member is a resistant, falls-forming siltstone unit designated the Laona Siltstone by Beck (1840) for the exposure we will see at our first stop at Laona, Chautauqua County. The Laona, ranging from 1 to 7.5 meters (3-25 ft.) in thickness, usually consists of quartzose siltstone beds which are about one foot in thickness; the most massive beds are usually at the base with thinner siltstone beds and interbedded shales towards the top. Presently, the Laona can be traced with certainty from Barcelona at the Lake Erie shore to Little Indian Creek near Perrysburg. An exposure near Gowanda originally identified as the younger Shumla Siltstone (Tesmer, 1963) now appears to be Laona on lithologic and thickness criteria (Tesmer, Pers. comm.). The anomolously high elevation recorded for the Corell's Point Bed southeast of Gowanda (House, 1966, 1968), however, suggests the possibility that the Laona could be present in northwest Cattaraugus County at a higher elevation than expected on the assumption of uniform southward dip of Devonian strata. However, no Laona deposit has yet been observed in that area (Tesmer, pers. comm.).

The Laona is unfossiliferous at most localities but near Nashville, Chautauqua County, a coquinite layer rich in brachiopods and bivalves was discovered by Tesmer, 1963. One of the present authors (Lash) is studying the Laona Member; based on thin section study and examination of sedimentary structures, he concludes that is unit is a non-graded gravity flow deposit. Tesmer's (1963) faunal list for this unit is interesting because it contains numerous taxa found in oxic upper prodelta and platform facies and which are distinctly absent from synjacent shales. It appears possible that these fossils may be allochthonous, and were transported downslope in one or more turbiditic flows into the anoxic or minimally oxygenated basin setting. We will see the Laona at Stops 1 and 4.

Westfield Shale Member (See Stop 4). Above the Laona Member is a 31 to 68 meter (100-220 ft.)-thick sequence of interbedded black and dark grey shale, grey mudstone, and thin siltstone beds designated the Westfield Shale Member by Chadwick (1923), for exposures on Chautauqua Creek near

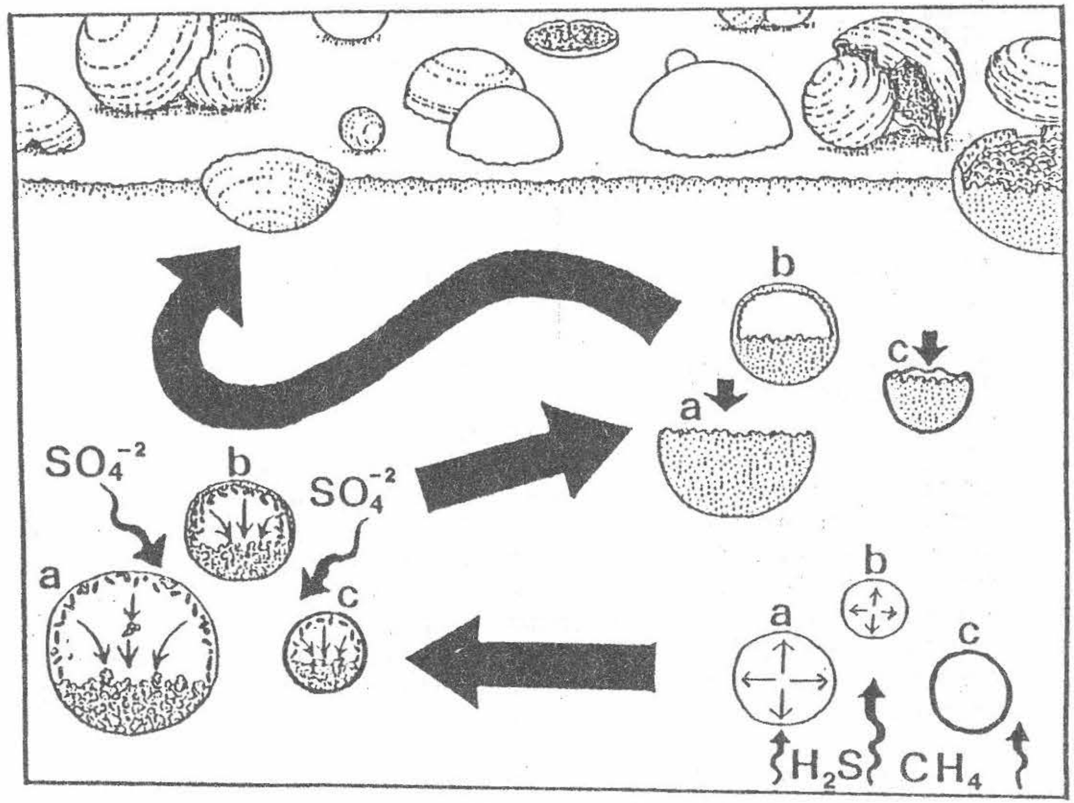

Fig. 7. Model for genesis of early diagenetic microsphere and partial (geopetal) microsphere pyrite. Sequential stages protrayed include: formation of bubbles (or spores) in near-surface turbiditic mud by rising decay gases; partial filling of bubble cavaties a and b sealing off flat floored geopetal cavity inside; and exhumation of shiny complete and partial spheres during scour events preceding deposition of black muds and/or turbiditic sediments (not shown here to facilitate viewing of multiple orientations of detrital pyrite grains on scour surface). Sphere c is a Sporangites (Tasmanites) spore which undergoes sequential partial filling by pyrite, collapse due to loading, and exhumation with presumed destruction of cutical cover. This latter interpretation is not favored here because no in-situ sphere and partial sphere pyrite is observed within spore cutical coverings.

Westfield, Chautauqua County. The Westfield is traceable from the Lake Erie Shore near the New York/Pennsylvania state line to the vicinity of Perrysburg where its bounding units (Laona and Shumla members) ceased to be present. The Westfield is lithologically similar to the Gowanda Member. We will examine Zebra facies in the lower Westfield at Stop 4.

Shumla Siltstone Member. Above the Westfield Member is an interval of thin-bedded siltstones up to 11 meters (35 ft.)-thick which is designated the Shumla Siltstone Member by Clarke, 1903, for beds outcroping along Canadaway Creek at Shumla, Chautauqua County. The Shumla is traceable from the Lake Erie Shore near the New York/Pennsylvania border to the vicinity of Perrysburg where it apparently pinches out (Tesmer, 1963). Lithologically the Shumla is similar to the Laona Member and it is usually unfossiliferous. As with the Laona, this unit consists of gravity flow units. We will not observe this member on the field trip.

Northeast Shale Member (See Stop 5). The Northeast Shale Member, named for exposures near Northeast, Pennsylvania by Chadwick, 1923, is a 125 to 188 meter (400-600 ft.)-thick unit composed mainly of interbedded silty grey mudstone and flaggy siltstone beds with a subsidiary component of dark grey and black shale beds in the middle and lower parts of the member. Calcareous "Cone-in-Cone" concretions occur at several levels within this unit (see Woodland, 1964; Gilman and Metzger, 1967). Shelly fossils are rare to absent in Chautauqua County Northeast exposures but become more common in equivalent beds in Cattaraugus County (Tesmer, 1963). However, several types of trace fossils are common in the Northeast Member; at Stop 5 they are visible as bas-relief (hypichnial) features on the soles of many siltstone beds.

The Northeast Member records part of the upward-transitional (regressive) record from anoxic to pervasively dysoxic facies. The greater percentage of siltstone beds in this unit is consistent with its more shallow and shoreward inferred depositional setting as compared with underlying Canadaway shale divisions. Preliminary examination of this unit by the present authors suggests that it could be further subdivided into mappable siltstone-rich, siltstone-poor, and black shale-rich stratigraphic divisions. We will briefly examine the Northeast Member at Stop 5.

Chadakoin Formation

Background:

Chadwick proposed the name Chadakoin for a sequence of interbedded lenticular grey siltstone and grey mudstone deposits exposed in quarries along the Chadakoin River at Dexterville (now the eastern part of Jamestown). Tesmer (1963) subsequently formalized this name to formation status. The two component members of the Chadakoin are, in ascending order, the Dexterville Siltstone and the Ellicott Shale.

Dexterville Siltstone Member (see Fig. 8). The Dexterville Member was proposed by Caster, 1934, for approximately 31 meters (100 ft.) of interbedded lenticular, grey siltstone and grey mudstone deposits exposed in quarries along the Chadakoin River at Dexterville, New York. This unit is distinguished from the underlying, sparsely fossiliferous Northeast Member, by the appearance of thicker and more numerous lenticular siltstone beds and by the appearance of pavements and coquinite concentrations of brachiapods, bryozoans and bivalves. As such this unit marks the upward change to "Chemung magnafacies" of Rickard, 1975.

Dexterville strata in the Jamestown, Cherry Creek, and Randolph areas are rich in the brachiopod "Pugnoides" duplicatus which is restricted to the Dexterville (Tesmer, 1963). Burrier (1977), however, reported this brachiopod within only the basal part of the stratigraphic section mapped by him as Dexterville on Chautauqua Creek. "Pugnoides" has not yet been observed in Pennsylvania Dexterville exposures by the present authors and it has not yet been conclusively confirmed at Chautauqua Creek. Shell-rich Dexterville can be traced southwestward ("downslope") into the Erie, Pennsylvania area. Southwest of Erie, this unit changes to a "Northeast Shale"-type appearance as it grades from outer shelf-upper slope "Chemung" magnafacies into the slope-to-basin "Portage" magnafacies.

Ellicott Shale Member (See Stops 6 and 7). The Ellicott Member was named by Caster, 1934, for exposures "along Hunt Road" in Ellicott township west-southwest of Jamestown. A few exposures exist in the vicinity of this road between Jamestown and Ashville (see the railroad cut northwest of the Sugar Grove-Hunt Road intersection at Lakewood: Tesmer, 1974: Field Trip Stop 5), but a "type section" for this unit is virtually nonexistent. However, what has come to be understood as "Ellicott" in Chautauqua County and in Erie County Pennsylvania includes some of the most fossiliferous facies in the region. Moreover, it may prove to be the most useful for establishing refined correlation of time-synchronous event-strata along prominent depth-related facies gradients from New York into northeast Ohio.

Crudely defined, the Ellicott Member is characterized by complexly-interbedded lenticular siltstone, mudstones, and coquinites. It is actually very similar to the Dexterville lithologically except that, at least, two siltstone-dominated ("Dexterville"-like) intervals alternate with three mudstone-dominated intervals (see Fig. 8). Coquinites and shell pavements are more abundant and fossil diversity generally increases upward. Distinctive fossils include the large rhynchonellid brachiopod Paurorhyncha newberryi which is abundant in a thick, upper Ellicott siltstone-dominated interval along a west-tributary of Chautauqua Creek, and the distinctive carbonaceous fossil Foerstia (Protosalvinia) which is abundant at the 1310-1330 foot elevation of the main channel of Twentymile Creek and at the 1380-1400

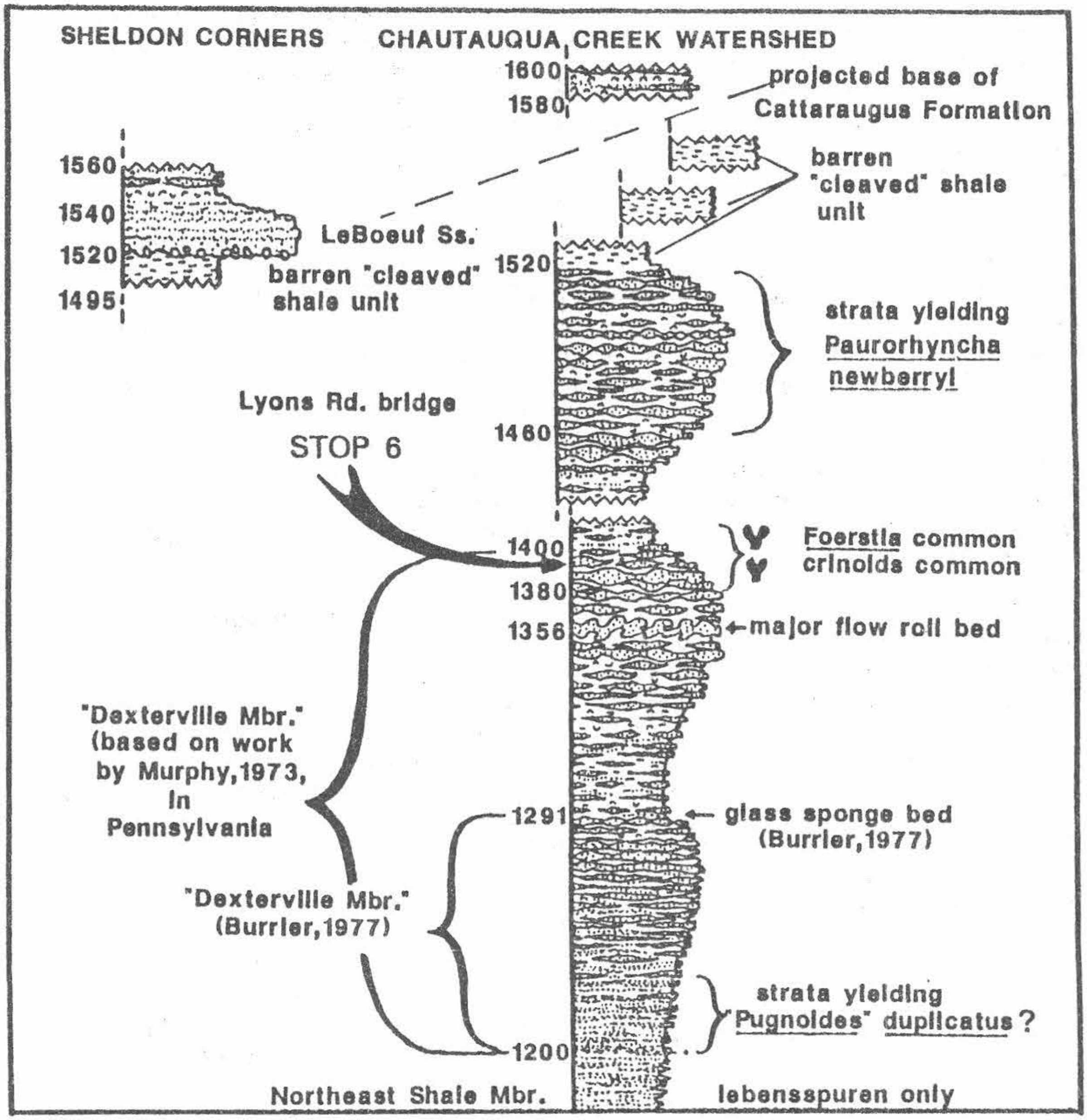

Fig. 8. Stratigraphy of Chadakoin Formation on Chautauqua Creek and its tributaries and also on nearby, small, unnamed, northwest-flowing tributory of Twentymile Creek, 0.7 mi. northeast of Sheldon Corners on the South Ripley 7.5 minute Quadrangle. Stratigraphic reconstruction is based partly on work of Tesmer (1963) and Burrier (1977) but information above elevation of 1380 ft. is largely to entirely based on recent mapping by Baird (see text). Newly recognized divisions in this area (Foerstia zone, Paurorhyncha-rich siltstone unit, sparsely fossiliferous to unfossiliferous variably fractured("cleaved") shale unit, and LeBoeuf Sandstone) are all well developed in the Union City, Erie, and Albion areas in Pennsylvania. Elevations (in feet) are from 7.5 minute topographic sheets.

feet elevation along Chautauqua Creek (See Stop 6: Figs. 8, 9). Foerstia is a probable reproductive structure of a fucoid alga (see Phillips, et al., 1972; Schopf and Schwietering, 1976). It is an extremely important and widespread zonal marker for North American Famennian deposits.

In the process of tracing the zone of abundant Foerstia from Conneaut Creek in Ohio northeastward to the vicinity of Twentymile Creek near Ripley, Chautauqua County, New York, using the report of Murphy, (1973), as a guide, one of the present authors (Baird) discovered that the "Dexterville-Ellicott" boundary of Murphy (1973), is much higher stratigraphically than that of Tesmer (1963), and Burrier (1977) (Fig. 8). It appears that Murphy's (1973), "Dexterville-Ellicott" boundary, coincident with his zone of abundant Foerstia, projects into Chautauqua Creek just below the defunct Lyons Road Bridge (See Stop 6) more than 31 meters (100 ft.) above the "Dexterville-Ellicott" boundary identified by Burrier (1977). As such, the "Ellicott" of Burrier (1977) includes about 80 meters (260 ft.) of strata on Chautauqua Creek (three "shale" and two "siltstone" divisions with most of the top shale unit missing), and the "Ellicott" of Murphy, 1973, encompasses 47 meters (150 ft.) of section (two "shale" and one "siltstone" division) at this section (see Fig. 8). Given this discrepancy, the present authors currently refer to the Chadakoin Formation along the Girard, Pennsylvania-Chautauqua Creek transect as including a total of three mappable siltstone units (the lowest being Dexterville (sensu Burrier, 1977) and three "shale" units (the base of the middle "shale" corresponding to the zone of densest Foerstia concentrations). Moreover, the top "shale" unit, marked by a widespread erosional discontinuity at its base and coarse basal Cattaraugus deposits (LeBoeuf-Panama members) at its top, is found to contain sparsely fossiliferous facies very different from that of underlying Chadakoin beds. These units are currently informal divisions, but, with continued work, they may be assigned formal stratigraphic names.

These six divisions can be traced southwestward to Little Elk Creek near Girard, Pennsylvania and three have tentatively been followed into northeast Ohio. The coquinite-, echinoderm-, and Foerstia-rich interval, coinciding with the "Dexterville-Ellicott" boundary of Murphy (1973), in the Chautauqua Creek-Erie, Pennsylvania region (see Stop 6), has tentatively been located along Conneaut Creek, southwest of Conneaut, Ohio where Foerstia and a low diversity brachiopod assemblage occur in association with interbedded grey and black shales in facies reminiscent of the Northeast Member in New York. If this boundary is an isochron, which we believe it is, then it will be possible to study fossil associations across major facies belts along time-controlled paleoenvironmental gradients through this region.

Cattaraugus Formation

Overview. The highest Devonian formational division was proposed by Clarke, (1902), to include strata from the Panama Conglomerate up to the base of the Knapp Conglomerate of Mississippian age. As such, this unit encompasses approximately 210 meters (650 ft.) of section in Chautauqua County which includes quartz pebble conglomerates, quartz-rich, but often micaceous sandstones, marine shell coquinites at many levels, lenticular siltstone beds, and both green and red shales (Tesmer, 1963). Most Cattaraugus beds are variably marine but "red beds" are reported in the hills south of Jamestown and in the eastern part of Chautauqua County. These are too far to the southeast to be visited on the present field trip. The strata from the Panama-level upwards to the base of the Mississippian are largely correlative with the Chagrin Formation of northern Ohio (see Chadwick, 1925; Caster, 1934; Pepper et al., 1954; Tesmer, 1963).

Numerous conglomeratic divisions have been traced by various workers over the past century providing some potential for the establishment for internal subdivisions, but the stratigraphy is still imperfectly known. Outcrops along creeks and roads in areas underlain by Cattaraugus strata are usually extremely poor due to the tendency for massive beds to migrate into creek channels through the process of slump and creep (See Stop 8). The best Chautauqua County outcrops observed by the present authors are along small creeks in the highest drained elevations west of Cherry Creek and south of Sherman.

Panama Conglomerate Member (See Stop 8). At the base of the Cattaraugus Formation is the Panama Conglomerate, first named by Carll, (1880), for approximately 21 meters (70 ft.) of quartz pebble conglomerate and buff sandstone near Panama, New York (See Stop 8). The Panama Conglomerate appears to be lenticular and discontinuous in the county. The coarse nature of this unit and its discontinuous distribution suggests that it may locally fill channels. The Panama has been correlated with the Leboeuf Sandstone which marks the top of Chadakoin deposits in the Erie-Albion area in Pennsylvania (Caster, 1934; Tesmer, 1963, 1974). One of us (Baird) has recently located the basal Cattaraugus sandstone, corresponding to the LeBoeuf thickness and lithologic character, both at Sheldon Corners (Fig. 8) at 1520 feet elevation and east of Summerdale on a tributory of Wing Creek at 1600 feet, in western Chautauqua County; this unit both thickens and coarsens southeastward assuming the typical Panama conglomeratic sandstone appearance south of the hamlet of Stedman Corners.

PROBLEMS AND QUESTIONS

Work Agenda:

Key questions pertaining to the Dunkirk-through Cattaraugus stratigraphic succession include the following:

Canadaway Formation

1. What process or set of processes accounts for the thin black and grey shale alternations comprising the zebra facies? What is the temporal significance of these beds and the sharp boundaries between them; are the black bands deposited slowly or rapidly? If many black bands were rapidly deposited, how were they deposited and what consistency was the organic-rich, black mud when it was transported? Which beds are turbiditic, which were produced by bottom-current processes, and which accumulated through slow background deposition from suspension?

2. What events and processes produced thick, non-graded siltstone units such as the Laona and Shumla? Are such depositional events linked in a process sense to slump-sheet and ball-and-pillow units observed in the shallower facies of the overlying Chadakoin Formation? Could these slump and/or gravity-flow beds be linked to ancient disturbances such as major storms or seismic events?

3. How far east can the Corell's Point Bed be accurately traced? Is the anomolously high reported occurence of this unit at 965 feet on South Cattaraugus Creek by House (1968) correct? If it is correct, can the Laona siltstone be located on this creek using the Corell's Point Bed as a control? If the Corell's Point and Laona units are truly this elevated, what impact does this have on stratigraphic correlations of higher divisions in this region? What impact does it have on oil and gas drilling prospects-is this the surface expression of the Bass Island structural trend?

4. Can the thick Northeast Shale Member be subdivided into smaller mappable divisions? Are turbidite bundles in the Northeast lenticular, as predicted in some submarine fan models, or are they sheet-like and widespread?

Chadakoin Formation

1. How far to the east can the key Chadakoin faunal and lithologic markers be mapped; can the zone of concentrated Foerstia and the Paurorhyncha newberryi-rich interval be traced across Chautauqua County into Cattaraugus County. Do the major siltstone-rich intervals retain their identity across this same interval; do these ultimately change to quartz pebble-rich sandstone facies if traced far enough?

2. What is the character and extent of structural folding and/or faulting of surface rocks in Chautauqua County, particularly along the "Bass Islands" structural trend? Recent mapping of upper Chadakoin and lower Cattaraugus divisions by Baird reveals anomolously high elevations for the Panama Conglomerate between Stedman and Panama in an area of intense oil and gas-action. Does this fold have a northeast-southwest trend? Does it connect to the aforementioned region of anomolously elevated Canadaway strata southeast of Gowanda?

3. What is the paleoenvironmental explanation for the uppermost Chadakoin, sparsely-fossiliferous, characteristically sheared ("cleaved") siderite-rich, unnamed mudstone division? Is this a regressive, nearshore facies unit? Does it correlate to the "Tanner Hill" redbed tongue reported below the Panama Sandstone at Warren, Pennsylvania (See Caster, 1934).

4. What is the impact of the Frasnian-Famennian extinction event on the slope and platform facies of the Catskill Delta? Is there a major restructuring of platform communities between the Frasnian Wiscoy Member and the Famennian Caneadea-Ellicott sequence? Are there corresponding changes in the depositional regime?

Cattaraugus Formation

1. This formation is not well understood; a need exists for basic mapping of key beds, but this work should probably commence in the largely-equivalent Chagrin Shale in Ohio, where outcrops are larger and better, and proceed eastward into Pennsylvania and New York. It appears that lower Cattaraugus strata offer some potential for mapping in Chautauqua County, but upper Cattaraugus beds may be mappable only through combined field and subsurface methods.

2. What is the origin of the thick conglomerate units? Do these overlie unconformities produced by sea level lowstand events? If so, the conglomerates should be lenticular but regionally mappable as is indicated by previous workers. If sea level oscillations are temporally superimposed on the progradation process, is there a predictable shoreward facies trend in the regressive sandstone and conglomerate units that can be documented? Miller (1974), suggests that this is the case, but more work is clearly needed to document dynamic changes which should be visible and measurable. Can neap-spring tidal cyclicity be identified in the cross-bedding laminations within this unit?

REFERENCES CITED

Aigner, T., 1985, Storm depositional systems. Dynamic stratigraphy in modern and ancient shallow marine sequences: Lecture notes in Earth Science, V.3, Springer-Verlag, New York, Heidelberg, Berlin, 174 p.

Alvarez, L.W., Alvarez, W., Asaro, F., and Michel, H.V., 1980, Extraterrestrial cause for the Cretaceous-Tertiary extinction. Experimental results and theoretical interpretation: Science, V. 208, p. 1095-1108.

Babcock, L.E., 1982, Paleontologic and sedimentologic character of Corell's Point faunal assemblages (Upper Devonian; Famennian), Southwestern New York State (abstr.): Amer. Assoc. Petrol. Geologists Bull., V. 66, No. 8, p. 1164.

Baird, G.C. and Brett, C.E., 1986, Erosion on an anaerobic seafloor: significance of reworked pyrite deposits from the Devonian of New York State: Palaeogeog. Palaeoclim. Palaeoecol., V. 57, p. 157-193.

Baird, G.C., Brett, C.E., and Kirchgasser, W.T., 1988, Genesis of Black Shale-roofed discontinuities in the Devonian Genesee Formation: In McMillan, N.J., Embry, A.F. and Glass, D. J., eds., Devonian of the World: Volume II: Sedimentation, Canadian Soc. Petroleum Geologists, Calgary, p. 357-376.

Beck, L.C., 1840, Report of the Mineralogical and chemical department of the survey of New York. New York Geol. Surv. Ann. Rpt., V. 4, p. 57-58.

Bowen, Z.P., Rhoads, D. C., and McAlester, A.L., 1974, Marine benthic communities in the Upper Devonian of New York: Lethaia, V. 7, p. 93-120.

Brett, C.E. and Baird, G.C., 1982, Upper Moscow-Genesee stratigraphic relationships in western New York: evidence for erosive bevelling in the Late Middle Devonian. In Buehler, E.J., ed., Field Trip Guidebook, 54th Meeting, New York State Geological Assoc., Buffalo, New York, p. 19-63.

Brett, C.E., Speyer, S.E. and Baird, G.C., 1986, Storm-generated sedimentary units: tempestite proximality and event stratification in the Middle Devonian Hamilton Group of New York: In Brett, C.E., ed., Dynamic stratigraphy and depositional environments of the Hamilton Group (Middle Devonian) in New York State, Part I. New York State Museum Bull., V. 457, p. 129-156.

Broadhead, R.F., Kepferle, R.C., and Potter, P.E., 1982, Stratigraphic and sedimentological controls of gas in shale-example from the Upper Devonian of northern Ohio. American Assoc. Petroleum Geologists, V. 66, p. 10-27.

Buehler, E.J. and Tesmer, I.H., 1963, Geology of Erie County, New York: Buffalo Soc. Natural History, Bull. V. 21, No. 3, 118 p.

Burrier, D. G., 1977, The paleoecology of the Chadakoin Formation of Chautauqua County (unpublished masters' thesis): S.U.N.Y. College, Fredonia, New York, 129 p.

Butts, C., Pre-Pennsylvanian stratigraphy of Pennsylvania: Pennsylvania Topographic and Geol. Surv. Rept. for 1906-1908, p. 190-204.

Byers, C. W. 1977, Biofacies patterns in euxinic basins; a general model: In Cook, H.E. et al., eds., Deep-water carbonate environments. Soc. Econ. Mineralogists Paleontologists Spec. Pub., V. 25, P. 5-17.

Carll, J.F., 1880, The geology of the oil regions of Warren, Venango, Clarion, and Butler counties: 2nd Pennsylvania Geol. Surv. Rept. 13, 58 p.

Caster, K.E., 1934, The stratigraphy and paleontology of northwestern Pennsylvania; Part 1, Stratigraphy: Bull. American Paleont. B. 21, No. 71, p. 19-37.

Chadwick, G. H., 1923, Chemung stratigraphy in western New York: Abstr. Geol. Soc. America Bull., V. 34, p. 68-69.

Chadwick, G. H., 1924, The stratigraphy of the Chemung Group in western New York: New York State Museum Bull., V. 251, p. 149-157.

Chadwick, G. H. 1925, Chagrin Formation of Ohio. Geol. Soc. America Bull., V. 36, p. 455-464.

Chadwick, G. H., 1933, Great Catskill Delta, and revision of Late Devonian succession: Pan-American Geologist, V. 60, p. 91-107, 189-204, 275-286, 348-360.

Clarke, J.M., 1902, Preliminary statement of the paleontological results of the areal survey of the Olean Quadrangle: New York State Museum Bull., V. 52, p. 524-528.

Clarke, J.M., 1903, Classification of the New York Series of geologic formations: Univ. State New York Handbook, V. 19, 1st edition.

Cooper, G. A., and others, 1942, Correlation of the Devonian sedimentary formations of North America: Geol. Soc. America Bull., V. 53, p. 1729-1794.

Cuomo, M.C. and Bartholemew, P.R., 1987, Identification of modern and ancient pellets using electron microscopy and microanalysis. Abstr. Geol. Soc. America, p. 63.

Cuomo, M.C. and Rhoads, D.C., 1987, Biogenic sedimentary fabrics associated with pioneering polychaete assemblages: Modern and ancient. Jour. Sed. Petrology, V. 57, No. 3, p. 537-543.

de Witt, W., Jr. and Colton, G., 1953, Bedrock geology of the Silver Creek quadrangle, New York: U.S. Geological Surv., Geol. Quad. Map GQ30.

Ettensohn, F. R., 1985, The Catskill Delta Complex and the Acadian Orogeny: A model: In Woodrow, D. L. and Sevon, W. D., eds., The Catskill Delta. Geol. Soc. America. Spec. Publ. No. 201, p. 39-50.

Ettensohn, F. R. et al., 1988, Characterization and implications of the Devonian-Mississippian Black-Shale sequence, eastern and central Kentucky, U.S.A.: Pychoclines, transgression, regression, and tectonism: In McMillan, N.J., Embry, A.F., and Glass, D.J., eds., Devonian of the World: Volume I: Regional Synthesis: Canadian Soc. Petroleum Geologists, Calgary, p. 323-345.

Gilman, R.A. and Metzger, W. J., 1967, Cone-in-cone concretions from western New York: Jour. Sed. Petrology, V. 37, No. 1, p. 87-95.

Goodfellow, W. D., Geldsetzer, H.H.J., McLaren, D. J., Orchard, M.J. and Klapper, G., 1988, The Frasnian-Famennian extinction: current results and possible causes, In McMillan, N.J., Embry, A.F. and Glass, D.J., eds., Devonian of the world: Volume III: Canadian Soc. Petroleum Geologists, Calgary, p. 9-22.

Hall, J., 1843, Geology of New York: Part IV, Comprising the survey of the Fourth Geological District: Albany, New York, 525 p.

Hartnagel, C.A., 1912, Classification of the geologic formations of the State of New York: New York State Museum Handbook V. 19, 2nd Edition.

House, M.R., 1962, Observations on the ammonoid succession of the North American Devonian Journal Paleontology, V. 36, p. 247-284.

House, M. R., 1965, A study in the Tornoceratidae: the succession of Tornoceras and related genera in the North American Devonian. Phil. Trans. Royal Soc. London, Ser. B, V. 250, p. 79-130.

House, M.R., 1966, Goniatite zonation of the New York State Devonian: In Buehler, E.J., ed., Field Trip Guidebook, 38th meeting New York State Geol. Assoc., Buffalo, New York, p. 53-57.

House, M. R., 1968, Devonian ammonoid zonation and correlation between North America and Europe: In Oswald, D.H., ed., International Symposium on the Devonian System, Calgary, Alberta Soc. Petroleum Geologists, V. II, p. 1061-1068.

House, M. R., Gordon, M., Jr., and Hlavin, W. J., 1986, Late Devonian amononoids from Ohio and adjascent States: Jour. Paleontology, V. 60, No. 1, p. 126-144.

Kidwell, S.M., 1986, Taphonomic feedback in Miocene assemblages: testing the role of dead hard parts in benthic communities: Palaios, V. 1, No. 3, p. 239-255.

Kidwell, S.M. and Aigner, T., 1985, Sedimentary dynamics of complex shell beds: implications for ecologic and evolutionary patterns, In Bayer, U. and Seilacher, A., eds., Sedimentary and evolutionary cycles, Springer Verlag, Berlin, p. 382-395.

Kirchgasser, W. T., 1974, Notes on the ammonoid and conodont zonations of the upper Devonian of southwestern New York, In Peterson, D.N., ed., Guidebook: Geology of Ne York State, 46th Meeting: Fredonia, New York State Geological Assoc., p. B9-B13.

McGhee, G.R. Jr., 1982, The Frasnian-Famennian extinction event: a preliminary analysis of Appalachian marine ecosystems. Geol. Soc. America Spec. paper, No. 190, p. 491-500.

McGhee, G.R., Jr., 1988. Evolutionary dynamics of the Frasnian-Famennian extinction event. In McMillan, N.J., Embry, A.F. and Glass, D. J., eds., Devonian of the World: Volume III: Paleontology, Paleoecology, and Biostratigraphy: Canadian Soc. Petroleum Geologists, Calgary, p. 23-26.

Miller, W. H., 1974, Petrology of Devonian Cattaraugus Formation and related conglomerates, Cattaraugus and Chautauqua counties, New York (Unpubl. master's thesis): State University of New York at Buffalo.

Murphy, J. L., 1973, Protosalvinia (Foerstia) zone in the Upper Devonian sequence of eastern Ohio, northwestern Pennsylvania, and Western New York. Geol. Soc. America Bull., V. 84, p. 3405-3410.

Pepper, J. F. and de Witt, W., Jr., 1950, Stratigraphy of the Upper Devonian Wiscoy Sandstone and the equivalent Hanover Shale in western and central New York: U.S. Geol. Surv. Oil and Gas Invest., Chart 37.

Pepper, J. F. and de Witt, W., Jr., 1951, Stratigraphy of the Upper Devonian Perrysburg Formation in western and west-central New York. U.S. Geol. Surv. Oil and Gas Invest. Chart OC-45.

Pepper, J. F., de Witt, W., and Demerest, D. F., 1954, Geology of the Bedford Shale and Berea Sandstone in the Appalachian Basin: U.S. Geol. Surv. Prof. paper, V. 259, 111 p.

Phillips, T. L., Niklas, K.J., and Andrews, H.N., 1972, Morphology and Vertical distribution of Protosalvinia (Foerstia) from the New Albany Shale (Upper Devonian): Rev. Paleobotany and Palynology, V. 14, p. 171-

Rhoads, D. C., and Morse, J.W., 1971, Evolutionary and ecological significance of oxygen-deficient marine basins. Lethaia, V. 4, p. 413-428.

Rickard, L.F., 1975, Correlation of the Silurian and Devonian rocks of New York State (Map. Chart Serv.): New York State Mus. Sci. Serv., No. 24, 16 p.

Sames, C. W., 1966, Morphometric data of some recent pebble associations and their application to ancient deposits: Jour. Sed. Petrology, v. 36, No. 1, p. 126-142.

Savrda, C.E. and Bottjer, D. J., 1987, The exaerobic zone, a new oxygen-deficient marine biofacies: Nature, V. 327, p. 54-56.

Schopf, J. M. and Schwietering, J.F., 1976, The Foerstia zone of the Ohio and Chattanooga Shales: U.S. Geol. Survey Bull., p. 1294-

Schwimmer, B.A. and Feldmann, R.M., 1990, Stratigraphic distribution of brachiopods and bivalves in the Upper Devonian (Famennian) Chagrin Shale in the Cuyahoga River Valley, northeast Ohio: Kirtlandia, No. 45, p. 7-31.

Scotese, C.R., Van der Voo, R., and Barrett, S. F., 1985, Silurian and Devonian base maps: In Chaloner, W. G. and Lawson, J. D., eds., Evolution and environment in the Late Silurian and Early Devonian. Phil. Trans. Royal Soc. London, V. B309, p. 57-77.

Stanley, D. J., 1987, Turbidite to current-reworked sand continuum in Upper Cretaceous rocks, U.S. Virgin Islands: Marine Geol., V. 78, p. 143-51.

Sutton, R.G., Bowen, Z. P., and McAlester, A.L., 1974, Marine shelf environments of the Upper Devonian Sonyea Grove of New York: Geol. Soc. America Bull., V. 81, p. 2975-2992.

Sutton, R.G., and McGhee, G. R., Jr., 1985, The evolution of Frasnian marine "community-types" of south-central New York: In Woodrow, D. L. and Sevon, W.D., eds., The Catskill Delta, Geol. Soc. America Spec. Publ., V. 201, p. 211-224.

Tesmer, I.H., 1963, Geology of Chautauqua County, New York: Part I, Stratigraphy and Paleontology (Upper Devonian), New York State Museum Bull., No. 391, 65 p.

Tesmer, I.H., 1974, A brief description of Upper Devonian units to be observed on Chautauqua County Field Trip. In Peterson, D.N., ed., Guidbook: Geology of New York State, 46th Meeting: Fredonia, New York State Geological Assoc., p. B1-B8.

Tesmer, I.H., 1975, Geology of Cattaraugus County, New York. Buffalo Soc. Natural Sciences Bull., V. 27, 105 p.

Tesmer, I.H., 1989, History of geology of westernmost New York State (1604-1899): Omni Press, Madison Wisconsin, 214 p.

Thayer, C. W., 1974, Marine paleoecology in the Upper Devonian of New York: Lethaia, V. 7, p. 121-155.

Weidner, W.E. and Feldmann, R.M., 1983, Paleoecological interpretation of echinocarid arthropod assemblages in the Late Devonian (Famennian) Chagrin Shale; northeastern Ohio: Jour. Paleontology, v. 59, p. 986-1004.

White, I.C., 1881, The geology of Erie and Crawford Counties: Pennsylvania Geol. Surv. 2d, Q4, 406 p.

Wignall, P.B., 1990, Observations on the evolution and classification of dysaerobic communities: In Miller, W., III, ed., Paleocommunity temporal dynamics: The long-term development of multispecies assemblies. Paleontological Soc. Spec. Pub., No. 5, p. 99-111.

Woodland, B.G., 1964, The nature and origin of cone-in-cone structure: Fieldiana: No. 4, p. 187-305.

Woodrow, D. L., 1985, Paleogeography, paleoclimate, and sedimentary processes of the Late Devonian Catskill Delta: In Woodrow, D. L. and Sevon, W. D., eds., The Catskill Delta. Geol. Soc. America Spec. Papr. No. 201, P. 51-64.

Woodrow, D. L., Dennison, J.M., Ettensohn, F.R., Sevon, W.T., and Kirchgasser, W. T., 1988, Middle and Upper Devonian stratigraphy and paleogeography of the central and southern Appalachians and eastern midcontinent, U.S.A.: In McMillan, N. J. Embry, A.F., Glass, D.J., eds., Devonian of the world: Volume I: Regional synthesis: Canadian Soc. Petroleum Geologists, Calgary, p. 277-304.

ROAD LOG
DEVONIAN STRATA AND PALEOENVIRONMENTS:
CHAUTAUQUA COUNTY REGION: NEW YORK STATE

TOTAL MILES	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Leave the Fredonia campus at the Temple Street exit. Turn left (south) onto Temple Street.
0.7	0.7	Intersection with Route 20. Proceed straight ahead on Water Street.
0.8	0.1	Cross Canadaway Creek. Gowanda Shale exposed in vicinity of bridge.
0.9	0.1	Bear left at intersection of Water and Liberty Streets.
1.3	0.4	Several levels of river terraces are exposed on each side of bus at this point associated with earlier and higher stages of Lake Erie.
1.8	0.5	Cross Canadaway Creek bridge. Good exposures of the upper part of the Gowanda Shale by bridge are continuous up to falls at Laona.
2.2	0.4	Cross railroad tracks.
2.4	0.2	Enter Laona, New York. Well defined stream terraces can be seen on the right side of the bus. An abandoned oxbow lake can be observed 8 meters (25 ft.) above the present level of the creek.
2.6	0.2	Intersection with Webster Road. Park cars on pull-off to right just before this intersection.

STOP 1. LAONA SILTSTONE MEMBER

Laona Siltstone over Gowanda Shale at waterfall 200 feet southwest of car park at bridge (Overlook Stop Only; we will be able to sample from this division at STOP 4). Note the sharp contrast between the conspicuously banded ("zebra" facies) of the Gowanda and the massive nature of the overlying Laona. The Laona and the higher Shumla siltstone are believed to be gravity-flow units which record downslope movement of silt or fine sand into the anoxic to minimally dysoxic lower slope-basin setting recorded by the Gowanda-Westfield-Northeast shale members.

Total Miles	Miles From Last Point	Route Description
5.2	2.6	Return to Temple Street entrance to the Fredonia campus, but proceed straight (north) on Temple Street towards Dunkirk.
5.6	0.4	Y-Junction; turn right (north) on Brigham Road.
6.1	0.5	Cross New York State Thruway
6.7	0.6	Enter City of Dunkirk
6.9	0.2	Pass Al-Tech Corp. factory (to right).
8.1	1.2	Junction with Route 5; turn left (towards southwest).
8.3	0.2	Turn right onto Point Drive North.
8.7	0.4	Turn right onto Cedar Beach parking area.

STOP 2: HANOVER SHALE-DUNKIRK SHALE CONTACT AT POINT GRATIOT

Point Gratiot is the type section for the Dunkirk Shale Member. Along the northeast side of the point the lower part of the Dunkirk is visible as is the uppermost 1 to 2 meters of the underlying Hanover Shale Member (Fig. 4A). The bioturbated grey Hanover contrasts strongly with the laminated brownish black beds of the Dunkirk. Pyritic burrow tubes are conspicuous in the uppermost Hanover and in the thin, 13.5 cm (4.5 in.), recurrent Dunkirk grey mudstone interval above the basal 15-17 cm (6.0-6.5 in.)-thick basal Dunkirk black bed, but no body fossils occur in the grey lithology except for pyritic goniatite steinkerns and wood debris; this grey sequence is classic for slowly deposited dysoxic facies (Rhoads and Morse, 1971; Byers, 1977).

The Dunkirk Shale is non-bioturbated at most levels but there is some evidence of internal burrowing as can be seen in the basal black bench. Body fossils in the Dunkirk are usually uncommon; the linguloid brachiopod _Barroisella campbelli_ occurs at some levels and both wood debris and fish fragments have been found. The top of the basal black bench is particularly good for carbonized logs and fish debris (Fig. 4A); when viewing is optimal, a thirty foot-long tree trunk is visible on the surface. In the spring of 1986 one of us (Baird) and several S.U.C. Fredonia geology students recovered a partial skeleton of the giant arthrodire _Dunkleosteus_ from this bed.

Although a bioturbated, conformable contact between Hanover and Dunkirk can be seen below the basal Dunkirk black bed which dips southward below the water at this section, the top of the 13.5 cm Dunkirk grey mudstone bed marks a submarine erosion surface which is "roofed" by black Dunkirk deposits; this contact is marked by abundant

Total Miles	Miles from last point	Route Description

STOP 2, continued

detrital pyrite in the form of reworked burrow tube fragments, nodules, and occasional goniatite steinkerns derived from the underlying grey mudstone interval which is conspicuously rich in pyritic tubes and nodules (Baird and Brett, 1986). Additional reworked components include fish bones, conodonts, and carbonized wood fragments. The abundance of wood and conodonts in the basal few centimeters of the overlying black shale suggests that this interval is unusually condensed, recording the descent of numerous logs from the water surface over a long period of time. This wood-rich unit also records bioturbation, which, at this section, was sufficient to flux the broken pyritic tubes into random orientations. Bottom erosion is believed to be due to sediment starvation on the seafloor during relative sea-level rise. Scouring of the substrate may have been accomplished by rare deep storm waves, bottom currents in the basin, or internal waves impinging a regionally sloped substrate (Baird and Brett, 1986; Baird et al., 1988). Exhumed and concentrated detrital pyrite was preserved (not oxidized) in the anoxic to minimally dysoxic Dunkirk bottom setting.

In the early 1980s George McGhee and Edward Olsen sampled this section for the occurrence of iridium, a trace element believed by some to mark catastrophic extraterrestrial collision events in the rock record (see Alvarez et al., (1980). The Late Devonian Frasnian-Famennian ("F-F") extinction event, one of five greatest Phanerozoic extinctions, was, until recently, believed to be coincident with the base of the Dunkirk. This event is similarly thought by some to be the possible record of an impact (Goodfellow, et al., 1988). However, no Iridium-rich horizon was found (McGhee, 1982, 1988). Recent bistratigraphic work indicates that the F-F boundary is somewhere within the upper Hanover (Klapper, Kirchgasser pers. comm.) at a level which has not been precisely identified.

Note the "bedded" till above the Dunkirk and the striated bedrock contact below this "till."

		Leave parking lot. Turn left (south) onto Point Drive North.
9.1	0.4	Intersection with Route 5. Turn right (to southwest).
10.1	1.0	Cross Canadaway Creek.
13.7	3.6	County Fly Ash Dump to the left (see Field Trip G, this volume).
14.8	1.1	Bridge over Little Canadaway Creek.
15.9	1.1	Entrance to Lake Erie State Park.

Total Miles	Miles from last point	Route Description
17.9	2.0	Bridge over Slippery Rock Creek. Exposures include the South Wales Member at the lake shore level and Gowanda Member at the bridge and upstream.
18.8	0.9	Bridge over Corell Creek. Exposures are in the Gowanda Shale Member. The Corell's Point pyrite-goniatite bed is exposed approximately 120 feet upstream from the bridge.
19.9	1.1	Turn right (northwest) onto property of trailer court. Park at beach by boat ramp and proceed on foot across small creek and along shore for approximately 100 yards.

STOP 3: CORELL'S POINT PYRITE-GONIATITE BED IN GOWANDA MEMBER

The Corell's Point Pyrite-Goniatite Bed, encompassing two regionally mappable levels of calcareous septarian concretions, is present at several creek localities in this county but this shore exposure is the best place to examine fossils and sedimentary structures (Fig. 4 B,C). At least two, laterally discontinuous beds rich in pyrite nodules and locally abundant pyritized cephalopod steinkerns can be traced within the lower septarian concretion zone along the shore and around the small headland. Goniatites include *Cheiloceras amblylobum*, *Tornoceras concentricum*, and *Aulatornoceras bicostatum* (Fig. 4C); these belong to the zone of *Cheiloceras* (II) in the Famennian (see House, 1966; Kirchgasser, 1974). Orthoconic cephalopods are also common; these are commonly encrusted by a reptate auloporid coral. Slightly-curved conical shells less than one inch in length may be bactritid cephalopods or coleolid tubes. Bivalves, including *Lunulicardium eriense*, *Praecardium multicostatum* and *Loxopteria corrugata* occur with the cephalopods but these are usually preserved as non-pyritic composite molds often with a faint organic patina which may be a remnant of the periostracum layer. Driftwood, usually partly carbonized and partly permineralized by pyrite, occurs with the other fossils. Spectacular large *Zoophycos* spreiten in the Corell's Point Bed indicate that this trace had become important in offshore, dysoxic facies by the Famennian.

Babcock (1982), believed that the fauna of this bed was selectively preserved by turbiditic smothering events; some beds in this unit have shallow sole marks and display lamination similar to those in flaggy siltstone beds elsewhere in the Canadaway Formation. However, evidence of periods of reduced sediment influx is shown by intense bioturbation at some levels and by the tendency for auloporid corals to not only colonize partly-buried cephalopods but to extend colonial growth onto the adjacent seafloor. The history of this unit is complex and the presence of so many fossils at this level is suggestive of an episode of increased bottom oxygenation and reduced average turbidity.

Total Miles	Miles from last point	Route Description

STOP 3, continued.

The Corell's Point Bed is well exposed in Corell's Creek, Slippery Rock Creek near Brocton, Little Canadaway Creek near Lamberton, Canadaway Creek upstream from Route 20, and Walnut Creek at Forestville (House, 1966, 1968).

Examine the Gowanda strata both below and above the Corell's Point Bed; notice the numerous brown-black shale beds which alternate with grey-green mudstone to produce the conspicuous striped banding along the shore (Fig. 4 B). This basinal "zebra" facies will be discussed in greater detail at STOP 4.

		Return to the bus. Leave trailer park and turn right (southwest) onto Route 5.
21.1	1.2	To the left (south) observe the elongate glacial landforms which characterize this specific part of the lake plain. These deposits may represent reworked sand from older sand deposits of higher lake stages.
21.6	0.5	Bridge over unnamed creek south of golf club. Exposures of Gowanda Shale include a 4.5 m (15 ft.) waterfall at the lake and a conspicuous fossil wood concentration in a siltstone bed between the falls and Route 5.
23.6	2.0	Bridge over Bournes Creek. Park on shoulder and enter property on left (south) of Route 5.

STOP 4: GOWANDA, LAONA, AND WESTFIELD MEMBERS

This outcrop on Bournes Creek affords an opportunity to examine the Laona Siltstone over the Gowanda Shale and to sample the lower part of the still-higher Westfield Shale upstream from the waterfall. The Laona is expressed here as three massive, but relatively thin, siltstone beds which are separated by intervals of interbedded black and green shale ("zebra" facies). It is much more poorly developed here than at STOP 1 or in creeks between here and Barcelona (see road log below); apparently the Laona gravity-flow event involved channelization of the mobile silt such that this unit develops the thick, massive character only locally. Here it appears to be represented by three discrete flow events which must have occurred at separate times.

Total Miles	Miles from last point	Route Description

STOP 4, continued.

We will hike upstream to examine the lower Westfield section which is characterized by good development of the finely interbedded black and green-grey shale depoits ("zebra" facies) that are characteristic of much of the Canadaway succession (Figs. 6, 7). The black shale bands, typically less than one inch-thick, are usually laminated and they can be quite silty; some appear to grade laterally into siltstone beds, commonly containing wood debris. Grey mudstone beds sometimes pinch out laterally allowing black beds to merge. The grey mudstone deposits are fine grained and minimally bioturbated such that they appear structureless on a fresh break surface. The grey beds appear to be composed of turbiditic mud; there appears to be a spectral gradient from the grey mudstone layers through silty mudstone beds with incipient sole mark development to cross-laminated siltstone beds with good sole marks; at an initial glance, this would appear to be reasonable suite of bed-types that one might expect to see in an ancient prodelta slope environment where turbiditic silt was scarce with respect to mud.

However, complex internal cross-lamination of many siltstone beds suggests that processes other than turbidity currents may have produced them and that some beds may record multiple depositional events (see Stanley, 1987). Moreover, it appears that, at least, some of the thin black shale beds do not simply record stagnant anoxia and slow accumulation of organic-rich mud. Beneath many, if not most, thin black shales beds is a millimeter-thick zone of pyritic microspheres and partial microspheres which appear to have formed <u>in situ</u> within the uppermost, water-rich grey mud layer (Figs. 6, 7). Most of these are partial spheres with brilliant curved exteriors and flat tops marked by dull polyframboidal granular surfaces (Fig. 7). Some bear crenulated shiny exteriors reflecting compressive burial affects following formation of the pyrite.

These sand-size microspheres apparently record early diagenetic, bacterially-mediated pyrite formation within spherical spaces. We suspect that surfaceward migration of CO_2 or methane may have produced bubbles which became trapped under the black mud layers or under bacterial mats associated with the black muds (Fig. 7). Sulfidic activity resulted in the partial-to-complete filling of the bubbles leaving the partially filled ones as useful geopetal indicators.

Within the basal few millimeters of many black shale beds, the microspheres are again visible. However, partial microspheres are randomly reoriented, indicating that they have been disturbed after formation. Evidently microbioturbation during black mud deposition served to reorient the pyrite in some instances. In other black shales, the microspheres are concentrated in lag concentrations; this suggests that these black shale layers may have been deposited under the influence of tractional currents. Cuomo and Bartholemew (1987) and

STOP 4, continued

Cuomo and Rhoads (1987), have observed that both modern and ancient black muds are extensively pelletized by bottom organisms. If this is true, then the pelletized black mud may have been easy to mobilize through current action because it would have been like "sand" or "silt". It is then possible that some of the thin black bands in the Canadaway Formation may be analogous to some of the tractional siltstone beds to which they sometimes laterally intergrade. Study of these complex and somewhat enigmatic deposits remains an on-going project.

In-situ microspheres are abundant beneath some of the black bands at this stop. Reoriented and hydraulically concentrated microspheres are locally common along the soles of siltstone beds where they have collected into scoured depressions, (corresponding to "positive" flutes, grooves, and excavated burrows) along such surfaces.

Total Miles	Miles from last point	Route Description
		Return to bus and proceed ahead (to SW) on Route 5.
24.6	1.0	Unnamed creek to right (north). Thick Laona section is present downstream from road.
26.0	1.4	Enter Barcelona, New York.
26.1	0.1	Pass Barcelona Harbor complex. Excellent shore exposures into the Gowanda Shale are developed north of dock area. This is a particularly clean section for observing "zebra" facies. Stone lighthouse was first to be illuminated by natural gas in the U.S.A.
26.2	0.1	Intersection of Route 5 and Route 394. Turn left (south) onto Route 394.
26.4	0.2	Pass Thruway entrance on left.
26.7	0.3	Entering Westfield.
27.7	1.0	Intersection of Route 394 and 20 in Westfield. Continue straight towards Mayville.
28.2	0.5	Crossing Glacial Lake Whittlesey beach berm.
28.6	0.4	Leave Westfield.
28.8	0.2	Cross Little Chautauqua Creek Gorge.
29.0	0.2	Turn right onto Gale Road.

Total Miles	Miles from last point	Route Description
29.45	0.45	Turn right onto car park before bridge and disembark.

STOP 5: NORTHEAST SHALE ALONG CHAUTAUQUA CREEK

At this brief stop we will examine a cutbank section and associated loose siltstone slabs which are typical of the Northeast Member. The Northeast is a typically "flaggy" sequence of thin grey siltstone beds interbedded with silty grey mudstone. Some siltstone layers appear to be turbidites which lack the basal graded division of the typical Bouma-sequence. Many beds display good sole marks with groove- and tool-marks. Networks of the trace fossil *Planolites* are common, and a trace resembling *Zoophycos* occurs more rarely. Some sole marks show hydraulic concentrations of exhumed and transported pyritic microspheres and partial microspheres in groove- and flute-casts; these were current-scoured depressions into which the coarser and heavier pyrite material selectively accumulated as currents waned. Cone-in-cone concretions occur at several levels within the Northeast Shale (Woodland, 1964; Gilman and Metzger, 1967); fragments of such concretions are occasionally observed in creek rubble at this stop. *In-situ* shelled fossils are rare to absent here as at many other sections of the lower Northeast Member. This facies records a dysoxic prodelta setting below the reach of most storm waves.

Total Miles	Miles from last point	Route Description
		Return to bus. Turn left from carpark onto Gale Road.
29.9	0.45	Junction with Route 394; turn right (south) towards Mayville.
31.4	1.5	Start to cross lip of prominent lake escarpment marking edge of Allegheny uplands.
34.4	3.0	Enter Mayville.
34.8	0.4	Junction of Route 394 and Route 430. Turn right (southwest) onto Route 430.
38.9	4.1	Turn right (west) onto Nettle Road (turn onto Nettle Rd. coincides with left (southward) turn of Route 430 towards Sherman).
39.0	0.1	Turn right (northwest) from Nettle Road onto Lyons Road. Group of buildings is hamlet of Summerdale.
39.1	0.1	Cross Summerdale Road.

Total Miles	Miles from last point	Route Description
40.0	0.9	Chautauqua Creek State Forest to right.
40.6	0.6	Lyons Road dead end at Chautauqua Creek (bridge is out). Park bus and disembark. LUNCH STOP.

STOP 6: FOERSTIA (PROTOSALVINIA) ZONE WITHIN ELLICOTT SHALE MEMBER

Exposures of the Chadakoin Formation on Chautauqua Creek are the most complete in New York; the lower division (Dexterville Siltstone Member) is entirely exposed, and approximately 75 to 80 percent of the overlying Ellicott Shale Member can be observed on this creek and along its upper tributaries (Fig. 8). Recent discovery of about 38 meters (120 ft.) of additional measureable Ellicott in a side tributory bordering Lyons Road allows us to observe a major siltstone division yielding the distinctive large rhynchonellid brachiopod *Paurorhyncha newberryi* (Figs. 8, 9): which has not been recorded prior to now within the county (Tesmer, 1963). In addition, discovery of the important algal taxon *Foerstia* (*Protosalvinia*) in the section at this stop (see text) allows us to establish equivalency of this outcrop with key parts of the Ohio, Antrim, New Albany, and Chattanooga black shales between New York and Oklahoma.

According to correlations and measurements of Tesmer (1963), and Burrier (1977), the Lyons Road section is within the Ellicott Shale approximately 33 meters (105 ft.) above the Dexterville Member. Mapping by Baird shows that the Dexterville-Ellicott boundary of Murphy (1973), corresponds to a level in Chautauqua County which is approximately 33 to 38 meters (105-125 ft.) above that of Burrier (see text). The Lyons Road section correlates to Murphy's Dexterville-Ellicott lithologic transition and the zone of abundant *Foerstia* that are characteristically associated with it; the boundary between Murphy's two members is approximately at the 1400 foot-elevation (Fig. 8, 9) which is below the old road shoulder (parking area for group) adjacent to the defunct bridge. This level also corresponds to an upward transition from siltstone-dominated "distal platform" Ellicott facies of Burrier (1977), to his mudstone-rich "prodelta" deposits at the upper end of his measured section. We will cross the mowed field area and collect from shell-rich, silty deposits near the boundary between the siltstone-dominated and upstream shale-dominated intervals.

Downstream from the bridge vicinity is siltstone-dominated, fossiliferous delta platform ("Chemung") facies of the Late Devonian (Rickard, 1975). The most conspicuous features are lenticular siltstone and fine sandstone beds interspersed with grey mudstone layers and coquinitic shell accumulations. Unlike the thinner and more continuously even-bedded slope and basin siltstone beds in the Canadaway Formation, these layers pinch and swell and there is abundant evidence of erosional truncation of older beds by younger ones. Storm layers dominate the section; tempestites, pararipples, occasional thick siltstone beds with hummocky cross-stratification, and gutter casts are

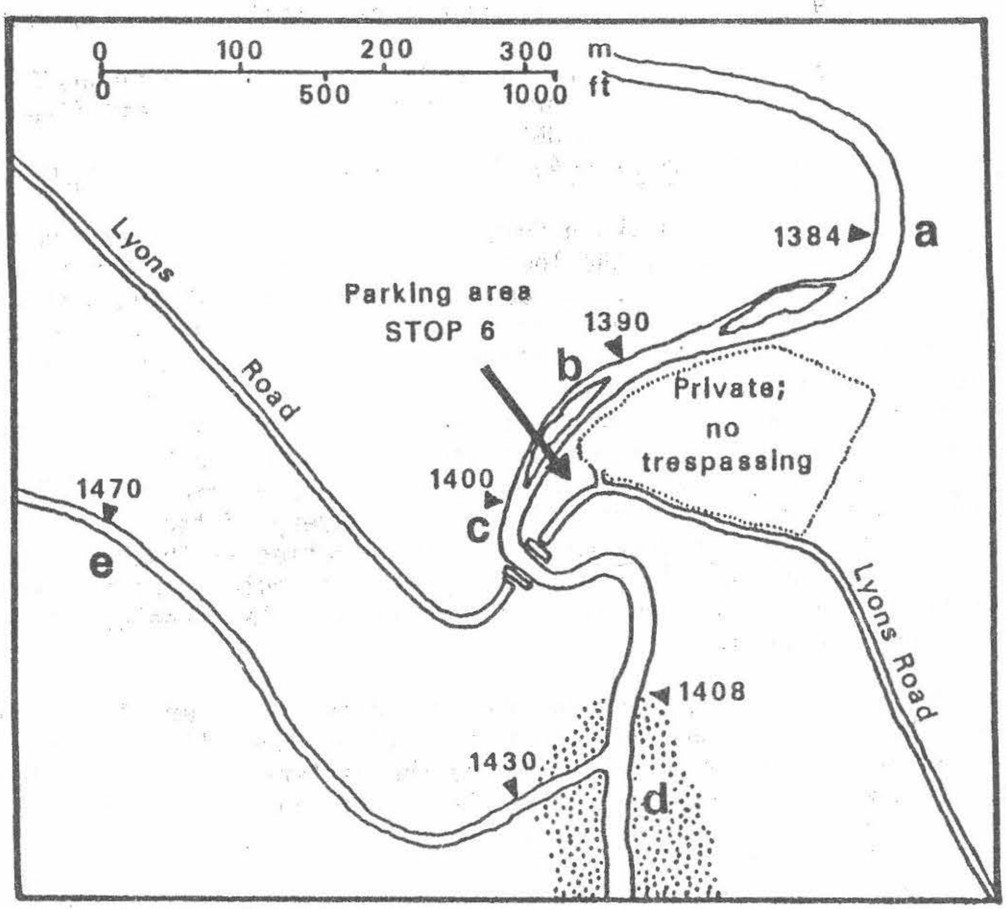

Fig. 9 Chautauqua Creek Devonian exposures in the vicinity of Lyon's Road crossing (see STOP 6). A) major flow roll bed; B) Interval of abundant Foerstia; B-C) top of siltstone-dominated interval corresponding to Dexterville-Ellicott boundary identified by Murphy (1973) in Pennsylvnia. Burrier (1977) interprets upward change from the siltstone-dominated unit to mudstone-dominated facies (at elevation 1395) as a transgressive change from "distal shelf" to "prodelta" conditions. The mudstone-dominated facies unit (C) near the defunct bridge yields echinoderms, Foerstia, and dictyosponges. D) No bedrock exposure; a Quaternary buried valley filled with stratified drift underlies the creek in this area; E) Strata yielding the large rhynchonellid brachiopod Paurorhyncha newberryi are exposed in large side tributary.

Total Miles	Miles from last point	Route Description

STOP 6, continued.

all evidence for the impingement of storm waves on the substrate. Good tempestites display a weakly graded concentration of reworked shells, overlain by laminated siltstone with low inclination cross-stratification displaying internal bedding discordances (see Aigner, 1985). Gutter casts are erosional runnels, usually less than a meter in length which often have interiors similar to tempestites; siltstone- and shell-filled gutters are the result of scour- and filling-processes involving both oscillatory and unidirectional currents during storms (Aigner, 1985). These runnels are presently casted with siltstone and coquinites and they display "tool marks" produced by the bouncing and rolling of shells, wood, and other debris during the storms. Sole marks under many siltstone beds show disarticulated brachiopod shells visible as concavities on the sole surface; this is the result of mud "sheltering" beneath the stationary shell during the storm which is subsequently buried by silt. Later differential weathering removes the sheltered mudstone leaving the shell as a negative feature on the siltstone surface. Chadakoin storm beds decrease in size and complexity downslope into Pennsylvania and Ohio along a depth-controlled proximality gradient (see Aigner, 1985); this gradient can be better assessed through refined stratigraphic mapping within this formation.

Not only are the thick proximal storm beds represented in this section but thin, mud-dominated layers produced by smaller storms are common, particularly upstream in the shaley Ellicott interval. These distal tempestites record the transport and settle-out of mud which often smothered bottom organism as currents dissipated (Brett, et al., 1986). Excellent examples of articulated delicate fossils, including crinoids, echinoids, and glass sponges, found at the Lyons Road section attest to numerous bottom-smothering events recorded in this outcrop.

Abundant fossils belonging to a few standard brachiopod and bivalve genera can be collected here. Brachiopods including the rhynchonellid *Camarotoechia contracta*, the spiriferid *Cyrtospirifer nucalis*, and a productid *Productella speciosa* are ubiquitous, as are the bivalves *Mytilarca chemungencis* and *Leptodesma potens*. In particular, notice the partially dissolved character of the brachiopod shells. Evidently, carbonate undersaturation in the near surface muds and/or oxidation of pyrite in these same muds caused many of these shells to undergo variable amounts of dissolution. Fossils to look for include hexactinellid sponges, articulated inadunate crinouds and undescribed archaeocidaroid echinoids. Small fossils include the fucoid algal structure *Foerstia* and abundant black, chitinous polychaete jaw elements called scolecodonts. The best *Foerstia* can be collected from shelly beds in the vicinity of- and downstream from the junction point of the north-trending, gently sloped path with Chautauqua Creek (Fig. 9). These resemble 0.5 to 1.0 mm-diameter black "tar splatter" marks on bed surfaces which frequently are branched in a characteristic "Y" pattern. A few bedding surfaces are crowded with this important fossil.

Total Miles	Miles from last point	Route Description
		Return to bus. Head back uphill on Lyons Road to Summerdale.
42.2	1.6	Junction of Lyons Road with Nettle Road at Summerdale. Proceed straight (south) on Lyons Road.
42.3	0.1	Lyons Road converges into Route 430. Proceed south on Route 430 to Sherman.
46.2	3.9	Enter village of Sherman.
46.8	0.6	Junction of Route 430 with Route 76 in Sherman. Turn left (south) onto Route 76.
45.9	0.3	Junction Route 76 with New Route 17. Turn left (east) onto Route 17.
48.1	0.9	Cattaraugus exposure on left side of road.
49.5	1.4	Ellicott Shale on right and left side of road for next half mile. It is rich in sideritic lentils and characterized by some pyrite-rich mudstone beds, fossils are scarce.
52.2	2.7	Cross Prendergast Creek. Ellicott Shale along creek below bridge. *Foerstia*-bearing strata equivalent to the section at STOP 6 occur along this creek north of (downstream from) Route 17 above the Stedman-Sherman road crossing at an elevation of 1380-1390 feet.
52.5	0.3	Ellicott Shale on left and right side of road for next 0.25 mile. Stop vehicles at west (downhill) end of section.

STOP 7: STRATA OF UPPERMOST ELLICOTT MEMBER

This will be a brief stop to examine beds in the highest Chadakoin Formation. In the lower part of the cut and, particularly in the drainage ditch, one can observe brachiopod coquinites associated with storm (tempestite) beds. The characteristic upper Ellicott rhynchonellid brachiopod *Paurorhyncha newberryi* occurs at one or two levels in this roadcut. Of particular interest are shells stacked like dishes due to the oscillatory motion of storm-currents on the substrate (see Kidwell and Aigner, 1985; Kidwell, 1986). The elevation of the upper (eastern) end of this outcrop is approximately 10 to 15 meters (30-50 ft.) below the projected level of the Panama Conglomerate which can be seen on the hill immediately south of this area (Tesmer, 1963).

Total Miles	Miles from last point	Route Description
		Return to bus. Proceed east on Route 17.
53.0	0.5	Exit Route 17 for Route 32.
53.3	0.3	Turn right (south) on Route 32 towards Panama.
55.9	2.6	We are crossing the northern limit of the "Bass Islands" structural trend of drillers. The base of the Panama Conglomerate is anomolously elevated to approximately 1740 feet in this immediate area. Note abundant evidence of drilling activity (blue pumps and tanks) in nearby fields.
58.4	2.5	Enter Panama, N.Y.
58.8	0.4	Junction of Route 32 with Route 474 in Panama. Turn right (west) onto Route 474.
59.0	0.2	Junction of Route 474 with Rock Hill Road. Turn left up the hill towards Panama Rocks Park.
59.2	0.2	Enter Panama Rocks Park on left.

STOP 8: PANAMA CONGLOMERATE MEMBER OF CATTARAUGUS FORMATION

The Panama Conglomerate, named by Carll (1880), for 21 meters (70 ft.) of quartz-pebble conglomerate and quartz-dominated sandstone exposed at Panama, Chautauqua County, is a conspicuous lenticular unit at the base of the Cattaraugus Formation (see Tesmer, 1963, 1974). It is one of several conglomerate-rich units within the Cattaraugus Formation of Chautauqua and Cattaraugus counties. The Panama is correlative with the LeBoeuf Sandstone in Erie County, Pennsylvania and in western Chautauqua County.

The Panama Conglomerate Member is composed of cross-bedded, quartz pebble conglomerate, quartz-rich sandstone and sandstones with dilute (sand-supported) pebble concentrations. Conglomerates are composed mainly of quartz pebbles with minor components of jasper and metamorphic rock. Pebbles are usually less than one inch in diameter, well rounded, and often display a distinctly flattened discoidal to prolate shape. Rare fossils described from the Panama include Cyrtospirifer chemungensis, Camarotoechia contracta, Ptychopteria sao, as well as gastropods, (Tesmer, 1963; Miller 1974).

Miller (1974) interpreted the Panama to be a "beach" or "near beach" deposit with the main sediment source area to the southeast. One line of evidence he used was the tabular shape of many quartz pebbles in

STOP 8, continued.

the Panama as opposed to the more ovoidal pebble shapes he observed in the "fluviatile" post-Devonian Knapp and Olean conglomerates (see also work of Sames, 1966); abrasive imbricate stacking and sliding of pebbles in a beach-foreshore environment was cited to explain the tabular pebble condition. In addition, the distinctly bipolar (NW-SE) paleocurrent pattern for measured cross-bedding sets within Panama (Miller, 1974) appears to reflect tidal current processes acting in a coastal setting. The occurrence of brachiopods and marine mollusks in the Panama is further evidence of marine influence in this deposit.

A major question that geologists confront when examining deposits such as these is the problem of transporting and accumulating the vast numbers of quartz pebbles in this outcrop; clearly, a great volume of source terrain must have been denuded to produce it because vein quartz, chert nodules, and pegmatitic quartz make up only small volumes of normal lithosphere. This problem is partly obviated by the fact that the Panama Rocks outcrop is really more a thick lentil or channel feature which attenuates laterally to thin Panama facies dominated by sandstone (Tesmer, 1963; Miller, 1974). Hence, the volume of Panama quartz pebbles is really much less than this outcrop would initially suggest. Many of these pebbles may have been recycled from conglomerates in older Paleozoic units. Conglomerates are conspicuous features in the Ordovician Bald Eagle and Juniata divisions, the Silurian Oneida-Shwangunk and Tuscarora deposits, and in Middle through Upper Devonian proximal deltaic deposits of the Catskill Delta; Acadian overthrusting events probably exposed some or all of these eastermost sedimentary divisions to erosion, thus freeing up older pebbles for recycling. Post-Chadakoin sea level-fall and westward-northwestward advance of the paleoshoreline in western New York and northwest Pennsylvania probably served to introduce large numbers of quartz pebbles into the Chautauqua County region.

Many questions remain unanswered concerning these conglomerate units and the non-conglomeratic facies in between them. There are very few places where basal Cattaraugus (Venango) coarse facies can actually be seen in place rather than as slump blocks in creek beds or on wooded hillsides; it is essential to observe upper and lower contacts of units such as this to establish any sense of context for these units as geological events.

For those particularly interested in landscape and groundwater processes Panama Rocks offers a superb view of slope creep in action as well as weathering processes along joint systems developed in this deposit. The numerous "Dens" and "Alleys" between blocks also provide opportunity to examine the important role of "root pry" in forcing blocks apart. This park is one of several such tourist areas developed in conglomerate-rich deposits in this region.

Total Miles	Miles from last point	Route Description
		Return to bus. Return downhill on Rock Hill Road to Junction with Route 474.
59.4	0.2	Junction with Route 474. Turn right (east) into Panama.
59.6	0.2	Junction of Route 474 with Route 32 in Panama. Turn left (north) and proceed towards Chautauqua Lake.
65.3	5.7	Pass beneath new Route 17. Continue straight (north) on Route 32.
66.2	0.9	Pass through Stedman. Continue straight. over Kent end moraine.
67.3	1.1	Cross Prendergast Creek and continue over Kent ground moraine to vicinity of Chautauqua Lake.
69.0	1.7	Junction of Route 32 with Route 394 at Chautauqua Lake south shore. Turn left (northwest) onto Route 394 towards Mayville. For the next several miles we will traverse over Pleistocene and Recent alluvial sand and silt.
70.7	2.8	Leave Chautauqua Lake shore area and proceed uphill (northwest) into center of Mayville.
71.5	0.8	Junction of Route 394 and Route 430 in Mayville. Proceed straight on Route 394 to Westfield.
77.5	6.0	Junction of Route 394 and U.S. 20 in Westfield. Turn right (northeast) onto Route 20 and proceed to Fredonia.
79.3	1.8	Leave Westfield (commercial area bordering village).
81.1	1.8	Ascend Lake Warren beach berm. Rt. 20 follows the top of this beach ridge for the next 8 miles. Numerous vineyards and orchards are developed on the sandy soil, as are numerous sand and gravel pits.

Total Miles	Miles from last point	Route Description
83.6	2.5	Enter town of Portland.
84.7	1.1	Enter town of Brocton.
86.0	1.3	Leave town of Brocton.
88.2	2.2	Cross Little Canadaway Creek. Resistant siltstone beds within Gowanda Shale hold up waterfall 100 feet downstream from road.
91.3	3.1	Enter village of Fredonia.
91.8	0.5	Cross Canadaway Creek. Monument (enscribed boulder) to left marks position of the first successful gas well which was drilled in 1825).
92.0	0.2	Junction of Temple Street and U.S. 20. Turn left (northwest) onto Temple.
92.7	0.7	Temple Street entrance to State College: Fredonia campus.

END OF TRIP

GEOLOGY AND OIL AND GAS EXPLORATION IN WESTERN NEW YORK

Jerold C. Bastedo (Ecology and Environment, Inc.)
and
Arthur M. Van Tyne (Van Tyne Consulting)

HISTORY OF OIL AND GAS DRILLING IN WESTERN NEW YORK

SEEPS

Long before any drilling took place, local Indians had found natural oil and gas seeps at several places in western New York. The first recorded observation by white men of such an occurrence was in 1627. In a letter written in that year a Franciscan priest described his visit to the Cuba oil spring in Allegany County. He was taken there by a band of Indians who had used the oil at various times for medicinal, fuel and ceremonial purposes.

In 1669 Indians took the French explorer LaSalle and his party to a natural gas seep which they knew of in western Ontario County. While there, they lighted the gas and watched it burn. The event was recorded in a diary by one of the party and this account was later published.

FIRST WELLS

Possibly the first gas well drilled anywhere was located in the bed of Canadaway Creek where it flows through Fredonia. In 1821, William A. Hart, drilled a hole into the shale there to a depth of 70 feet and obtained a flow of gas. He piped and sold the gas to various places of business in the Village and it was also used to light street lamps.

According to Herrick (1949) the Hart well was still producing gas in 1858. From 1821 to 1858 others produced gas for commercial use, with varying success, from gas seeps in the Fredonia area. In 1858, searching for an additional supply of gas, Preston Barmore and Elias Forbes made a location for a new gas well. This was near a gas seep in Canadaway Creek about one mile north of the Hart well. The new well consisted of a dug cavity about 30 feet deep in the bottom of which two holes were drilled to depths of 100 and 150 feet. The holes found gas and the well was hooked up to supply gas to the Village.

In August of 1859 Edwin L. Drake made his great oil discovery near Titusville, Pennsylvania. That 69½ foot hole showed that oil was reservoired in rocks and could be recovered from rock in greater quantity than from a seep by drilling a well into it. After the Drake discovery men began to drill all over western Pennsylvania and southwestern New York looking for oil.

OIL WELL DRILLING

As already described, the earliest wells drilled in New York were attempts to find natural gas. According to Herrick (1949) the first actual oil test in New York was drilled on the Moore farm in northwestern Allegany County in 1860. The hole was drilled to a depth of 600 feet and found some oil but not enough to pay. In 1865 the hole was deepened to 900 feet but no further oil sands were found and the well was abandoned.

The first commercial oil production in New York came from a well drilled by Job Moses in 1865 in the Town of Carrollton in Cattaraugus County. The well was drilled on the Hall farm near the Village of Limestone and is in a northern projection of the Bradford oil field which lies mainly to the south in Pennsylvania. When completed, the well produced about seven barrels of oil a day from the Bradford Third sandstone.

In 1878 and 1879, O. P. Taylor found the first oil production in the Allegany field in Allegany County. This became the largest oil field in New York. Subsequent drilling, including the Richburg extension in 1881, enlarged the limits of the field and discovered a number of separate small pools. Some of these extend eastward across the Allegany County line for a short distance into southern Steuben County.

Chautauqua County is the only other New York County which has had significant oil production. The first drilling for oil took place in the southeastern part of the County in 1919 and continued for several years with negative results. The shallow Busti oil field was discovered in 1945. The following account is taken from an article by Van Tyne in the Guidebook for the 1974 NYSGA meeting at Fredonia: "In 1945 Todd M. Pettigrew, backed by the Thomas brothers of Chicago, began a drilling program to develop oil production in the Busti area located about four miles southwest of Jamestown. Several wells were drilled over a three year period and modest production was established from the Glade sand at about 700 feet in depth. However, the sand is tight and initial production declined rapidly making the operation uneconomic. By late 1948 the properties were abandoned or farmed-out to other interests who later abandoned them. An interesting aspect of the Pettigrew operation was the use of a "secret" electric device to aid in locating oil bearing rocks". After the invention of hydraulic fracturing of wells to stimulate production the development of the Busti area was revived and over 300 wells have been completed there.

GAS WELL DRILLING

ALLEGANY COUNTY.

In Allegany County the first deep gas wildcat was drilled on the Buell farm southwest of the Village of Hume in the northern part of the

County in 1899. The well was taken to a total depth of 3,326 feet but only a few shallow shows were found and the hole was abandoned.

"The first deep gas in Allegany County was found by a well on the Gilbert farm in the Town of Wirt. The location is slightly to the north and east of the Richburg oil field area. The well was completed in 1928 and produced gas from fractured Tully limestone at a depth of about 4,000 feet. It is now being used for the storage of natural gas." (from Van Tyne & Foster, 1980)

The deepest well in the County was completed in 1963 by Consolidated Gas on the Wolfer farm in the southwest part of the Town of Hume. The well ended in the Potsdam at a total depth of 7,560 feet and was unsuccessful. About one and one-half miles to the southwest in the same Town, Parsons Brothers had drilled a well in 1959 to a depth of 7,337 feet. That well was also unsuccessful.

Not counting the abovementioned two deep tests, only 17 Medina sandstone tests have been drilled in Allegany County. Four of these were completed as gas wells - three are small producers and one is shut-in.

CATTARAUGUS COUNTY.

The first deep gas test in the County was drilled on the Vinton tract in the Village of Gowanda in northwestern Cattaraugus County in 1883. The well was drilled to a total depth of 1,700 feet, through the Onondaga, but found only a show of gas in the upper shales. It was later deepened to the Medina but was still unsuccessful.

"The first deep gas here was discovered in the Medina sandstone by a well drilled in 1898 at Skinner Hollow in the Town of Otto. Deep drilling in later years resulted in the discovery of the Perrysburg and Nashville (Medina) Fields in 1924 and 1926 in the Town of Perrysburg and adjoining Town of Hanover in Chautauqua County.

The first Oriskany sandstone gas production in Cattaraugus County was from the Allegany State Park Field, discovered in 1955. The discovery well, one of nine eventually drilled on the Lockwood farm, came in for 8.4 million cubic feet of gas per day but could not be controlled. The well blew wild for several days until increasing salt water killed the gas flow. Later wells drilled further to the west re-established gas production from this Oriskany pinch-out type trap. The field is the largest Oriskany pinch-out field in New York. In 1957 the unusual Ischua Oriskany gas field was discovered. This unique one-well field produced from a small outlier of Oriskany sandstone separated from and north of, the main pinch-out line." (From Van Tyne & Foster, 1980)

The deepest well in the County, and the second deepest well in New York, was drilled in 1972 by Pennzoil-Amoco in the southeastern part of the County near the New York-Pennsylvania state line. The Enterprise-

Transit-State, or ET-1, well was completed at a depth of 11,680 feet in Pre-Cambrian rocks. No commercial gas was found in the deep rocks but the well was plugged back and produced a small amount of gas from the Oriskany sandstone after treatment.

In 1957 and 1958, Iroquois Gas drilled two deep tests near Perrysburg in the northwestern part of the County. No deep production was found and one well was plugged-back for use as a gas storage well and the other well was plugged and abandoned. In 1971 the same company drilled two more Theresa tests in the same general area but both were dry and abandoned. In late 1989 Fault Line Oil was drilling a 7,500 foot Theresa test in the Town of Ashford.

CHAUTAUQUA COUNTY.

The following material is taken from the account by Van Tyne in the Guidebook for the 1974 NYSGA meeting at Fredonia: "The first deep well was drilled by Alvah Colburn in 1871 at his mill located south of Main Street in Fredonia. The well, which was drilled to a depth of 1,256 feet, encountered gas between 130 to 300 feet, and reached the Onondaga limestone at 1,079 feet.

During the autumn of 1886, and the first half of 1887, the first Medina sandstone well in the county was drilled about one-half mile southeast of the village by the Fredonia Gas and Fuel Company. Additional Medina drilling did not take place until 1903 when the South Shore Gas Company and the Brocton Gas Company began to drill Medina wells in the Brocton and Silver Springs areas. Since 1903, drilling in Chautauqua County has continued on a sporadic basis with the majority of wells being drilled for Medina sandstone gas production.

The first of ten deep wells drilled in Chautauqua County (Note: to 1974; one additional deep hole was drilled in 1976) was the No. 1 Cassity of Frost Gas located one-half mile east of Dunkirk. That well was originally drilled to a depth of 2,052 feet in 1908 and was re-entered and drilled deeper to a depth of 4,035 feet in 1916. The Niehaus well, located two and one-half miles northeast of Dunkirk, was also an old well drilled deeper to 4,517 feet in 1949.

Since then, eight (Note: now nine) more deep wells have been completed, all ending in Cambrian sandstones except one which stopped in the Trenton. No well has been drilled to undoubted basement rocks in Chautauqua County, but the deepest well in the county, the No. 1 Harrington of Wolf's Head Oil located six miles northwest of Jamestown was completed at 7,694 feet in the Cambrian Potsdam sandstone which overlies basement rocks. No commercial gas or oil production has so far been found in the Cambro-Ordovician rocks of Chautauqua County."

ERIE COUNTY.

According to Bishop (1895) the first gas test in Erie County was drilled at Getzville in 1858 or 1859. Eventually, at least 20 to 30 wells were drilled in the area around Getzville. The Getzville gas production is quite interesting because it occurs at the shallow depth of 450 to 500 feet and is found in the Irondequoit limestone. This is the only gas occurrence in New York from this zone although it has also been productive to the west across the Niagara river in Ontario, Canada.

Only a few scattered wells were drilled for gas in Erie County from 1859 until the early 1880's. In 1883 the Buffalo Cement Company began the first systematic search for gas within the City of Buffalo (Bishop, 1895). Within a few years eleven wells had been drilled on their property which was located about one-half mile southwest along Main Street from the University of Buffalo.

In the latter 1880's and in the 1890's many more wells were put down in Buffalo and other parts of Erie County with varying success. By the turn of the century the natural gas industry was well established and drilling in Erie County has continued to the present day. To date, 22 deep wells testing for possible gas in Cambro-Ordovician rocks have been drilled in Erie County. Only one of these wells was moderately successful.

WYOMING COUNTY.

The first well in this County was drilled for oil by the Vacuum Oil Company in the Oatka Creek valley in the Town of Middlebury in 1877-1878. The well, known as the "Pioneer" well, found a salt bed and ended at a depth of 1,455 feet, in the Salina. In the latter 1800's many other salt wells were drilled in the Oatka Creek valley and in other parts of Wyoming County.

In 1883 a well was drilled to a depth of 1,960 feet at Attica. Although the well penetrated the Medina it was dry. In 1897 a well drilled 400 feet west of this well to a depth of 1,708 feet became the first gas producer in Wyoming County and the discovery well of the Attica (Medina) gas field.

Fifteen wells have been drilled to the Trenton, or deeper, in Wyoming County. The first of these was drilled at the K.R.Wilson plant in Arcade in 1946. The well was drilled to a total depth of 7,144 feet but was dry. In 1961 a well was drilled near the Village of Gainesville by Consolidated Gas. The well reached a depth of 7,182 feet and finished in the Potsdam as a dry hole.

In 1963, Trans-American Petroleum Corp. re-opened a 1961 dry hole located on the Strathearn farm in the Town of Middlebury. They drilled the well deeper from its original depth of 2,481 feet to a new total depth of 5,507 feet. This deepened well discovered gas in the Theresa formation, one of only a few such producers in western New York. Within a year, four other deep wells had been drilled in the vicinity, one of these to the Pre-Cambrian. Only one other well found gas production in the Theresa. None of the other eight deep tests in the County was successful.

REGIONAL GEOLOGY OF PRODUCING FORMATIONS

(Note: Much of what follows has been taken from the publication: "Inventory and Analysis of the Oil and Gas Resources of Allegany & Cattaraugus Counties, New York" by Van Tyne and Foster, 1980)

UPPER DEVONIAN SANDSTONES.

Oil and gas producing sandstones of Late Devonian age are found in Allegany, Cattaraugus, Chautauqua and Steuben Counties (Fig. 1). These are interfingering and lensing rocks that were deposited in shallow water at the distributary front of a large delta complex which was built out from the east during Middle and Late Devonian time. The sandstones have generally low porosity and permeability that does not appear to be related to regional trends or structures.

Lithologically, the sandstones are very fine to fine-grained graywackes consisting of angular quartz grains, rock fragments, and subordinate mica. Little or no feldspar is present. The inter-granular cementing material is largely silica.

Where productive they have an average porosity of 12 to 14 percent with an average permeability of 3 to 10 millidarcies (md.). Other values have been measured in core tests of the sandstones but these values appear to apply to most of the productive zones. Porosities in productive areas are generally in the above range, but production has been obtained in areas with permeabilities of 1 md. or less.

DEVONIAN BLACK SHALES.

Several black shale sequences occur within the Upper and Middle Devonian rocks of New York. The uppermost of these shales is the Dunkirk which lies at the base of the Perrysburg Formation. The Dunkirk outcrops and has been a gas producer in the Lake Erie area of Chautauqua County. East of Cattaraugus County, it thins and becomes grayer.

COMPOSITE PALEOZOIC STRATIGRAPHIC SECTION

FOR SOUTHWESTERN NEW YORK

PERIOD		GROUP	UNIT		THICKNESS	PRODUCTION
Penn.		POTTSVILLE	OLEAN	Ss,Cgl	75-100'	
Miss.		POCONO	KNAPP	Ss, Cgl	50-100'	
DEVONIAN	UPPER	CONEWANGO		Sh,Ss,Cgl	700'	
		CONNEAUT	CHADAKOIN	Sh,Ss	700'	
		CANADAWAY	UNDIFF. †	Sh, Ss	1100-1400'	Oil,Gas
			PERRYSBURG#	Sh,Ss		Oil,Gas
			DUNKIRK	Sh		
		WEST FALLS	JAVA		375-1250'	Oil,Gas
			NUNDA	Sh,Ss		
			RHINESTREET			
		SONYEA	MIDDLESEX	Sh	0-400'	
		GENESEE		Sh	0-450'	
	?		TULLY	Ls	0-50'	Gas
	MIDDLE	HAMILTON	MOSCOW	Sh	200-600'	
			LUDLOWVILLE	Sh		
			SKANEATELES	Sh		
			MARCELLUS	Sh		Gas
			ONONDAGA	Ls	30-235'	Gas, Oil
	LOWER	TRISTATES	ORISKANY	Ss	0-40'	Gas
		HELDERBERG	MANLIUS	Ls	0-10'	
			RONDOUT	Dol		
SILURIAN	UPPER		AKRON	Dol	0-15'	Gas, oil
		SALINA	CAMILLUS	Sh, Gyp.	450-1850'	
			SYRACUSE	Dol,Sh,Salt		
			VERNON	Sh, Salt		
		LOCKPORT	LOCKPORT	Dol	150-250'	
		CLINTON	ROCHESTER	Sh	125'	Gas
			IRONDEQUOIT	Ls		
	LOWER		SODUS	Sh	75'	
			REYNALES	Ls		
			THOROLD	Ss	2-8'	
		MEDINA	GRIMSBY	Sh,Ss	75-160'	Gas
			WHIRLPOOL	Ss	0-25'	Gas
ORDOVICIAN	UPPER		QUEENSTON	Sh	1100-1500'	Gas
			OSWEGO	Ss		
			LORRAINE	Sh	900-1000'	
			UTICA	Sh		
	MIDDLE	TRENTON-BLACK RIVER	TRENTON	Ls	425-625'	Gas
			BLACK RIVER	Ls	225-550'	
	LOWER	BEEKMAN-TOWN	TRIBES HILL-CHUCTANUNDA	Ls	0-550'	
CAM-BRIAN	UPPER		LITTLE FALLS	Dol	0-350'	
			GALWAY (THERESA)	Dol,Ss	575-1350'	Gas
			POTSDAM	Ss, Dol	75-500'	Gas
PRECAMBRIAN			GNEISS, MARBLE, QUARTZITE, etc.			

† INCLUDES GLADE, BRADFORD 1st, CHIPMUNK BRADFORD 2nd, HARRISBURG RUN, SCIO, PENNY, & RICHBURG

INCLUDES BRADFORD 3rd, HUMPHREY, CLARKSVILLE, WAUGH & PORTER, & FULMER VALLEY

Figure 1.

The Rhinestreet may have some possible gas potential. In the Lake Erie shoreline area the Rhinestreet is a massive black shale with interbedded gray shale and argillaceous limestones in the upper section. To the east it contains thin silty interbeds which can be gas reservoirs.

The Middlesex is a highly organic brownish-black shale. It commonly consists of laminae of dark organic matter alternating with clays and silt-size quartz grains. When broken, it exudes an oily odor. There is no known gas production from this zone.

The Geneseo black shale overlies the Tully limestone, where present, and is cut out by erosion in far western New York. There is no gas production from this zone in New York.

The Marcellus black shale is the basal formation of the Hamilton Group which overlies the Onondaga limestone. This is a highly organic black shale and the most highly radioactive shale in the New York Devonian section. It may be recognized by a distinctive, strong, rightward deflection on a gamma ray log.

ONONDAGA LIMESTONE.

The Onondaga limestone varies from about 10 feet in Steuben County to more than 200 feet in Chautauqua County. This fossiliferous, medium gray limestone may contain oil and gas in fault-generated fractures or in primary porosity in fossil coral reefs. The faulted Onondaga limestone will be discussed in the "Bass Islands" section under Recent Developments.

In 1967, the first Onondaga pinnacle reef was discovered in a wildcat well drilled on the Cornell farm in the Town of Jasper, Steuben County, by the Wyckoff Development Company. An open flow of about one million cubic feet of gas per day (mmcfgpd) was recorded from the Onondaga reef. Gas was also found in the Oriskany sandstone and the final open flow from this well was about 7 million cubic feet of gas. The discovery was later designated as the Wyckoff Field. The Homer Banks well, drilled by the Sylvania Corporation, penetrated 196 feet of Onondaga reef but was completed and produced initially from the Oriskany sandstone (Fig. 2). The Oriskany produced over 912 mmcf of gas from 1968 to 1971. The well was re-completed in the Onondaga in 1972 and has produced over 2.8 billion cubic feet (bcf) of gas to date.

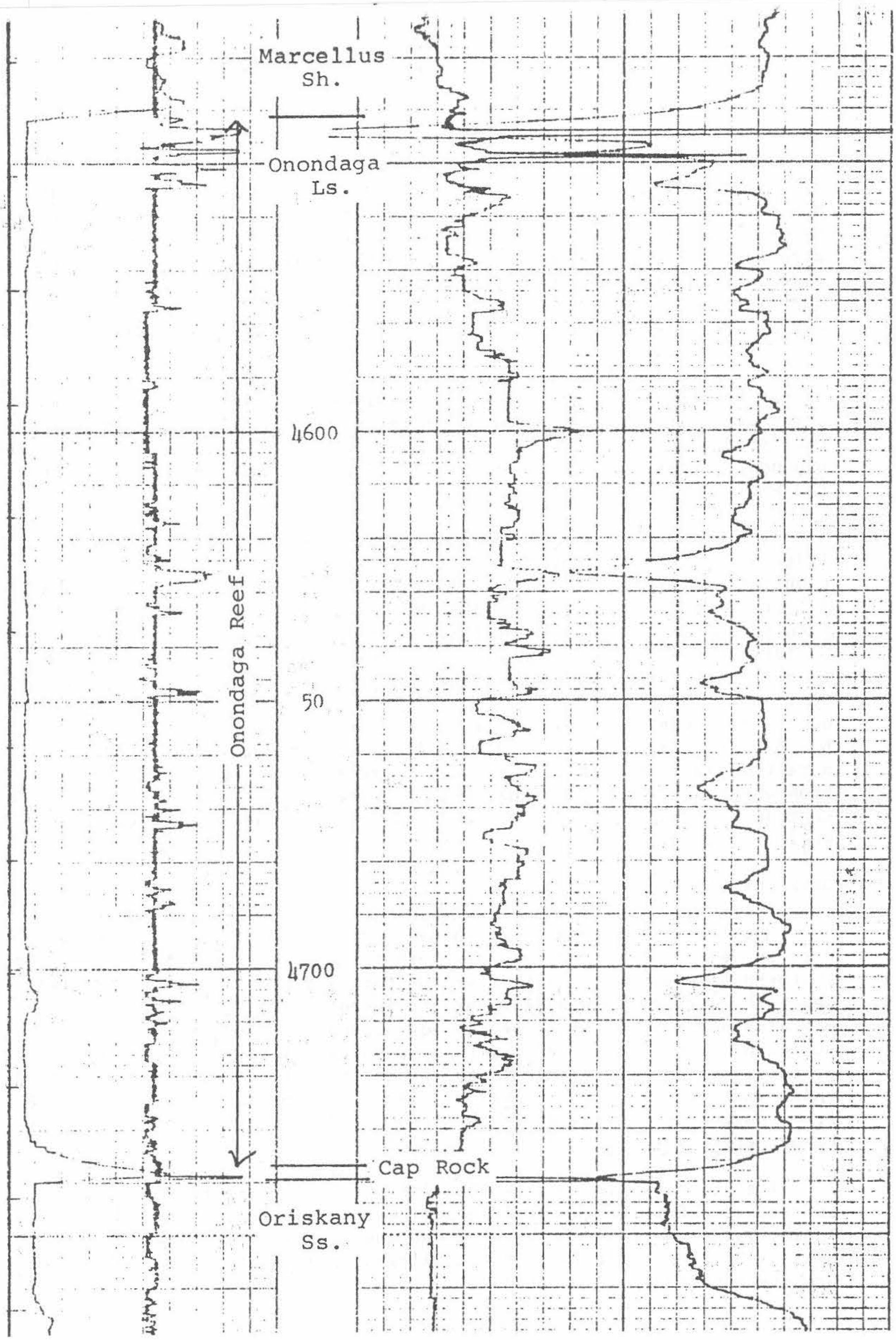

Figure 2. Geophysical log of an Onondaga pinnacle reef in the Homer Banks well, Wyckoff Field, drilled by the Sylvania Corporation in July 1967. After acidizing, the well had an open flow of 3,843 mcfgpd.

From 1968 to 1981, six more pinnacle reefs were discovered, five in New York and one in Pennsylvania. The pinnacle reefs project above the base of the Onondaga limestone to about 200 feet in thickness and may be more than 6,000 feet across. These Devonian age coral reefs created reservoirs that have had production from .5 bcf of gas in the Flatstone reef in Cattaraugus County to over 6.6 bcf from the Raish #1 well in the Adrian Reef field (Fig. 3) in the Town of Canisteo, Steuben County.

The Wyckoff Field has had production from both the Oriskany sandstone and the Onondaga reef. The Oriskany gas was produced from three wells from 1968 to 1974 and totaled over 4.2 bcf. The Onondaga reef production began in 1972 from three wells and over 4.8 bcf has been produced to date. A total of over 9 bcf of gas has been produced from the Wyckoff Field thus far.

The Onondaga limestone also contains numerous bioherms or reefs (Fig. 4) which are completely contained within the Onondaga. The bioherms may be from 80 to over 100 feet in thickness. Their lateral dimensions are uncertain as offset wells, 2,000 feet away, generally miss the bioherm. Several of these bioherms have been discovered in Cattaraugus, Chautauqua and Erie Counties. Many have been cased off because the primary target was the deeper Medina Formation (Fig. 5). Some have produced significant quantities of oil and gas, although they do not have the reserves of the larger pinnacle reefs. One reef well has produced several thousand barrels of oil and it is reported that more than 40 mmcf gas and over 1000 barrels of oil have been produced from another. These bioherms, which can be encountered at shallow depths, can augment production and add to the economic significance of a well if recognized.

ORISKANY SANDSTONE

The Oriskany is a grayish-white quartzitic sandstone varying from 0 to 35 feet thick in western New York (Fig. 6). It is present only in southern Allegany and southeastern Cattaraugus Counties in far western New York. Both gas and salt water are found in the Oriskany. The gas migrates up-dip and is trapped in any closed structurally higher position. These gas traps may be up-dip against faults, in closed domes or folds, or up-dip regionally to the north where the Oriskany sandstone thins and pinches out. The major Oriskany gas production, however, is from faulted anticlines where the associated fracturing develops a much higher effective porosity.

The Oriskany pinchout is the limit of the Oriskany sandstone in the subsurface. Several gas fields have been found along the pinchout line. These fields range in size from about one-quarter billion cubic feet to over 20 billion cubic feet in the Allegany State Park field and normally produce condensate with the gas.

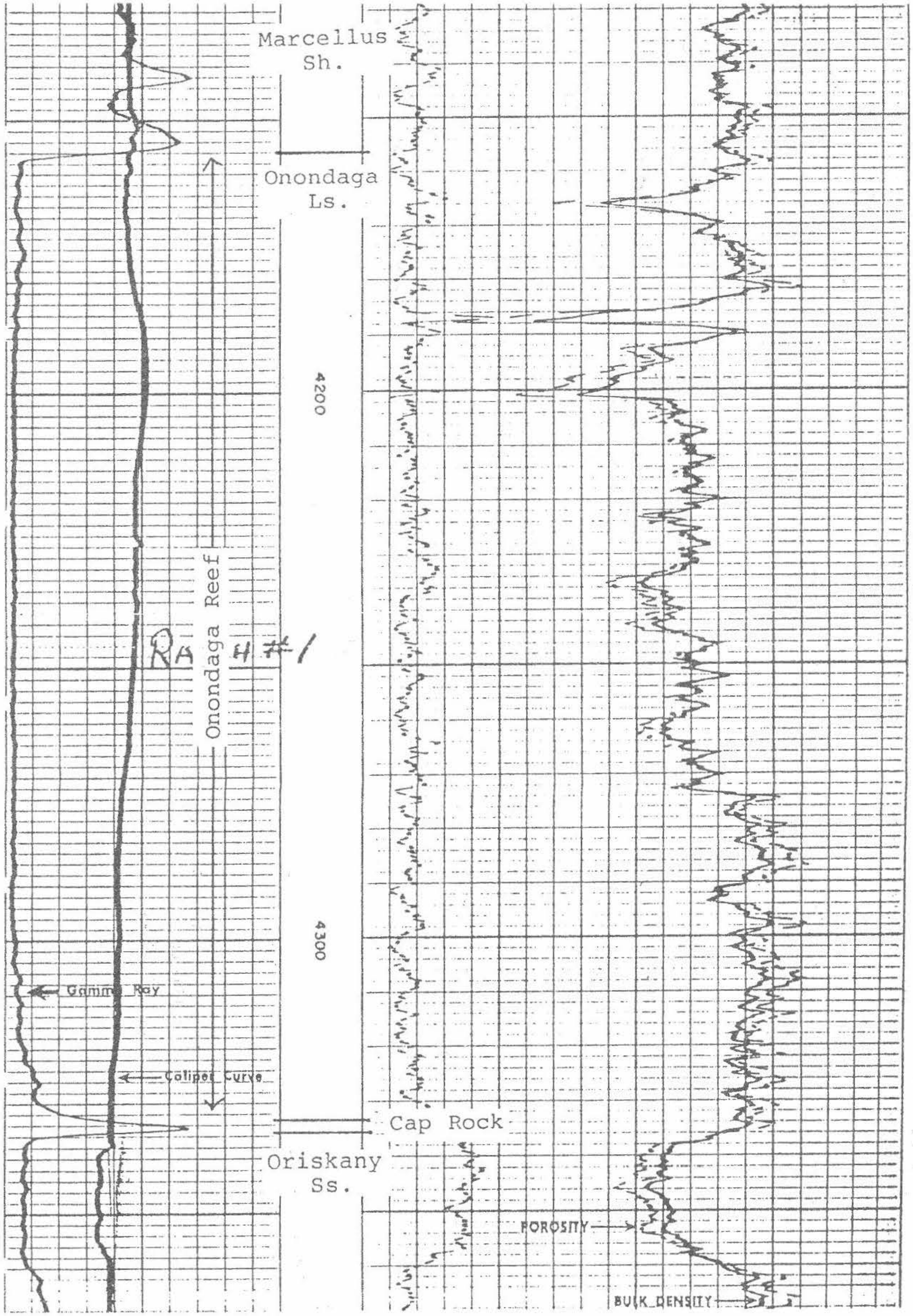

Figure 3. Geophysical log of an Onondaga pinnacle reef in the W.J. & L.I. Raish well, Adrian Reef Field, drilled by the Cabot Corporation in July 1971. The well had an estimated open flow of 11,200 mcfgpd.

Sat. B11

Figure 4. Geophysical log of an Onondaga bioherm in the L. Philips #1, drilled by Empire Exploration, Inc., in the Town of Villenova, Chautauqua County, N.Y.

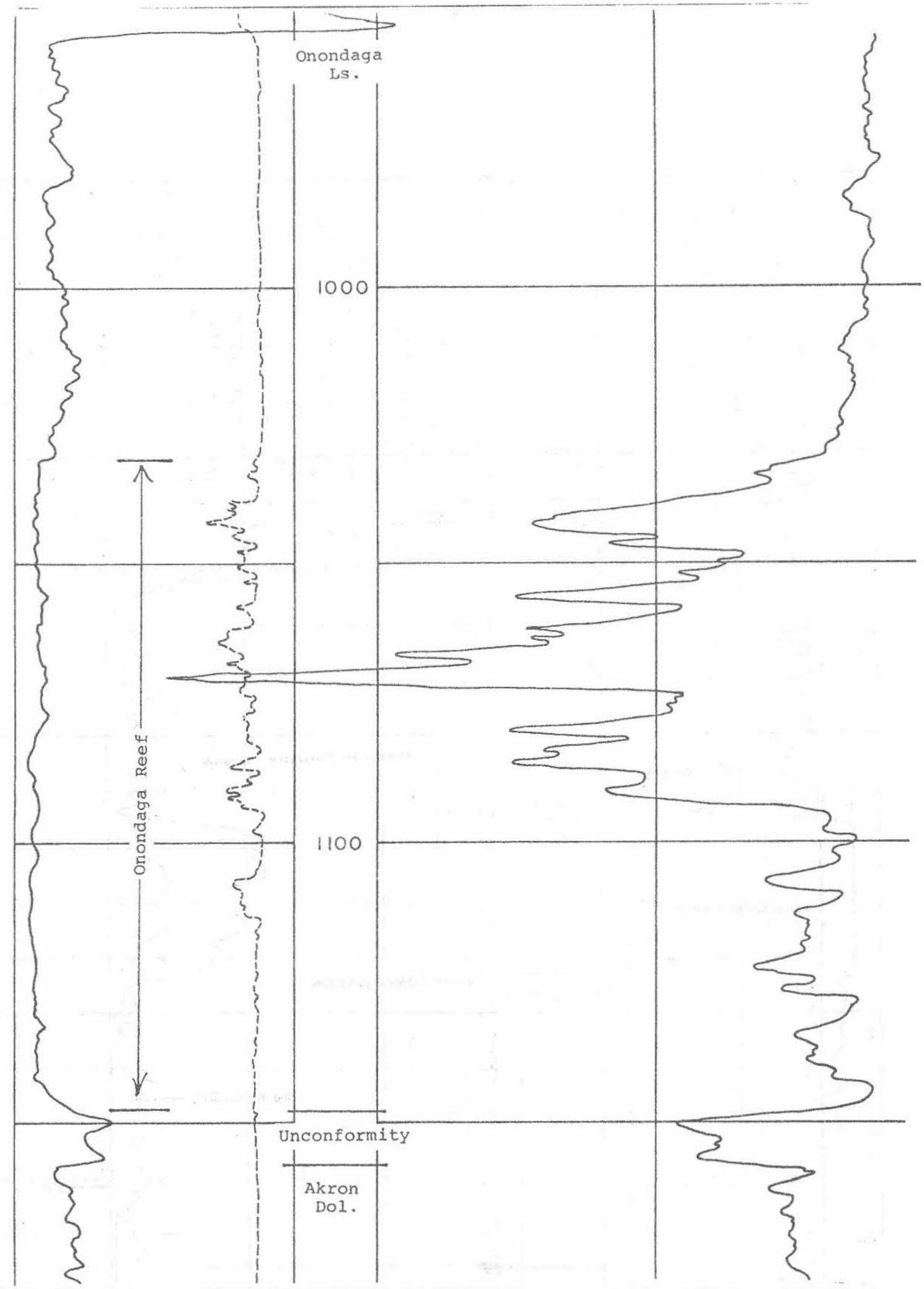

Figure 5. Geophysical log of an Onondaga bioherm in the E. Majka #1 well, drilled by Local Energy in the Town of Pomfret, Chautauqua County, N.Y.

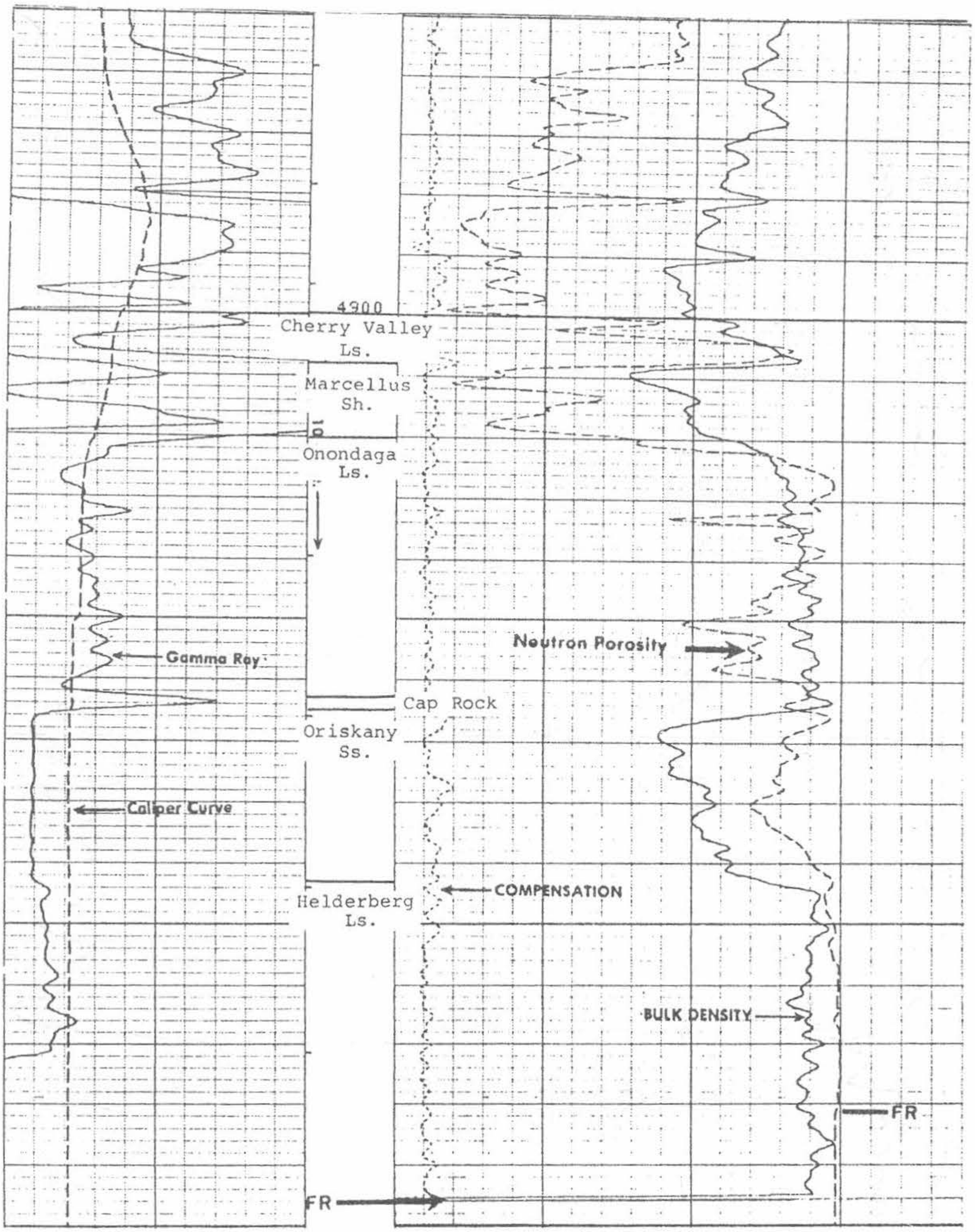

Figure 6. Geophysical log of a representative Oriskany well drilled by Penn York Energy Corporation in the Town of Willing, Allegany County, N.Y.

MEDINA GROUP.

In western New York the Medina Group is divided into the Grimsby sandstone (upper Red Medina), the Power Glen shale and the Whirlpool sandstone (lower White Medina) (Fig. 7). Medina Group rocks were deposited in near-shore, shallow marine environments following the deposition of the Queenston delta complex.

The Grimsby consists of fine to medium-grained red and mottled red and white sandstones with interbedded red and light green shales. Cross bedding, ripple marks, channel deposits, and mud cracks are common sedimentary features. In the Niagara Gorge, the Grimsby is up to 52 feet thick, increasing in thickness to the east in Genesee County to over 100 feet.

The Power Glen shale consists of finely laminated, gray to greenish gray shales with interbeds of lenses of grayish-white sandstones. This unit is referred to by drillers as the "shale break" between the overlying Red Medina sandstone and underlying White Medina sandstone. The Power Glen is about 36 feet thick in the Niagara Gorge, pinching out to the east.

The Whirlpool is a light gray to white, fine to coarse-grained quartz sandstone up to 25 feet thick in the Niagara Gorge. The Whirlpool sandstone has porosity zones in the subsurface in Erie, Chautauqua and the western portion of Cattaraugus Counties that are excellent producers of natural gas. The Whirlpool pinches out to the east with only the Grimsby remaining to represent the Medina Group.

The Medina has been the focus of the vast majority of the drilling programs in western New York. The high success rate of Medina wells has been one of the leading factors in this drilling. Grimsby wells may average 80-100 million cubic feet (mmcf) of gas in fifteen years of production. Whirlpool wells, in areas of enhanced porosity, may have much better production of up to 250 to 300 mmcf or more over fifteen years. Currently, several companies are concentrating their exploration activities in searching for the more lucrative Whirlpool wells.

ORDOVICIAN AND CAMBRIAN ROCKS

The red Queenston is the youngest Ordovician unit in New York. It forms a clastic wedge, probably of deltaic origin, thickening westward from a feather edge in eastern New York The lower Queenston has a gradational and erratic color boundary with the underlying green Oswego sandstone.

Because the source for Queenston sedimentation was to the east and south-east of its present location, the unit has a coarser clastic content in the east and consists of finer clastics to the west. In Erie County the Queenston is a medium red and grayish-red shale and mudstone with silty and very fine sandstone interbeds. Scattered light green

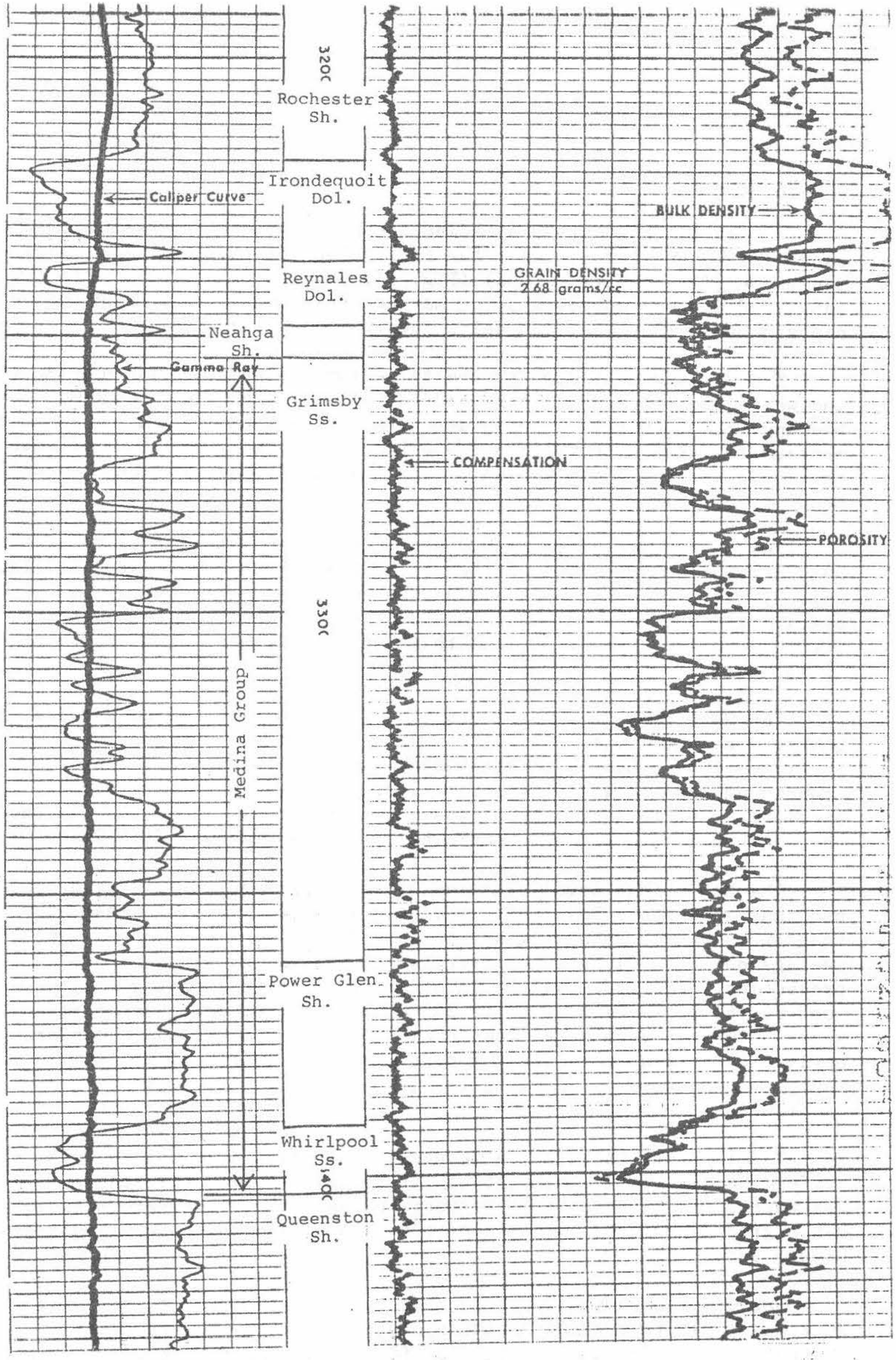

Figure 7. Geophysical log representative of a Medina well. Bemis Unit, drilled by Paragon in the Town of Westfield, Chautauqua County, N.Y.

shale is also present. The Queenston has produced gas from some of these interbedded sandy zones, mainly in its upper portion, in western New York.

The Trenton-Black River section is a brown and gray carbonate sequence varying in thickness from about 700 feet in Chautauqua County to about 1,100 feet eastward to Allegany County. The Trenton has produced gas from shallow wells south and west of the Adirondacks and occasional shows of gas have been reported in the Trenton from wells in western New York. Traps in lower Black River rocks could be formed by draping of porous beds over erosional remnants left on the underlying Lower Ordovician disconformity surface.

Sandstones in the Galway (Theresa) Formation often have shows of gas and salt water. However, a structural closure or fracture system would have to be present to form a gas trap. This is also true of the underlying Potsdam sandstone.

RECENT DEVELOPMENTS

"BASS ISLANDS" TREND

In February of 1981 Envirogas, Inc., while drilling the No. 8 Wassink well just west of the Village of Clymer in Chautauqua County, encountered a large flow of oil from a section of rock below the Onondaga limestone. The source of this oil proved to be fractured Akron dolomite. Later in 1981 various wells being drilled for Medina gas in northeastern Chautauqua County also unexpectedly encountered high flows of oil and gas from this and adjacent fractured zones. This resulted in some blowouts and fires which signaled that a new producing trend had been discovered.

Operators involved in the early phases of this discovery applied the name, "Bass Islands" to the productive zone because they were more familiar with the Ohio name for this Upper Silurian section than with the name Akron which is the equivalent rock unit in New York.

The wells in this trend occur in a structurally complex area found by Van Tyne in 1978. This occurred while he was doing subsurface structural mapping for the Eastern Gas Shales Project (Devonian black shales) of the United States Department of Energy. The work was done while he was head of the New York State Oil and Gas Research Office and acting as a contractor for the DOE.

By the use of Gamma Ray logs from an area of extensive Medina drilling in the Town of North Harmony, south of Chautauqua Lake, he was able to map a low-relief, highly thrust-faulted anticlinal feature. The structural similarity to other such features in the well-known Appalachian thrust belt farther southeast in New York and Pennsylvania was obvious. Further work revealed faulting in other wells south of

Chautauqua Lake. The presence of faults in two wells northeast of the lake and some surface evidence of faulting suggested that the feature could form a long, narrow northeast-southwest trending structure. This would extend completely across Chautauqua County, the northwest corner of Cattaraugus County and into southern Erie County. Subsequent Gamma Ray log correlation work in those areas bore out that assumption. The feature as mapped and appearing in Black Shale publications in 1980 is about 65 miles long and mostly about one and one-half miles wide (Fig. 8).

The structure consists of a series of linear, en-echelon thrust faults which form an anticline consisting of a complex of horst and graben blocks. The feature is a decollement structure with faults emanating from a glide plane in the Vernon "B". Little or no structure occurs from that zone down to the Queenston where the Medina sandstone wells are stopped.

Production occurs from highly fractured zones along the fault trends at depths from about 2,600 to 2,900 feet. Oil and gas has been found in the Marcellus shale, Onondaga limestone, and underlying Bois Blanc, Akron dolomite and Bertie dolomite. The best production has been in the Akron and Onondaga sections. The State Division of Mineral Resources has so far delineated 43 separate pools in this trend.

The oil produced is a high gravity, paraffin base crude. Gas cap production has been marked by the high flows which could be anticipated from such a highly permeable, fractured reservoir. Initial gas flows as high as 60,000 MCFGPD and oil flows up to 2,400 BOPD have been reported. At present, no new drilling is taking place in the trend and production is showing an extreme decline. Total gas production from the trend, through 1989, is estimated at 8½ billion cubic feet and oil production about 1.6 million barrels.

DEEP GAS DRILLING.

The search for deeper gas has focused on basement faulting and rift zones. Such faults often extend upwards into the Trenton and evidently provide pathways for fluid migration leading to dolomitization. Dolomitized limestones can form porosity traps and the faulting can provide extensive fracture systems for migration of dolomitizing fluids and for fracture porosity traps.

Several tests searching for such deep traps have been drilled along the north-south Clarendon-Linden fault system in Monroe, Orleans, Genesee and Wyoming Counties without success so far. In other areas, Columbia Gas has drilled three tests, and others one well, on deep rift features in northeastern Steuben and north-central Schuyler County. The second well in Steuben County was drilled to a depth of 7,961 feet by Columbia Gas in late 1985. Some deep gas was found and the well has been extensively treated and tested in the deep zones.

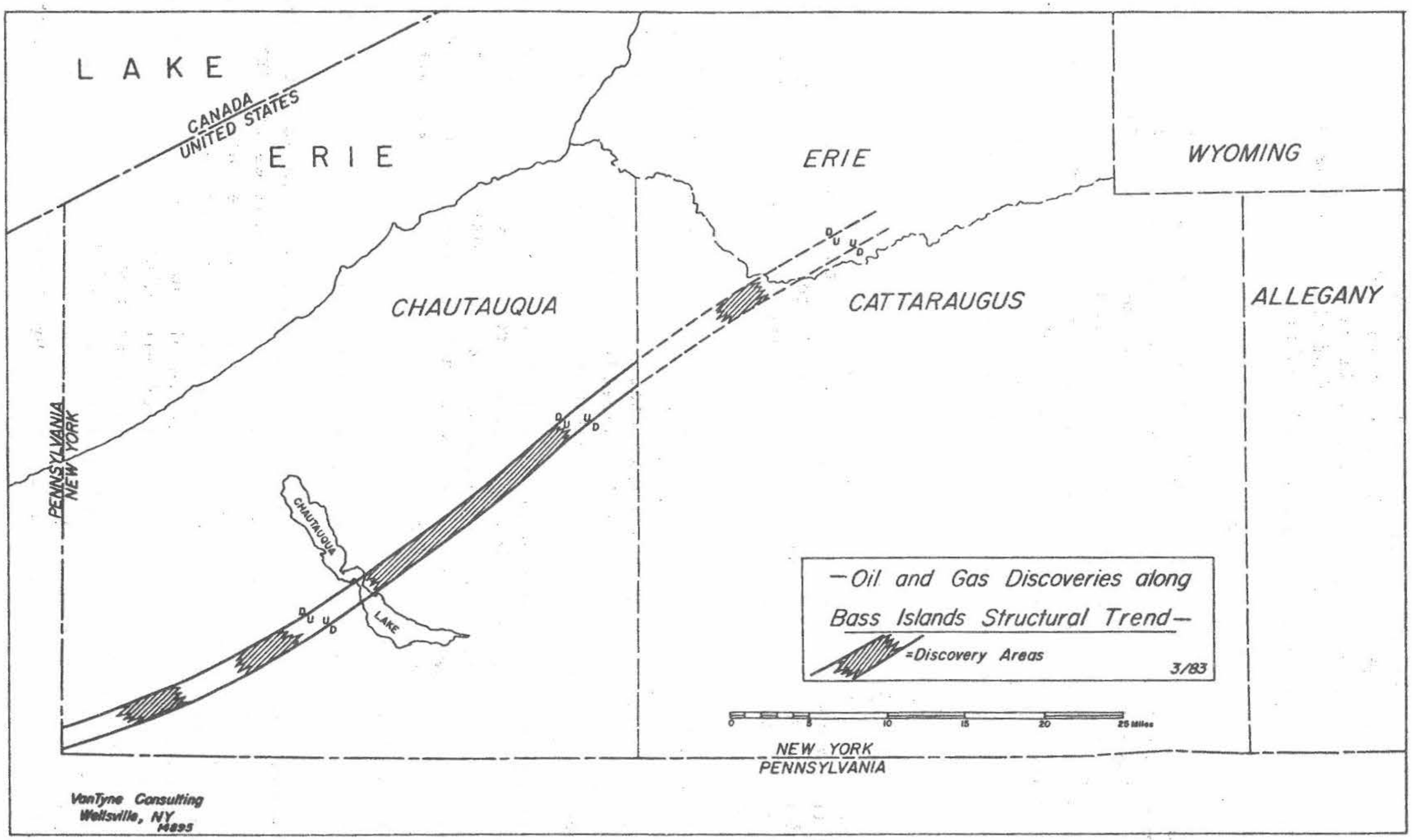

Figure 8. Map Showing Extent of the "Bass Islands" Structural Trend in New York. Only Faults Shown are Bounding Reverse Faults.

In Schuyler County Columbia Gas drilled two test wells in the Town of Reading to depths of 8,397 and 8,510 feet in 1986. Both found dolomitization of the deep limestones as well as gas shows. They were both treated and tested. However, only one of the wells has been completed and shut-in as a possible gas producer.

STORAGE FIELDS.

Storage fields are developed in formations where stratigraphic and/or structural traps have contained a significant amount of gas. These fields have been previously produced and must offer a large amount of storage capacity to justify development. The porosity and permeability of the storage formation is important for injection and withdrawal rates. Once a formation has been delineated and designated as a potential storage field, new wells are drilled for injection and withdrawal of gas and a compressor station is constructed to inject the gas.

There are 21 natural gas storage fields in New York. These have been developed in the Onondaga limestone-Akron dolostone, Oriskany sandstone and the Grimsby and Whirlpool sandstones of the Medina. Gas from local production and the southwestern United States is pumped into the storage fields during the summer months for withdrawal during the winter as required.

National Fuel Gas Corporation developed the first underground storage field in the United States in 1916. This field was originally discovered in the late 1800's and was produced until development as a storage field. National Fuel, or its subsidiary Penn York Energy Corporation, operates 15 of the 21 storage fields in New York State.

Although most of the gas storage in New York is for local consumption, some storage service, such as that offered by Penn York Energy Corporation, is provided for customers on the East Coast. The growing market for natural gas in the eastern United States will stimulate a demand for the development of additional storage fields in New York and neighboring states.

DRILLING AND COMPLETION METHODS.

The speed and efficiency of rotary drilling has replaced the cable tool rigs of the past. Today the drilling process involves the drilling of a surface hole and installation of a ten-inch surface casing which is cemented to surface. The surface casing would be set through the over-burden into bedrock for a total length of 250 to 500 feet through fresh water zones. In some valleys filled with glacially derived sediments more than 1,000 feet of surface casing may be required. A 7-7/8" hole will then be drilled to total depth (T.D.) and a 4½" production string run through the producing zones and cemented in place. The sand is then perforated through the casing opposite the productive zones, as determined by the analysis of geophysical logs, fracture treated, cleaned-up, and shut-in for pipeline hookup and production.

Completion techniques during the past few years have undergone several changes and improvements based on increased technological advancements available to the industry. The efforts put into the completion program are just as important as finding the productive zone and may determine whether a well produces up to its expectations.

ENVIRONMENTAL CONCERNS.

During the last twenty years environmental problems have been increasingly brought to the public's attention. The oil and gas industry is concerned about the environmental affects it may have relating to the exploration and production of oil and natural gas.

Well drilling activities, pipeline installations and the installation of surface and subsurface storage areas for oil and natural gas directly involve environmental considerations. The industry has taken measures to ensure that our vital natural resources are protected. Proper surface casing installation and cementing procedures are implemented to ensure protection of the groundwater from salt water, oil or natural gas. Drill cuttings and fluids and formation fluids are contained on site for proper disposal. Berm dikes are constructed around oil storage tanks to contain the contents should a tank rupture.

The New York State Department of Environmental Conservation, Division of Mineral Resources, issues drilling permits and regulates drilling and completion activities. Their responsibilities also include authorizing the plugging of new and old wells. The oil and gas industry works closely with the Mineral Resources Division in establishing proper procedures to protect the environment and with landowners to minimize disruptions to their land.

Environmental regulations have added additional costs to drilling programs and at times have been controversial. These added costs are a major concern that must be considered when developing an exploration or development program. Environmental considerations will continue to be important for the oil and gas industry in all future activities.

FUTURE DRILLING

Drilling in New York is presently about one-fourth that of the peak drilling years in the early to mid 1980's. About 150 wells were drilled in 1989. Oil well drilling is virtually non-existent so almost all drilling now is for gas. The great majority of gas wells are drilled for Medina gas in far western New York and Queenston gas production in central New York. Several Oriskany sandstone wells and several exploratory tests of various kinds are also drilled each year.

Drilling for Oriskany gas is confined to searching for new traps on known Appalachian fold and fault structures. High resolution seismic work and a better understanding of the tectonic geology of these features has helped in this search.

There has been little or no drilling for possible Onondaga reefs in recent years. Extensive seismic work has been done searching for more reefs but indications of reefing have so far not been found.

As already discussed, there is an increased interest in drilling prospects in deep Ordovician and Cambrian rocks. This could increase if there is an improvement in the wellhead price for gas. These rocks have rarely been targeted in most areas of western New York.

The outlook for an upward movement in wellhead gas prices is good but probably only on the basis of a small annual increase. The average wellhead price in New York is probably about $2.25 per MCF at present.

The price for oil is currently $24.50 per barrel (8/20/90) up from a low of $16.50 per barrel in late June. This rapid increase is due to the Iraq-Kuwait crisis. However, there is little or no oil left to be recovered from the old New York oil fields no matter what the price. For new tertiary recovery projects to be initiated the oil price would probably have to be at least $30.00 per barrel and would have to stay at that level, or higher, for several years.

ACKNOWLEDGEMENTS

Thanks are extended to the Division of Mineral Resources, New York State Department of Environmental Conservation, and especially to Tom Wickerham of the Region 8 office in Avon, for Onondaga reef production information. Roger Willis of Universal Well Services in Meadville, Pa. was helpful in supplying well completion information. Don Thompson of Empire Exploration in Buffalo provided information about gas storage fields. Thanks are due Twila Day of Quaker State Oil Refining Corp. in Titusville, Pa. for current information about Penn Grade oil prices.

REFERENCES

BISHOP, I.P., 1897, Petroleum and Natural Gas in Western New York: in New York State Museum Report 51-2, p. 9-63.

__________, 1895, The Structural and Economic Geology of Erie County: in 15th Annual Report of the State Geologist, p. 305-392, 6 Fig.

HERRICK, J.P., 1949, Empire Oil, New York, Dodd, Mead & Company, 474 p.

LUTHER, D.D., 1896, The Brine Springs and Salt Wells of the State of New York, and the Geology of the Salt District: in 16th Annual Report of the State Geologist, p. 169-226.

VAN TYNE, A.M., 1974, Geology and Occurrence of Oil and Gas in Chautauqua County, New York: in Guidebook, Geology of Western New York State, 46th Annual Meeting, New York State Geological Association, Fredonia, p. H1-H8.

____________, 1983, Oil and Gas Developments in New York in 1982: American Association of Petroleum Geologists Bulletin, v. 67, p. 1554-1557.

____________, 1983, Natural Gas Potential of the Devonian Black Shales of New York: Northeastern Geology, v. 5, Nos. 3 & 4, p. 209-216.

VAN TYNE, A.M. and FOSTER, B.P., 1980, Inventory and Analysis of the Oil and Gas Resources of Allegany & Cattaraugus Counties, New York: Southern Tier West Regional Planning and Development Board, Part I, p. 17-48.