

STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE
LOWER PART OF THE MARCELLUS FORMATION
(MIDDLE DEVONIAN) IN EASTERN NEW YORK STATE

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INTRODUCTION

The "layer cake" stratigraphy of the Hamilton Group in western and central New York appears to change into a more complex and confusing sequence towards the east, where strata thicken and are increasingly dominated by coarse-grained siliciclastics. These trends are exemplified by the lower part of the Marcellus Formation. In western and central New York, this part of the Marcellus Formation is characterized by poorly fossiliferous, black shales with limestone interbeds. These limestones vary in type from intervals of barren or fossiliferous carbonate concretions to complex meter-scale packages of skeletal limestone beds that can be easily correlated over most of this region. Lateral facies changes and the dramatically increased thickness make correlation difficult in strata of the lower part of the Marcellus Formation in easternmost exposures. An approximate 13-fold increase in thickness in eastern New York is accompanied by a transition to more medium- to coarse-grained siliciclastics that overlie the initial black shale deposits. However, the distinctive faunas, sedimentary fabrics, and taphonomic indicators present in some of the strata persist through the facies transition. These strata form useful marker beds that provide a more detailed understanding of the evolution of the northern Appalachian Basin during late Eifelian time.

The purpose of this field trip is to examine the stratigraphic, sedimentologic, and taphonomic changes across the limestone-shale/coarse-grained siliciclastic transition in the lower part of the Marcellus Formation. The following report is a result of two separate ongoing studies. The first is a detailed examination of the limestone-rich facies of the Cherry Valley Member and the upper part of the Union Springs Member in western and central New York State (DHG). The second study involves regional correlation of strata in the lower part of the Marcellus Formation in eastern New

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York State (CAVS). This project includes correlation of the limestone-rich facies of the Cherry Valley Member with the equivalent terrigenous sand-rich facies above the Stony Hollow Member (restricted) in the Hudson Valley.

Initial studies of the Marcellus Formation date back to Hall (1839) and Vanuxem (1840). Clarke (1889, 1901a, b, 1903) was the first to focus attention on the formation and its fauna. The classic work of Cooper (1930, 1933, 1934, 1941) provided the framework on which most modern stratigraphic relations in the Hamilton Group are based. Subsequent stratigraphic studies in the lower part of the Marcellus Formation include reports by Chadwick (1933), Cooper (in Goldring, 1943), Goldring (1935, 1943), Rickard (1952, 1984, 1989), Baird and Brett (1986), and Brett and Kloc (in Anderson *et al.*, 1988).

Post-Clarke paleontologic studies of the lower part of the Marcellus Formation chiefly focused on the limestones of the Union Springs and Cherry Valley Members (Flower, 1936, 1943; Miller, 1938; Cottrell, 1972). Paleontologic studies of the black shale facies include those by Goldring (1935, 1943), Brower *et al.*, (1978), and Brower and Nye, (1991).

GEOLOGIC SETTING

Tectonics and Paleogeography

The Hamilton Group (Middle Devonian) of New York State consists mainly of marine basin and basin-margin siliciclastics and minor, widespread carbonates that form an eastward-thickening clastic wedge (Brett, 1986). These siliciclastics represent the first major phase of Acadian orogenic sedimentation in the northern Appalachian Basin (Faill, 1985; Ettensohn, 1985a).

Deposition of the sediments that now form the Hamilton Group followed the lithospheric downwarping associated with tectonic loading (Ettensohn, 1985b; Beaumont, 1988) and a eustatic sea level rise (TR cycle Id of Johnson *et al.*, 1985). These events combined to terminate shallow shelf carbonate deposition of the Onondaga Formation. Deposition of the Marcellus Formation began in the proximal foreland basin and prograded westward onto the more stable craton (Ettensohn, 1985a). The basin was most likely affected by thermohaline density stratification, and this contributed to the decreased oxygen content of the bottom waters (Ettensohn, 1985b; Woodrow, 1985). Intervals of current-generated sedimentary structures, bioturbation, and shell beds that contain benthic fossils all suggest episodic fluctuations in sea floor oxygenation and reworking by bottom currents, possibly storm currents (Baird and Brett, 1986; Brett *et al.*, 1991; Griffing, 1991).

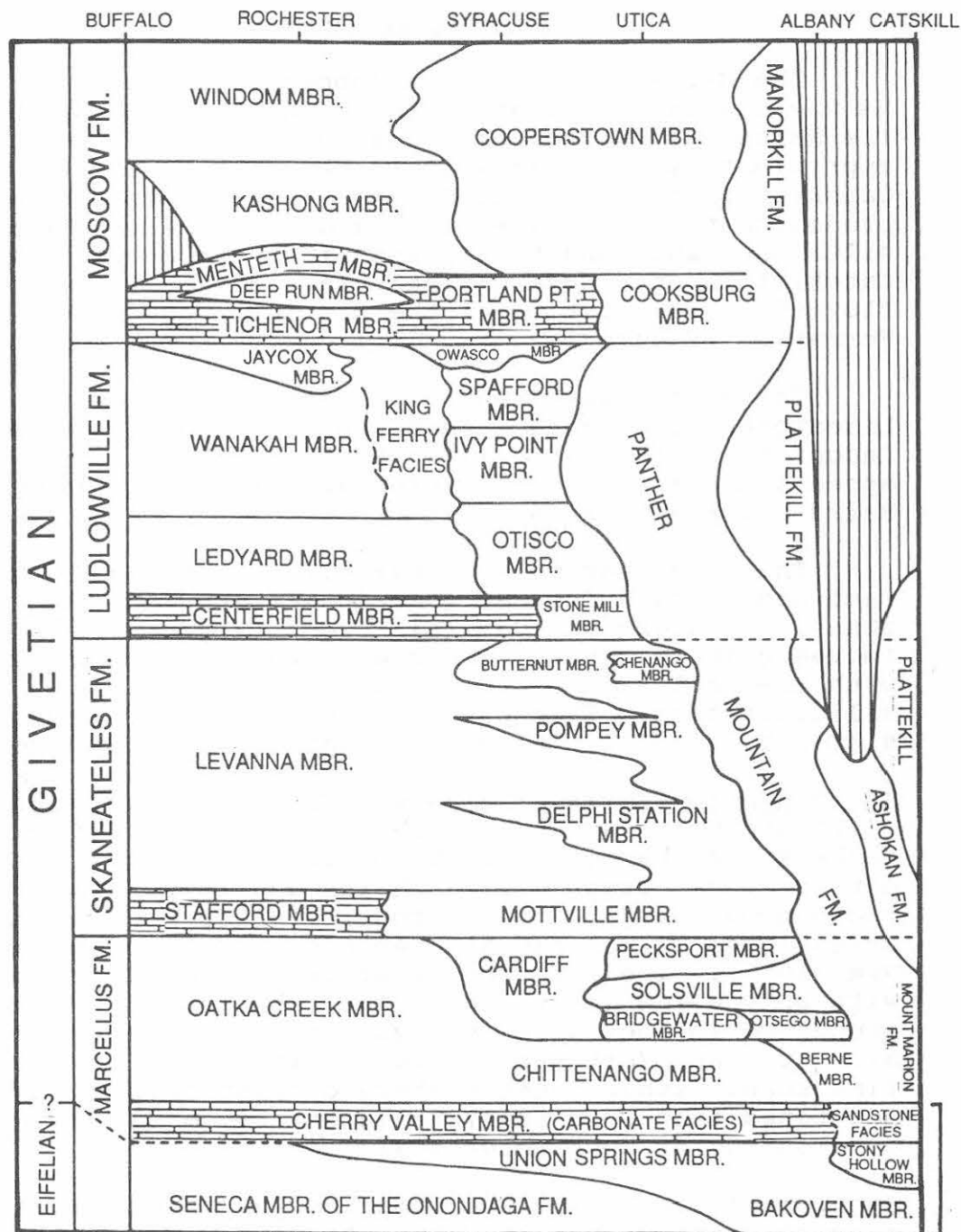


Figure 1.-- Stratigraphic correlation chart for the Hamilton Group in New York State. Bracket to the right of the diagram indicates the units to be discussed in this report. Block pattern highlights geographically widespread limestone members. Based on Rickard (1975), as modified by: Baird (1979), Baird and Brett (1986), Grasso (1986), and Ver Straeten (this report).

Stratigraphic Overview

The Marcellus Formation (upper Eifelian-lower Givetian) is the lowermost formation in the Hamilton Group (Figure 1). The Marcellus Formation ranges in thickness from approximately 7.5 m in western New York to 579.0 m along the Catskill Front (Rickard, 1989). The formation consists predominantly of marine black and gray shales, terrigenous siltstones and sandstones, and minor carbonates. Along the Catskill Front, these marine strata give way to nonmarine, fluvial siliciclastics of the partially equivalent Ashokan Formation (Figure 1).

The Marcellus Formation directly overlies the Onondaga Limestone. The contact represents a major, regional unconformity (Rickard, 1984; Brett and Baird, 1990), yet it appears gradational and conformable locally (Oliver, 1954; Baird and Brett, 1986).

The lower part of the Marcellus Formation also thickens eastward, from a feather edge in western New York to more than 150 m along the Catskill Front (Figure 2). The rapid increase in thickness across eastern New York is associated with the inclusion of relatively coarser grained siliciclastics. This part of the Marcellus Formation is distinctive and can be divided into several members.

Bakoven/Union Springs Members. The Bakoven (eastern New York) and Union Springs (western and central New York) Members are characterized by black to dark gray, pyritiferous, organic-rich shales and limestones. These rocks generally are poorly fossiliferous with low diversity assemblages of pelagic and benthic organisms (Brower and Nye, 1991). The Bakoven Member is predominantly dark shale with only a few limestones. The ratio of limestone to shale abundance in the Union Springs Member increases westward along the New York outcrop belt. The majority of the limestones within these members consist of dark lime mudstones that form small to large (0.1 m to 1.0 m-wide) concretions or centimeter-scale continuous beds.

Stony Hollow Member. The Stony Hollow Member is a calcareous to dolomitic, fine- to medium-grained siliciclastic unit that characteristically weathers buff to dark gray in color. It commonly forms a prominent ridge with the Cherry Valley Member between the less resistant dark shales of the underlying Bakoven and overlying Berne Members. The Stony Hollow Member ranges from finely laminated shales and siltstones with a low degree of burrow mottling in the lower part of the unit to a bioturbated fine- to medium-grained sandstone near the top. Rare pelagic faunal elements in the lower part of the unit are replaced by benthic assemblages with trilobites,

Isopach map of the Bakoven/Union Springs, Stony Hollow, and Cherry Valley Members (Marcellus Formation).

(modified from Rickard, 1989)

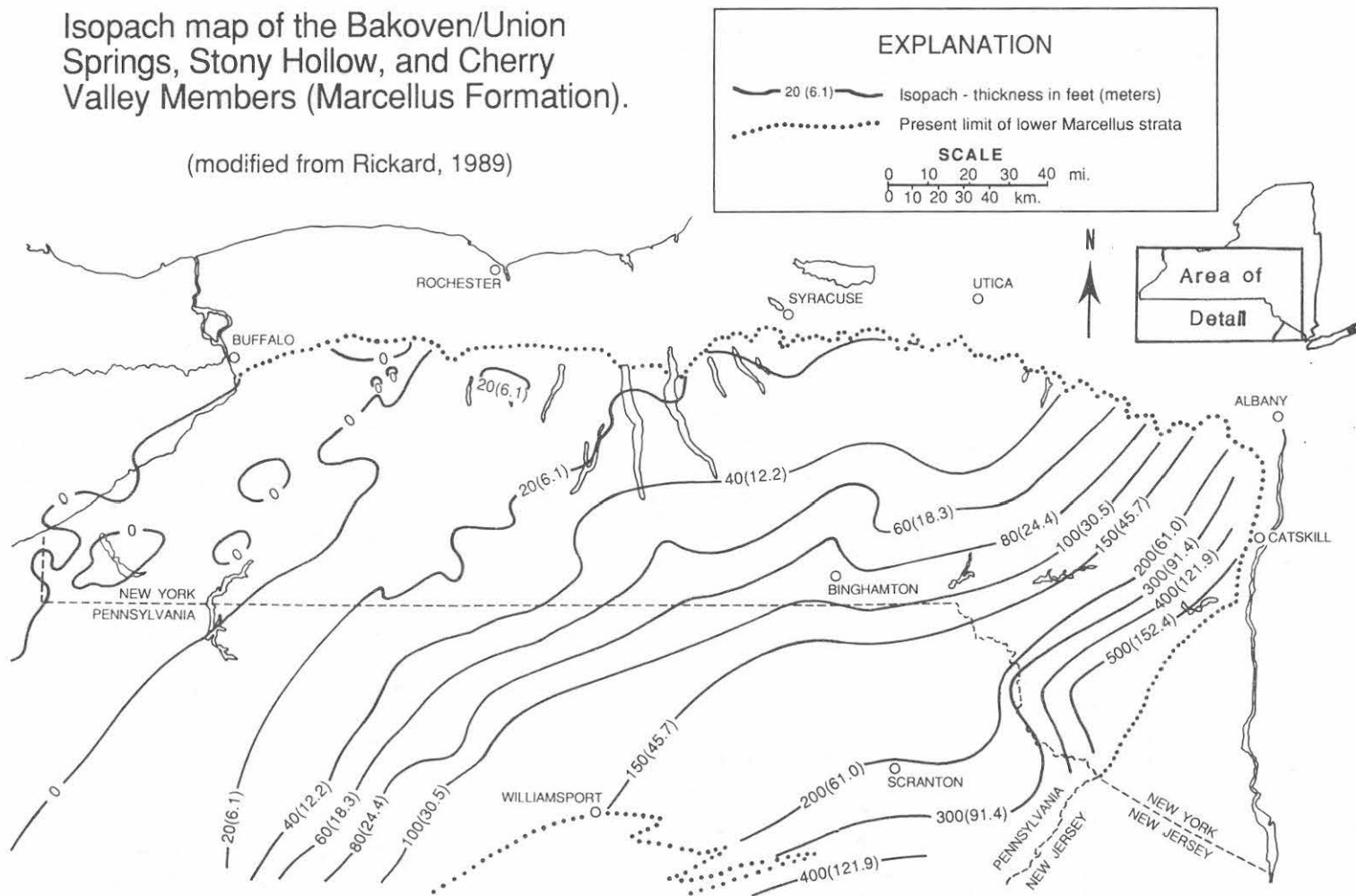


Figure 2.-- Isopach map of the lower part of the Marcellus Formation in New York State and northern Pennsylvania. Modified from Rickard (1989).

brachiopods, crinoids, and small rugose corals near the top. The Stony Hollow is approximately 75 m-thick at Kingston. It thins northward, and at Onesquethaw Creek (southwest of Albany), the Stony Hollow is approximately 6 m-thick. The unit thins west of Onesquethaw Creek and pinches out.

Cherry Valley Member. The Cherry Valley Member forms a package of skeletal limestones and shaly intervals that is recognized from the Genesee Valley (south of Rochester) eastward to Onesquethaw Creek (southwest of Albany). It consists primarily of dark, fetid, argillaceous, massive to nodular bedded styliolinid-cephalopod packstones with a limited benthic skeletal component. The faunas and sedimentary fabrics of the Cherry Valley Member limestones are comparable to the Devonian pelagic/hemipelagic limestones of Europe and north Africa.

Recent studies show that the Cherry Valley Member contains a rapid transition to a more terrigenous sand-rich facies south of Albany along the Catskill Front. The terrigenous sandstones are generally intensely bioturbated and are accompanied by intervening shell hashes, which feature small brachiopods and styliolinids. A southward increase in thickness is associated with the inclusion of thick silty shale intervals in the sandstones. Although uncommon, nautiloid and goniatitic cephalopods also occur in the terrigenous sand-rich facies of the Cherry Valley Member.

THE CHERRY VALLEY MEMBER AND ASSOCIATED
LIMESTONES OF WESTERN AND CENTRAL
NEW YORK

Introduction

The Cherry Valley Member of the Marcellus Formation was originally defined by Cooper (1930) as one of several relatively thin, widespread limestones of the Hamilton Group in New York State (Figure 1). Detailed study of the limestones of the Hamilton Group reveals that they comprise complex packages of beds, which exhibit a variety of rock types, taphonomic features, and bedding styles (Baird, 1979; Gray, 1984; Grasso, 1986; this report). These limestones represent significant changes in depositional conditions across the northern Appalachian Basin during Middle Devonian time (McCave, 1973; Brett and Baird, 1985).

The westward thinning of the Marcellus Formation across western and central New York leads to the condensation and union of the Cherry Valley Member with limestones in the upper part of the Union Springs Member. This westward amalgamation of limestone beds has hampered the differentiation of characteristic Cherry Valley Member faunal assemblages from those of the Union Springs Member.

In addition, the amalgamation of these limestones has led to erroneous thicknesses previously documented for the Cherry Valley Member. One particular group of Union Springs limestones maintains a close stratigraphic association with the Cherry Valley Member across this outcrop belt. These limestones have previously been included in the Cherry Valley Member at some localities and are distinctly different from other limestones of the Union Springs Member. A more detailed discussion of these beds is provided below.

Chestnut Street Beds

A thin package of centimeter-scale, skeletal-peloidal wackestone and packstone beds underlie the Cherry Valley Member in central New York State. These skeletal limestones feature abundant molts of Proetus haldemani, a trilobite that is rare in other parts of the sequence. The informal name "Chestnut Street Beds" will be used to identify this package of limestones, instead of the name "Proetid Bed" used by Brett and Kloc (in Anderson et al., 1988). The new name is derived from the extensive exposures of these limestones at the Chestnut Street roadcut (STOP 1) located approximately 5.0 km east of the village of Cherry Valley.

The Chestnut Street Beds are the uppermost limestones of the Union Springs Member in central New York (Figure 3). The basal contact of the Chestnut Street Beds is erosional. Dark, argillaceous, lime mudstone concretions are commonly amalgamated to the base of the Chestnut Street Beds. Hypichnial skeletal packstone casts of 1.5 to 2.5 cm-wide Cruziana traces commonly protrude into the underlying shales between these concretions. Where the Chestnut Street Beds directly overlie black shales, the lowermost wackestones or packstones contain small pyritized nodules with 1 to 2 mm-wide, septarian calcite veins. Some veins continue upward beyond the nodule boundaries. In east-central New York, the upper contact of the Chestnut Street Beds is sharp, but conformable, with overlying calcareous silty shales and siltstones. The siltstone beds commonly contain in situ auloporid corals, crinoid ossicles, and the goniatite Agoniatites nodiferous.

Although the Chestnut Street Beds are separated from limestones of the Cherry Valley Member in east-central New York by siltstones, silty gray shales, and black shales, the Chestnut Street Beds are amalgamated to the base of the Cherry Valley Member in west-central New York. The Chestnut Street Beds and the Cherry Valley Member are separated only by a scalloped, pyritized hardground in this area. The Chestnut Street Beds can be distinguished from the directly overlying Cherry Valley limestones by a lighter (white to medium gray) weathering color and a distinct faunal assemblage. Although gastropods, styliolinids, nowakiids, auloporid corals, rhynchonellid brachiopods, and crinoid

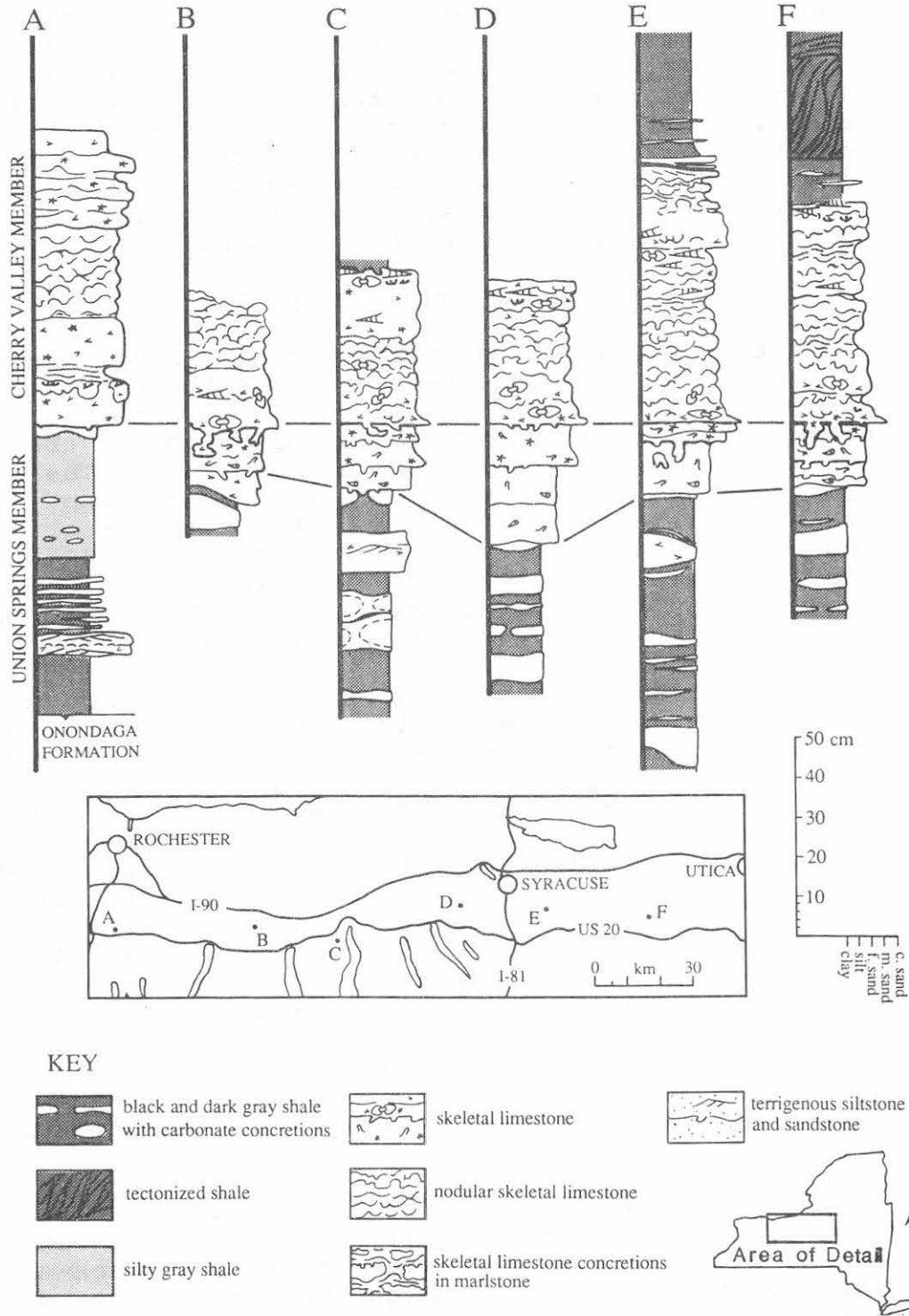
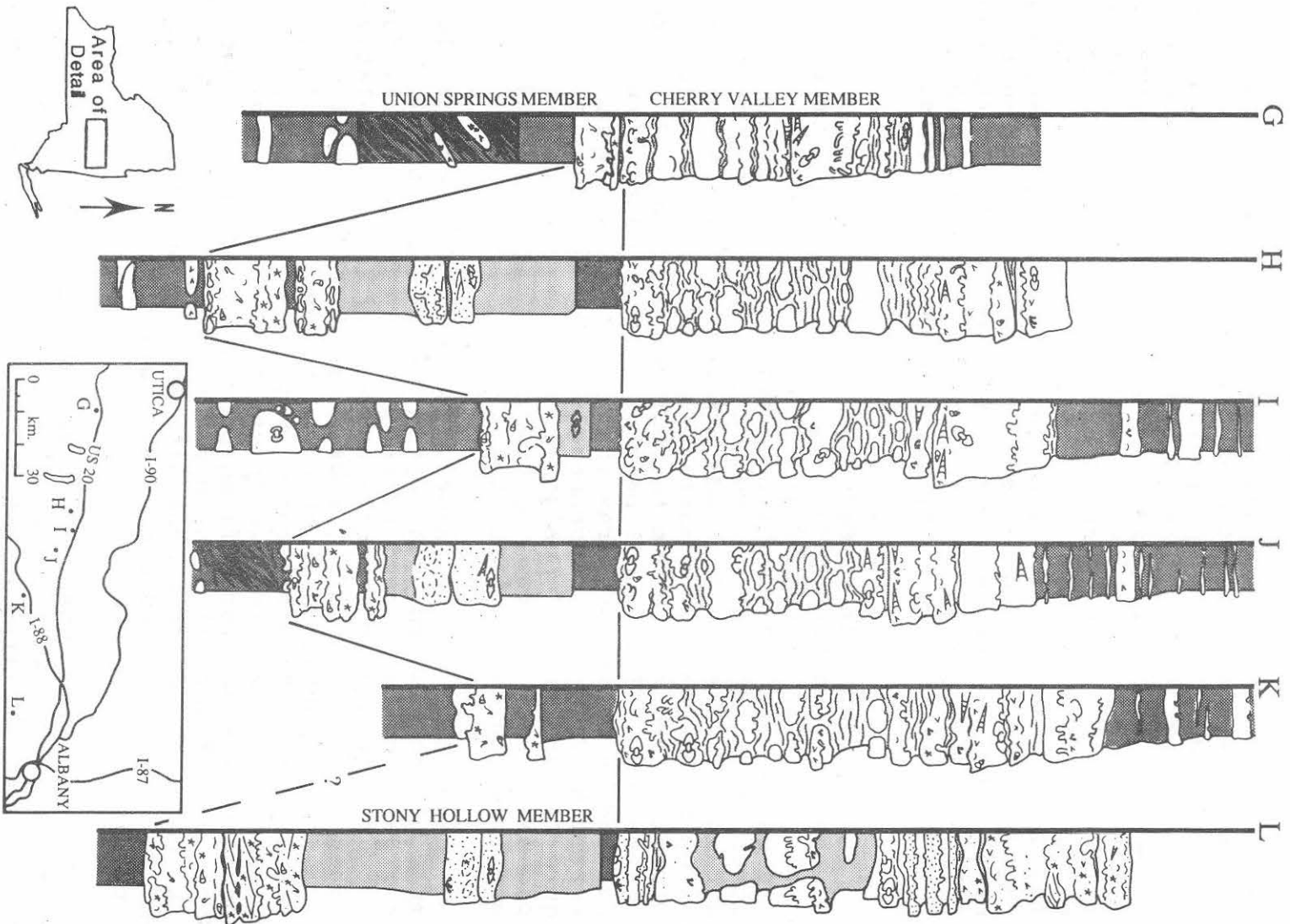


Figure 3.-- Selected stratigraphic sections of the Chestnut Street Beds and the limestone-rich facies of the Cherry Valley Member in New York State. Datum is the base of the Cherry Valley Member. Lower correlation lines mark the base of the Chestnut Street Beds. Locality names for each lettered section are supplied in Appendix I.



debris are common to both limestones, the Chestnut Street Beds lack the characteristic nautiloid and goniatite cephalopod fauna of the Cherry Valley Member. In addition, only the Chestnut Street Beds commonly contain calices of the small crinoid Haplocrinites clio (see Baird and Brett, 1986), atrypid and pentamerid brachiopods, and stereolasmid corals, as well as the proetid trilobites discussed above. The Chestnut Street Beds also contain a distinctive late Eifelian conodont fauna. The conodont Tortodus kockelianus kockelianus (kockelianus zone), previously considered to be a basal Cherry Valley element at Stockbridge Falls (Klapper, 1971), was actually found within the amalgamated Chestnut Street Beds at this locality (G. Klapper, 1991, personal comm.).

The Chestnut Street Beds are commonly united to form one coherent limestone ledge, as at the Chestnut Street roadcut (Section I, Figure 3). There, the beds are bioturbated, and individual bed contacts are diffuse. However, relict fining-upward bedding can be recognized. The bases of these relict beds are defined by the coarse-grained fragmented and disarticulated skeletal fraction. Protrusive feeding and shelter burrows originate at the top of these beds. Individual beds or sets of beds may be separated by calcareous gray shale, as at Cox Ravine (Section H, Figure 3), Rosenberg Road Ravine (Section J, Figure 3), and Mineral Springs (Section K, Figure 3). Hypichnial casts of Cruziana traces are also observed at these limestone-shale contacts.

In addition to the Chestnut Street Beds-Cherry Valley Member contact, sharp, scalloped, commonly pyritized, firmground and hardground surfaces also separate individual Chestnut Street Beds in west-central New York. A relatively greater contrast in color, rock fabric, and skeletal fragmentation/abrasion is observed between individual Chestnut Street Beds separated by these discontinuity surfaces. For example, two Chestnut Street Beds are separated by a scalloped firmground at Seneca Stone Quarry (Section C, Figure 3). The upper of these two beds is a dark, crinoid-rich packstone with heavily abraded skeletal debris. The lower bed consists of a lighter gray bioturbated wackestone.

The number of Chestnut Street Beds decreases westward across central New York. However, changes in the total thickness of the package are not systematic. In fact, the Chestnut Street Beds change in thickness from a maximum of 26 cm to 6 cm across the outcrop (a distance of 20 m) at Rosenberg Road Ravine.

Seven to eight beds of proetid-trilobite-bearing limestone form a 42 cm-thick ledge below the Cherry Valley Member at Long Road Ravine, Albany County (STOP 3). These

beds consists primarily of quartz-sand- and crinoid-rich packstones and grainstones. Although bioturbated, these beds exhibit relict small-scale cross-stratification. This package of limestones appears to be completely or partly equivalent to the Chestnut Street Beds farther west (as is discussed in detail later in this report).

Limestones of the Cherry Valley Member

The dark-gray- and brown-weathering, hackly fracturing, argillaceous skeletal limestones of the Cherry Valley Member form a distinctive, meter-scale, resistant package within an interval of relatively non-resistant black shales. Natural exposures, such as the common stepped waterfalls in stream beds, are spotty across New York State. Carbonate dissolution, tufa crusts, and heavy moss overgrowths combine to obscure subtle textural details in these exposures. However, an extensive collection of polished rock samples from these outcrops, along with a limited number of good quarry and roadcut exposures, illustrate many of the details in these strata.

The limestone-rich facies of the Cherry Valley Member can be recognized in exposures that extend from the General Crushed Stone ("5 Points") Quarry, near Lima, Livingston County, to Onesquethaw Creek, Albany County. The limestone package ranges in thickness from a minimum of 0.37 m at Flint Creek, Ontario County, to a maximum of 2.4 m at Onesquethaw Creek. No exposures of the Cherry Valley Member are at present known west of the Genesee Valley south of Rochester. The disappearance of the Cherry Valley and Union Springs Members in western New York is most likely due to erosional truncation of the members prior to deposition of the overlying Oatka Creek Member (see Baird and Brett, 1986). However, early reports of Cherry Valley-like limestones that directly overlie the Onondaga Limestone in salt shafts at Retsof, Livingston County (Luther, 1894), and of Cherry Valley Member faunas within the uppermost Onondaga Limestone at Erie County (Clarke, 1901) suggest that part of the Cherry Valley may reappear farther west below the regional sub-Oatka Creek disconformity (Rickard, 1984).

The carbonate content of the limestone-rich facies of the Cherry Valley Member consists primarily of skeletons of the minute dacryoconarid Styliolina fissurella and neomorphic calcite microspar. The microspar texture obscures the differentiation of primary cements, fine skeletal debris, and peloids. Brower and Nye (1991) estimated the composition of the Cherry Valley Member, near Syracuse, to include 86% calcite, 12% clay, and 1% organic carbon, plus minor pyrite. The clay and organic content of the Cherry Valley Member increases to the east and varies vertically within each section. The styliolinid packstones and (minor) grainstones of the Cherry Valley Member also

contain auloporid corals, minute brachiopods, bivalves, gastropods, nowakiids, coleolids, placoderm fish plates, and a famous nautiloid and goniatite cephalopod fauna (see Flower, 1936; Miller, 1938).

The basal contact is sharp across central and western New York, especially where the Cherry Valley Member overlies the amalgamated Chestnut Street Beds or other concretionary limestones of the Union Springs Member (as at the "5 Points" Quarry). Rickard (1952) defined the top of the Cherry Valley Limestone at the contact of the uppermost massive limestone with overlying black shales. This contact is gradational and conformable in east-central New York, where the Cherry Valley underlies a thin interval of relatively resistant, calcareous, fossiliferous black shales and thin dacryoconarid packstones. In contrast, the upper contact in west-central New York is generally a sharp erosional discontinuity with the overlying poorly fossiliferous black shales of the Oatka Creek Member (discussed above).

Rickard (1952) recognized a three-part subdivision within the Cherry Valley Member of east-central New York. This subdivision consists of (1) a lower massive limestone, (2) a middle nodular limestone/shaly interval, and (3) an upper massive limestone. Although this basic three-part subdivision can be recognized across central New York, closer inspection of the Cherry Valley reveals a gradation in textures between the massive and nodular intervals. For example, the continuous packstone bed that forms the base of the Cherry Valley Member at the Chestnut Street roadcut (STOP 1) is as extensively bioturbated and lumpy as the overlying two layers of nested, diffusely-bounded, concretionary packstone bodies (Section I, Figure 3). The highly calcareous, skeletal shales or marlstones that separate these "nodules" both exhibit the continuation of diffuse migrating burrow traces that originate in the packstones and also contain similar skeletal debris. The nested packstone nodules weather to form part of what Rickard (1952) considered the lower massive subdivision, due to the relatively greater calcium carbonate content of the lower marlstones. Marlstones above this level weather more like shale and exhibit differential compaction around the packstone "nodules."

The fabric of the middle nodular limestone/shaly interval varies systematically across the outcrop belt. This interval consists of tightly interlocked 2 to 6 cm-wide nodules with thin discontinuous shaly partings (classic nodular limestone fabric of Garrison and Fischer, 1969; Kukal, 1975; Raiswell, 1987) in west-central New York. This texture grades into numerous 10 to 20 cm-wide, diffusely bounded concretionary bodies in marlstone in east-central New York, and eventually into a few layers of 10 to 30 cm-

wide, sharply bounded concretions in slightly calcareous silty shales in eastern New York (Figure 3).

The upper massive limestone beds are bioturbated, but they retain some primary sedimentary structures. Sharp, erosional contacts at the base of beds and relict, planar omission surfaces are locally preserved in these beds. The argillaceous omission surfaces commonly display protrusive, lined and unlined burrows, in contrast to the retrusive burrows that dominate most Cherry Valley beds.

Complete skeletons and very coarse-grained skeletal debris most commonly occur in the lower and upper massive limestone beds. These skeletal accumulations, recognized in the condensed Cherry Valley Member in west-central New York, constitute thin, highly concentrated intervals. For example, Clarke (1901b) and Flower (1936) noted that cephalopods of the Cherry Valley Member are most common in one or two intervals in central New York. In contrast, the numerous "shell beds" of the Cherry Valley Member in east-central and eastern New York are less concentrated. This makes the correlation of individual skeletal accumulations between west-central and east-central New York sections difficult. Although goniatites are common throughout the limestones of the Cherry Valley Member, orthocone nautiloids appear to be more common in the upper massive limestone beds. A limited number of bedding plane exposures in west-central New York exhibit a roughly unidirectional, southeasterly orientation from the orthocones (see Figure 4). This orientation is nearly perpendicular to the isopachs for the lower part of the Marcellus Formation (compare with Figure 2). Only 15% to 30% of the complete goniatite and nautiloid conchs in these skeletal concentrations have a non-horizontal orientation. Reoriented geopetal fills of some vertically or subvertically oriented cephalopods indicate a post-cementation sedimentary reworking origin for such orientations. Horizontal geopetal fills in other non-horizontal conchs may represent either original vertical emplacement or early reorientation by burrow activity.

Complete conchs of Agoniatites vanuxemi commonly display fine, well preserved ornamentation. However, partial preservation of cephalopods has long been noted as a characteristic of the Cherry Valley Member (Flower, 1936). Partial preservation of Cherry Valley cephalopods is most commonly due to synsedimentary fragmentation. Loss of the upper parts of walls and septa in horizontally oriented conchs is also observed at packstone-marlstone contacts along microstylolitic surfaces, and at sedimentary discontinuities (e.g. the Cherry Valley-Oatka Creek Member contact in west-central New York).

Cherry Valley Member cephalopod concentrations are closely associated with thickets of in situ auloporids. Auloporids are uncommonly found as encrustations on goniatite conchs. Coleolid tubes commonly occur with cephalopod concentrations as horizontally oriented broken fragments, but they are also locally clumped into patches of vertically or subvertically oriented tubes. Cephalopod conchs also uncommonly display shell borings of probable sponge origin.

The original microfabric of calcitic dacryoconarids and auloporids is preserved in these strata, and they are the only limestone skeletal components that occur in the marlstones. Most other large skeletons display a post-compactional replacement of shell carbonate by a coarse, brown epitaxial calcite spar. Thin pyritic coatings line the interior of many cephalopod conchs and aulopodid corallites. Surficial weathering of the pyrite and calcite spar gives many skeletal concentrations an orange, limonitic, moldic appearance on outcrop.

Cherry Valley Member at "5 Points" Quarry

The westernmost exposure of the Cherry Valley Member at the "5 Points" Quarry, near Lima (Section A, Figure 3), retains the three-part subdivision but differs significantly from more easterly exposures in composition and texture. It consists of light- to medium-gray-weathering crinoid-styliolinid grainstones and minor packstones. Large disarticulated crinoid ossicles are common throughout, but are most abundant in the upper interval, which is thin-bedded instead of massive. Fenestrate bryozoan fragments are common in the grainstones. In situ auloporids are abundant. In contrast, diagnostic cephalopods of the Cherry Valley Member have been found (G. Kloc, 1990, personal comm.) but are relatively uncommon by comparison with their abundance farther east.

Cherry Valley Member in Transition

The limestones of the Cherry Valley Member begin to show drastic changes in sedimentary fabrics with the influx of coarse-grained, siliciclastic sediments at Long Road Ravine (STOP 3), Albany County. The massive/bioturbated nature of the lower and upper subdivisions gives way to thin, heterolithic, terrigenous silt/sandstone and argillaceous limestone beds. Heterolithic fine quartz sandstone-skeletal packstone beds in the upper subdivision take on an alternating laminated and burrow reworked bedding style. Burrow reworking is greatly decreased relative to sections farther west. Primary packstone and grainstone bedding is also partly preserved in the middle nodular/shaly interval. Preservation of carbonate skeletons is moldic in the silty/sandy beds. Skeletal fragments in the uppermost

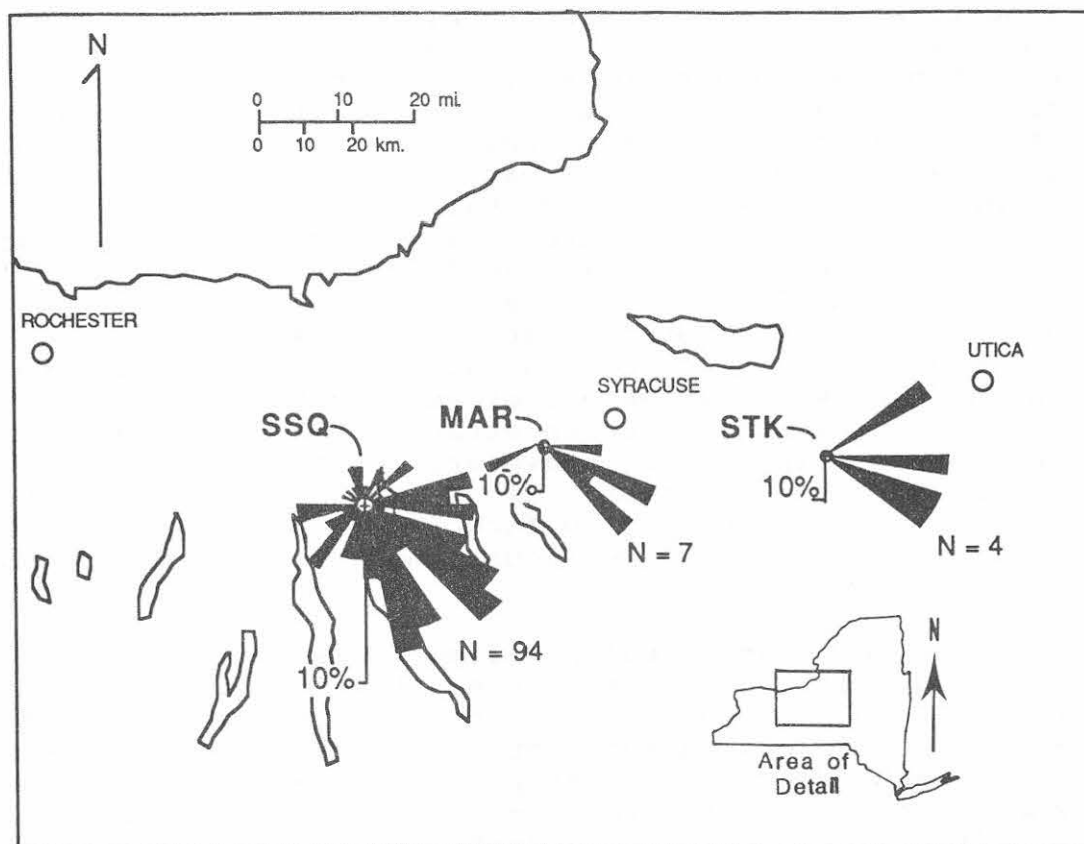


Figure 4.-- Paleocurrent roses generated from orthocone cephalopod orientations from the uppermost limestones of the Cherry Valley Member in west-central New York. SSQ = Seneca Stone Quarry, MAR = Pleasant Valley Road in Marcellus, STK = Stockbridge Falls.

beds of the Cherry Valley Member are highly comminuted and abraded.

Comparison with Other Devonian Cephalopod Limestones

Relatively thin, red and black cephalopod-rich limestones represent a characteristic facies in Paleozoic and Mesozoic "miogeoclinal" strata of the world (Wendt and Aigner, 1982), particularly in the Middle Devonian to Lower Carboniferous of Europe and north Africa (Tucker, 1974; Bandel, 1974; Wendt and Aigner, 1985). These extensively studied Devonian cephalopod limestones share important similarities with the limestones of the Cherry Valley Member.

Wendt and Aigner (1985) defined several recurring subfacies in the Devonian-Carboniferous cephalopod limestones of Europe and north Africa (Morocco). These include (1) thick-bedded, crinoid-rich dacryoconarid packstones and grainstones; (2) dacryoconarid packstones and grainstones with abundant orthocone nautiloids and iron-stained discontinuity surfaces; (3) thin-bedded, orthocone-poor dacryoconarid nodular packstones; and (4) thin-bedded, nodular packstones in marly shale. Lateral changes in these subfacies (see Figure 5) also show strong similarities to the changes observed in the Cherry Valley Member. In addition, unidirectional orientations observed in the orthocones of the Moroccan strata are usually sub-perpendicular to isopachs (Wendt *et al.*, 1984), as are those in the Cherry Valley Member of west-central New York. Cephalopods in the Moroccan strata are also found in highly concentrated intervals. However, cephalopod concentrations in the Moroccan limestones can range from 40 to 2000 per square meter of bedding surface (Wendt and Aigner, 1985), as compared with 5 to 15 per square meter in the Cherry Valley Member.

The Devonian cephalopod limestones of Europe and north Africa are interpreted to represent very slow pelagic and hemipelagic sedimentation on storm-swept, sediment-starved marine platforms and adjacent slopes (Tucker, 1974; Wendt and Aigner, 1985). Nodular packstone/marly shale sequences appear to represent more offshore platform and slope conditions (Figure 5). In addition, Wendt and Aigner (1985) suggested that the absolute depths of the platforms where cephalopod limestones accumulated ranged from near sea level to about 100 m.

A similar interpretation seems suitable for the Cherry Valley Member. The nodular/concretionary subfacies is associated with deeper water conditions in the scheme of Wendt and Aigner (1985). However, similar textures have been reported from rocks of shallow-water origin (Kukal, 1975). Textures of this subfacies probably represent early diagenesis resulting from an increase in the proximity to fine-grained, terrigenous sediment sources and from changes in the accumulation rates of terrigenous mud relative to biogenic carbonate (Raiswell, 1987). The lack of slump and debris flows (common in other Devonian cephalopod limestones) in the nodular limestones of the Cherry Valley indicates deposition on a gentler slope than its European and African counterparts. Less concentrated cephalopod accumulations in the Cherry Valley Member may simply reflect shorter periods of sediment starvation and/or less frequent reworking by strong bottom currents.

The faunas of the Chestnut Street Beds and the Cherry Valley Member are commonly associated with a change from exaerobic to dyaserobic and marginally aerobic sea-floor

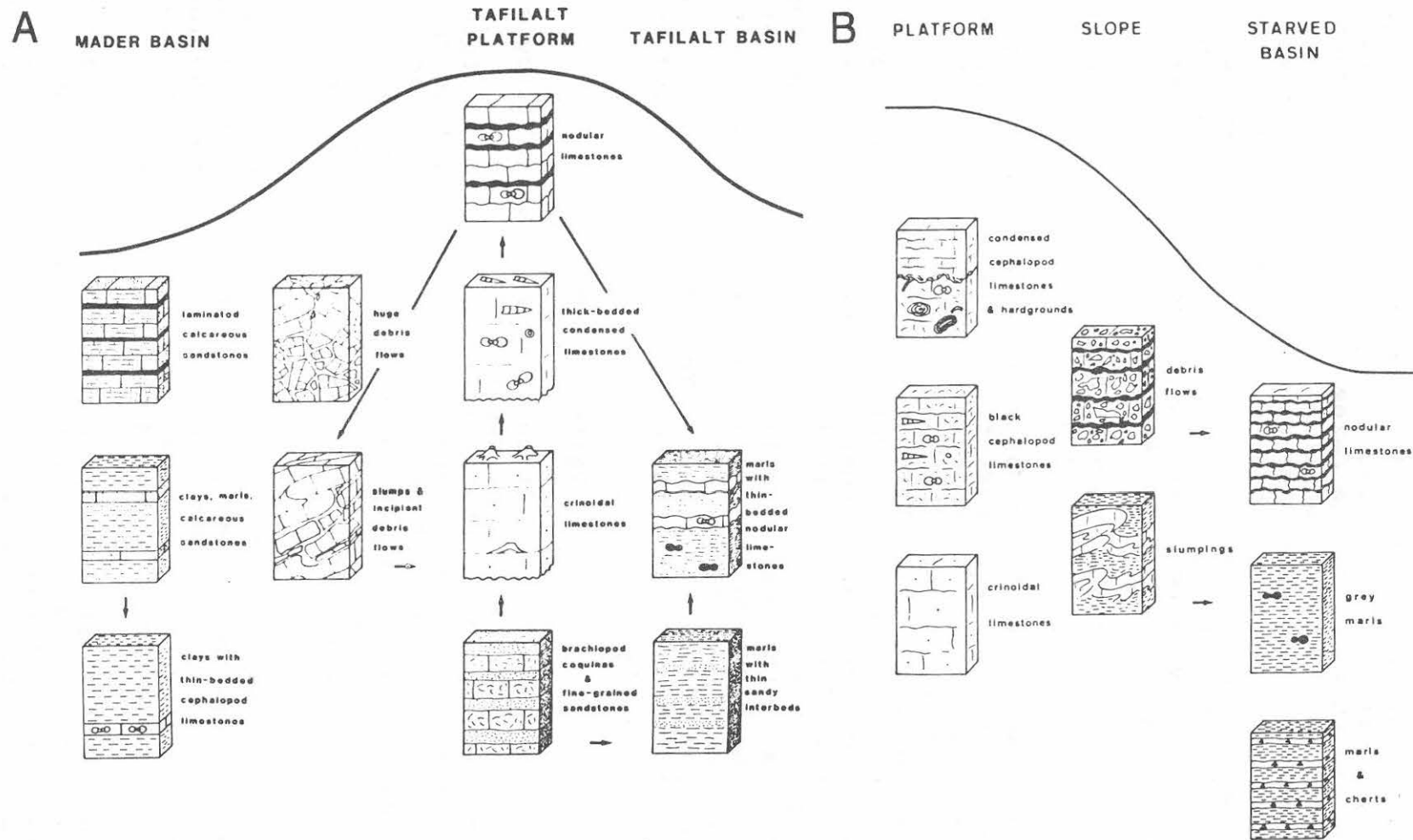


Figure 5.-- Generalized subfacies distribution for Upper Devonian cephalopod limestones in (A) the Anti-Atlas of Morocco and in (B) the Montagne Noire of France. From Wendt and Aigner (1985).

conditions (Brett and Kloc, in Anderson *et al.*, 1988; Brower and Nye, 1991). Few unambiguous taphonomic indicators present are that aid in the determination of water depth for the deposition of these two limestone packages. However, relict graded beds, submarine erosional discontinuity surfaces, and oriented orthocone cephalopods within these limestone packages in western and west-central New York suggest that the sea floor in that area was shallow enough for episodic reworking by strong storms (Brett and Kloc, in Anderson *et al.*, 1988; this report).

STRATIGRAPHIC RELATIONS IN THE LOWER PART OF THE MARCELLUS FORMATION (CAVS)

The lower part of the Marcellus Formation in eastern New York State is a southeasterly, rapidly thickening wedge of strata that ranges in thickness from approximately 12 m at Cherry Valley to more than 150 m at Kingston. Correlation of key units through this interval along the outcrop belt provides a more detailed understanding of relationships between the Cherry Valley, Stony Hollow, and Bakoven/Union Springs Members (see Figure 6). Recognition of strata in the Hudson Valley equivalent to the limestone-rich facies of the Cherry Valley Member permits correlation of the member into coarse, siliciclastic-dominated facies in the easternmost outcrops. A framework of the internal stratigraphy of the Stony Hollow Member and the upper parts of the Bakoven/Union Springs Members has also emerged and will be summarized below.

Cherry Valley Member

Figure 7 shows correlations for the Cherry Valley and Stony Hollow Members and the upper parts of the Bakoven/Union Springs Members along 143 km of the outcrop belt in eastern New York State. A key point to this new stratigraphic interpretation is the separation of the terrigenous sand-rich facies of the Cherry Valley Member from the underlying Stony Hollow Member (restricted) between Localities 4 and 13 (west of Clarksville to Kingston, respectively).

Cooper (1941) first described the Stony Hollow Member and regarded it as the sandy equivalent of the Cherry Valley Member. He noted that the upper part of the Stony Hollow Member at Onesquethaw Creek had a few layers of limestone that became the Cherry Valley Member to the west.

The stratigraphic revision proposed in this report is based upon the recognition of two relatively thin units with proetid trilobites and an intervening massive sandstone near the top of the Stony Hollow Member (discussed below). These data and use of the black shales of the Berne/Chittenango Members that overlie the Cherry Valley Member permit

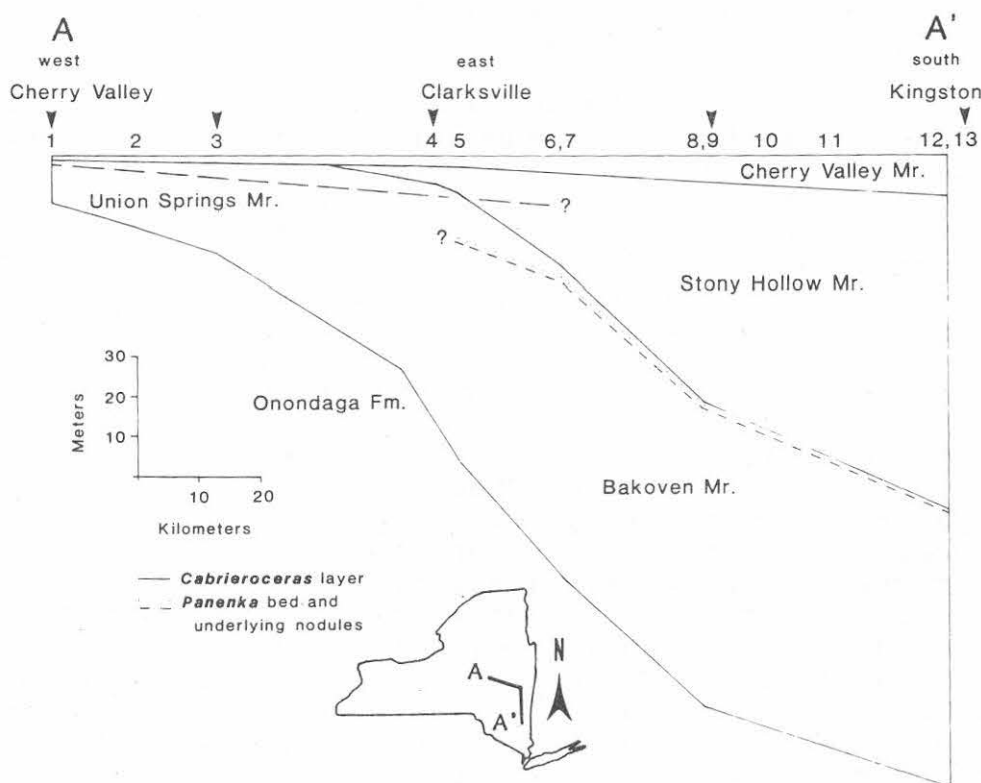


FIGURE 6.-- Thicknesses and relationships of the lower part of the Marcellus Formation in eastern New York State. Localities 1-13 are shown on Figure 8 and listed in Appendix II. Arrows indicate field trip stops (left to right, STOPS 1-5, respectively). Thicknesses of Bakoven/Union Springs Members from Rickard (1989).

physical correlation of the classic limestone-rich facies of the Cherry Valley Member with the equivalent terrigenous sand-rich facies in the Hudson Valley. It is proposed herein that these equivalent sand-rich strata be separated from the top of the Stony Hollow Member (restricted) and be included in the Cherry Valley Member. Therefore, the Cherry Valley "Limestone" (designation abandoned) is only a facies of a more areally extensive lithosome termed the "Cherry Valley Member" and the term "Cherry Valley Limestone" is no longer valid.

The argillaceous sandstones of the Cherry Valley Member in the Hudson Valley are fine-grained and are generally highly bioturbated. Some sandstone layers may exhibit planar bedding to cross-stratification, a low degree of burrow mottling (including apparent escape burrows), and sole marks. Body fossils are not generally common in the sand-rich facies. However, calcareous bedded to nodular layers that feature small brachiopod and styliolinid shell hashes with abundant quartz sand do occur. Nautiloid and

goniatite cephalopods are uncommon to rare in the terrigenous sandstone facies.

Between Cherry Valley and Clarksville, the Cherry Valley Member has three subdivisions and nearly doubles in thickness from 1.3 to 2.4 m. The member is not well exposed through much of the Hudson Valley, but a completely exposed section measures 10 m in thickness near Kingston. In the latter area, it is composed of five highly bioturbated arenaceous subdivisions separated by sandy shale intervals, all on the order of 1 m-thick.

Stony Hollow Member

"Proetid Units". Two richly fossiliferous units similar to the previously discussed Chestnut Street Beds occur in the upper part of the Stony Hollow Member. These two units (herein termed the "Upper" and "Lower Proetid Units") are characterized by a relatively rich benthic fauna that features proetid trilobites. Other faunal elements include abundant crinoid debris, aulopodid and small rugose corals, and brachiopods. These are accompanied by uncommon orthoconic nautiloid and goniatitic cephalopods and fish bones. The Upper and Lower Proetid Units of the Stony Hollow Member generally are separated by a 3.2-6.0 m-thick interval that features a prominent massive to thin-bedded sandstone unit. It is not currently known whether the Chestnut Street Beds near the top of the Union Springs Member represent the Upper or Lower Proetid Unit or if the former represent both Proetid Units of the Stony Hollow Member.

The Upper Proetid Unit of the Stony Hollow Member in the northern part of the outcrop belt is a coarse crinoidal limestone faunally similar to the Chestnut Street Beds near the top of the Union Springs Member to the west. South of Clarksville (Locality 6 and vicinity), the Upper Proetid Unit appears as a brachiopod-rich bed, dominated by Pacificocoelia? and athyridacean brachiopods. In the Kingston area (Locality 12), the Upper Proetid Unit is represented by a series of thin, fossiliferous, proetid-bearing beds that occur in sandy shales.

The Lower Proetid Unit of the Stony Hollow Member underlies a thin-bedded to massive sandstone unit near the top of the Stony Hollow Member. The faunal assemblage of the lower unit is nearly identical to that of the upper unit and has proetid trilobites, crinoid debris, brachiopods, and small rugose corals. At some localities, the Lower Proetid Unit overlies a brachiopod-rich bed (Localities 6, 7, 12, and 13/STOP 5b). At Locality 9 (STOP 4), the lower proetid unit is composed of two or more beds that total 0.6 m in thickness.

Massive Sandstone Unit. A thick, massive to thin-bedded sandstone occurs between the Upper and Lower Proetid Units near the top of the Stony Hollow Member. The sandstone unit is generally on the order of 4 m in thickness and commonly forms the caprock of prominent waterfalls and roadcuts. This argillaceous, quartz-rich sandstone is generally highly bioturbated, although it appears less burrowed and more thin-bedded in the northern and southern parts of the study area. Body fossils are less common in the massive sandstone unit than in the underlying and overlying Proetid Units.

Other Regionally Correlatable Units Within the Stony Hollow Member. At least three other prominent units within the Stony Hollow Member are locally correlatable along the outcrop belt. The first is a resistant, argillaceous, fine-grained sandstone that features scattered auloporida corals and several thin beds with small streptelasmid rugose corals. This unit occurs 9-12 m below the Lower Proetid Unit and ranges from 3.5 to 6+ m in thickness. It is moderately to highly bioturbated and features scattered small fossil debris and uncommon fish plates. This unit also forms the caprock of some exposures, as in Plattekill Creek in the village of Mount Marion, 10.0 km north of Kingston.

Another correlatable sandstone unit occurs approximately 5-9 m below the unit described above (13-23 m below the Lower Proetid Unit) between Kingston and north of Catskill. In the Kingston area (Localities 12 and 13/STOP 5b), it is represented by 0.9 m of buff-weathering, fine-grained sandstone. This sandstone may be subdivided into two subunits: a lower, more argillaceous part that contains abundant skeletal components and an upper, more resistant part that is highly bioturbated and contains scattered auloporida and small rugose corals. North of Catskill (Localities 8 and 9/STOP 4), the sandstone (1.6 m-thick) forms the caprock of several waterfalls.

A 7-10 m-thick interval of thin, buff-weathering beds that occurs in the lower part of the Stony Hollow Member is also correlatable between Kingston and the Catskill area. These thin dolomitic beds, which range from 2 to 22 cm in thickness, form resistant, buff-weathering bands on highly weathered outcrops. They appear to be moderately to highly burrow-mottled in contrast to the thinly laminated character of the surrounding strata. Small body fossils (nowakiids and small brachiopods) are uncommon to rare in the thin dolomitic beds.

As the Stony Hollow Member thins north of Localities 8 and 9 (STOP 4), these three units become indistinct. At Localities 6 and 7, an interval with occasional small chonetid brachiopods characterizes the middle part of the Member.

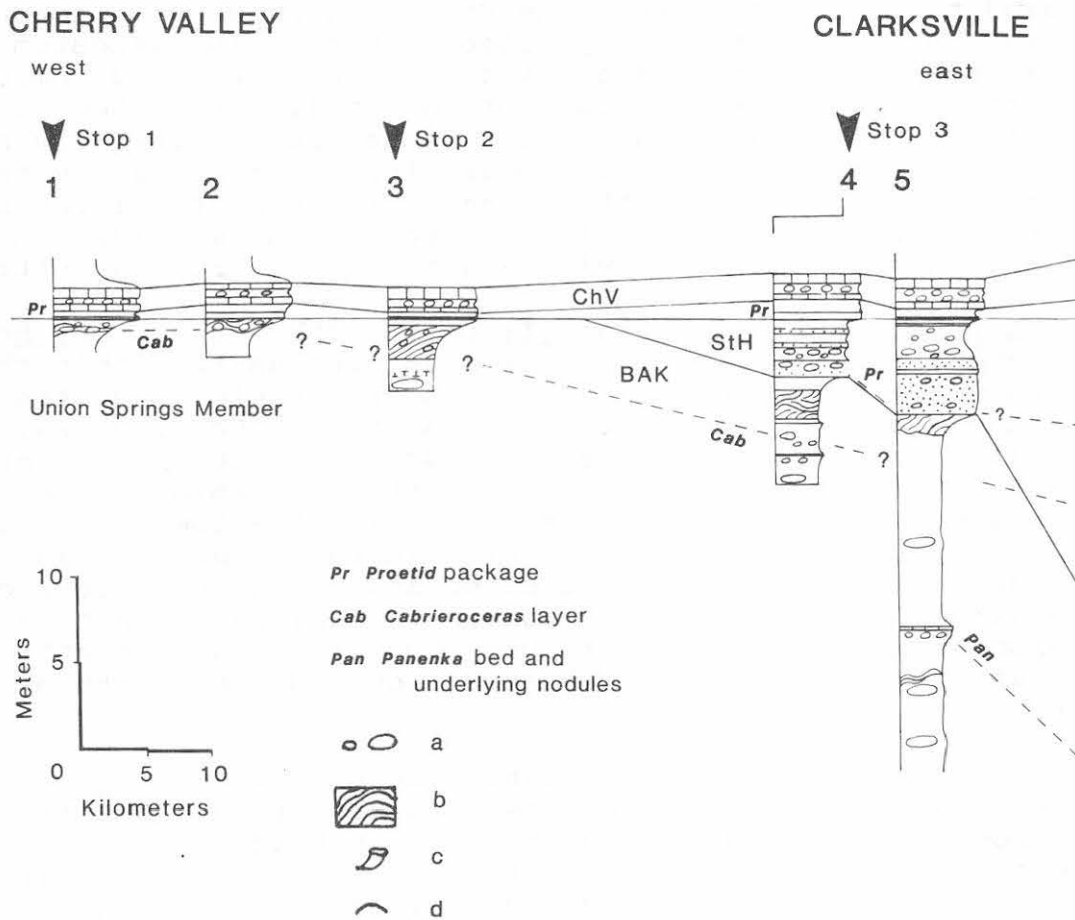
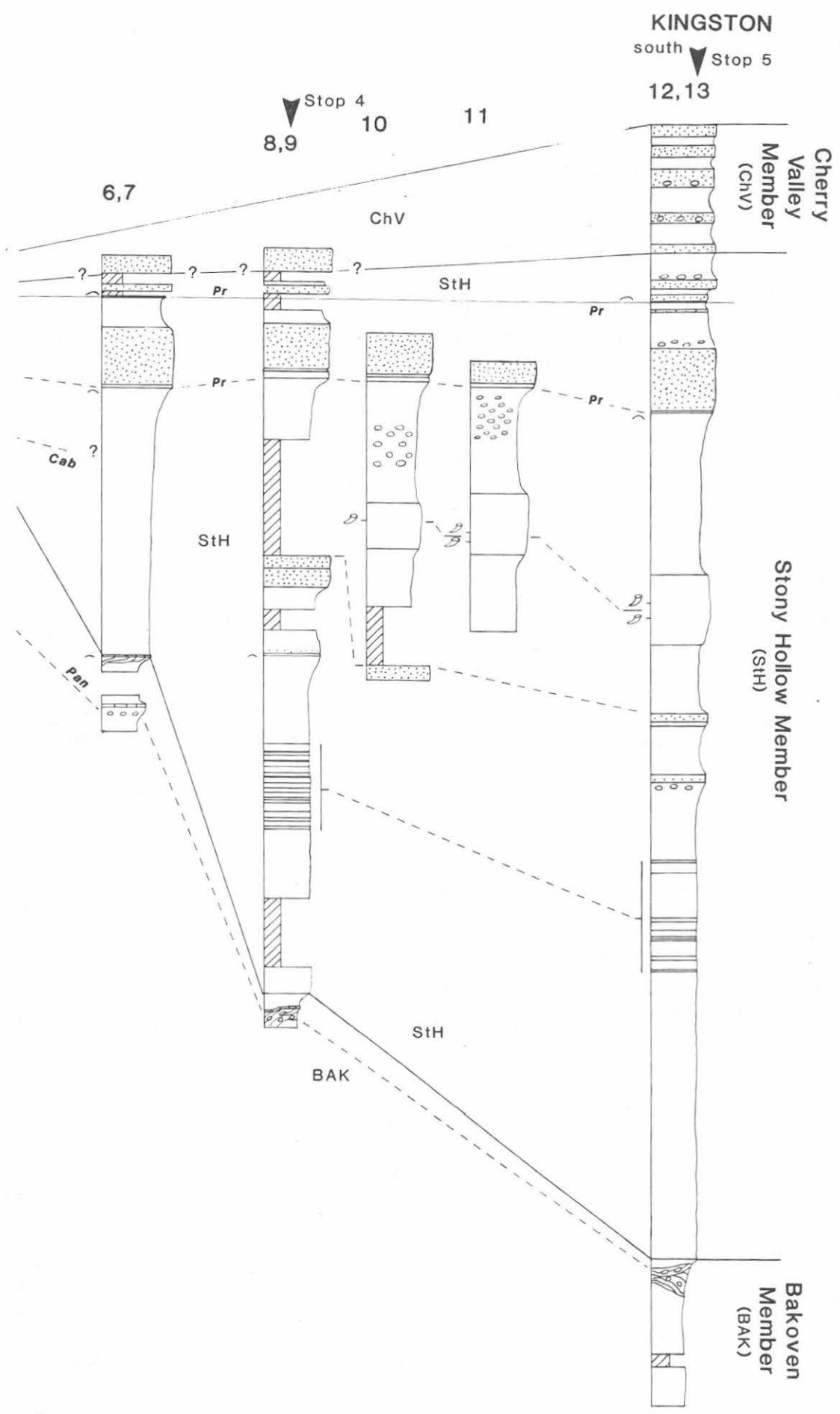


FIGURE 7.-- Correlations in the lower part of the Marcellus Formation across the field area. Datum equals the Upper Proetid Unit/Chestnut Steet Bed. Localities are shown on Figure 8 and are listed in Appendix II. a, calcareous nodule horizons; b, tectonized shale intervals; c, rugose coral beds; d, brachiopod-rich beds.



Bakoven/Union Springs Members

Tectonized Shale Interval. The uppermost strata of the Bakoven and Union Springs Members in eastern New York are marked by a widespread, tectonized shale interval. The interval occurs at, or within a meter below, the contact of the black shales with the overlying Stony Hollow Member, or in the absence of the latter, at or near the base of the Chestnut Street Beds near the top of the Union Springs Member. This tectonized shale interval has been interpreted as a decollement produced during late stages of the Acadian or Alleghenian Orogeny (see Bosworth, 1984 a, b). Faults in the Stony Hollow and/or Cherry Valley Members at Localities 1 (STOP 1) and 5 may be associated with the same thrusting event. Similar smaller scale structures occur throughout other parts of the Bakoven and Union Springs Members, where they generally underlie concretionary to thin-bedded limestone layers.

Cabrieroceras Bed. A series of calcareous nodule layers occurs in the upper part of the Union Springs Member at Cherry Valley (Locality 1/STOP 1). A layer of larger nodules approximately 0.7 m below the Upper Proetid Bed features the goniatite Cabrieroceras. This unit was previously noted by Flower (1936, p. 236; 1943, p. 17-18, "Werneroceras Bed") and Miller (1938, p. 60, "Anarcestes Limestone") and was correlated through central New York State by Flower (1936). Brett and Kloc (in Anderson *et al.*, 1988, p. 123) informally renamed the unit the Cabrieroceras Bed and noted that Rickard (1952, 1981) and subsequent authors (see House, 1962, 1981; Klapper, 1971, 1981) confused Flower's nodular Werneroceras Bed with the overlying Chestnut Street Beds. Rickard (1952) did note the true Cabrieroceras Bed approximately 3.4 m below the base of the Stony Hollow Member at Locality 4 (STOP 3) of this report. The Cabrieroceras Bed appears to pass laterally into the Stony Hollow Member south of Clarksville. Cabrieroceras has been found in the upper part of the Stony Hollow Member in northern Greene County (Localities 6 and 7).

Panenka Bed. A thin, condensed, fossil-rich limestone (ca. 0.1-0.3 m-thick) occurs in the upper part of the Bakoven Member in the northern part of the Hudson Valley outcrop belt. This unit, herein termed the "Panenka Bed", is characterized by a fauna of small brachiopods and bivalves, accompanied by the large bivalve Panenka. Gastropods, goniatites, and orthoconic cephalopods are also common in the unit. At Onesquethaw Creek (Locality 5), orthoconic cephalopods on the top surface of the Panenka bed exhibit a distinct north-south orientation. The Panenka Bed underlies the base of the Stony Hollow by approximately 12 m at Onesquethaw Creek. As the Stony Hollow Member thickens

south of Clarksville, the interval between the base of it and the Panenka Bed thins, and at Locality 8, the two units are separated by 1.0 m of black shale. The Panenka Bed disappears north of Kingston.

The Panenka Bed overlies another calcareous nodular layer with goniatites (including Cabrieroceas). This nodular unit generally underlies the Panenka Bed by approximately 0.5 m in the northern part of the Hudson Valley and appears to correlate with a similar nodular unit within the tectonized shale interval at the top of the Bakoven at Kingston (Locality 13/STOP 5b).

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APPENDIX I

The following list is a locality directory for the lettered stratigraphic sections of the Chestnut Street Beds and the Cherry Valley Member as featured in Figure 3.

- Section A - Exposures along the southern lip of the General Crushed Stone ("5 Points") Quarry, located 3.7 km northwest of the village of Lima, Livingston County.
- Section B - Low falls on Flint Creek, located 0.5 km northeast of the Wheat Road bridge that crosses Flint Creek and 2.9 km southwest of the village of Phelps, Ontario County.
- Section C - Exposures along the southern lip of Seneca Stone Quarry, located 5.1 km south-southeast of the village of Seneca Falls and 1.8 km west of the village of Canoga Springs, Seneca County.
- Section D - Low falls directly north of Pleasant Valley Road, located 1.4 km east of the intersection with N.Y. Rte. 175, village of Marcellus, Onondaga County.
- Section E - Low falls 0.3 km south of N.Y. Rte. 173, located 3.1 km west of the village of Manlius and 4.9 km east of the village of Jamesville, Onondaga County.
- Section F - Roadcut on the north side of Stockbridge Falls Road, located 3.4 km southwest of the village of Munnsville, Madison County.
- Section G - Low falls in creek along Gulf Road, located 3.1 km east of the village of West Winfield, Herkimer County.
- Section H - High falls in Cox Ravine (type-section of the Cherry Valley Member), located 1.1 km northwest of the village of Cherry Valley, Otsego County.
- Section I - Chestnut Street roadcut (STOP 1), located directly southwest of the intersection of Chestnut Street (Otsego Co. Rte. 54) and U.S. Rte. 20, 3.8 km east of the village of Cherry Valley, Otsego County.
- Section J - Low falls in the ravine 0.1 km north of Rosenberg Road, located 0.95 km west of the junction with Schoharie Co. Rte. 40 and 2.7 km northwest of the village of Seward, Schoharie County.
- Section K - Stream cut exposures, located 0.25 km south of Schoharie Co. Rte. 1 in the village of Mineral Springs (STOP 2), Schoharie County.
- Section L - Stepped falls in the ravine directly north of Long Road (STOP 3), located 3.8 km from the junction with N.Y. Rte. 443 and 1.8 km southeast of the village of Thompsons Lake, Albany County.

APPENDIX II

The following list is a locality directory for the numbered stratigraphic sections of the lower part of the Marcellus Formation that are shown in Figures 7 and 8.

1. Outcrop near intersection of Chestnut Street and U.S. Rte. 20, 3.8 km northeast of Cherry Valley (Otsego Co.). Equals Section I of Appendix I.
2. Waterfall in stream along Rosenberg Road, 2.7 km northwest of Seward (Schoharie Co.). Equals Section J of Appendix I.
3. Outcrop in outlet stream of Cobleskill Reservoir, 200 m south of Mineral Springs (Schoharie Co.). Equals Section K of Appendix I.
4. Ravine along Long Road, 2.3 km southeast of Thompsons Lake (Albany Co.). Equals Section L of Appendix I.
5. South branch of Onesquethaw Creek, 3.7 km northwest of Clarksville (Albany Co.).
6. Ravine south of farm pond along Greene Co. Rte. 51, 3.9 km north-northwest of Roberts Hill (Greene Co.).
7. Ravine south of Hass Hill Road, 1.5 km southwest of Roberts Hill (Greene Co.).
8. Ravine, south side of power lines, 0.4 km west of south end of Hollister Lake (Greene Co.).
9. Buttermilk Falls, 1.0 km west of Green's Lake (Greene Co.).
10. Underhill Road, 0.6 km north of New York Rte. 23a, 2.3 km east-northeast of Kiskatom; and north side of ravine, 1.3 km north-northeast of Underhill Road outcrop (Greene Co.).
11. Roadcut along New York Rte. 32, 1.0 km west of Katsbaan (Ulster Co.).
12. Roadcuts along New York Rte. 209, 1.2 km north of toll booth, Exit 19 of New York State Thruway (Ulster Co.).
13. Roadcuts and railroad cut along New York Rte. 28, 1.2-3.2 km west-northwest of toll booth, Exit 19 of New York State Thruway (Ulster Co.).

ROAD LOG

The road log begins at Exit 17 of Interstate Route 88, east of Oneonta, New York.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Leave I-88 eastbound at Exit 17.
0.3	0.3	Turn left (north) onto N.Y. Rte. 28.
1.8	1.5	Cross intersection with N.Y. Rte. 7. Continue north on Rte. 28. Note exposures of Gilboa Fm. in roadcuts north of this intersection.
9.2	7.4	Enter village of Milford.
9.6	0.4	Turn right (east) onto N.Y. Rte. 166 northbound at the junction.
10.9	1.3	Note exposures of the Panther Mountain Fm. in small roadcut on the north side of the road.
24.5	13.6	Enter village of Roseboom.
26.7	2.2	Cross junction with Otsego Co. Rte. 33. Continue north on Rte. 166. Note outcrop of lower Hamilton Group shales on west side of the road, north of the junction.
28.5	1.8	Enter village of Cherry Valley.
28.8	0.3	Turn right (east) at intersection with Otsego Co. Rte. 54. Continue on combined Rte. 166 northbound/54 eastbound.
29.4	0.6	Veer right onto Rte. 54 (leaving Rte. 166) at fork.
31.9	2.5	Note roadcut of lower strata of the Marcellus Fm. on the right (south) side of the road.
32.1	0.2	Park at the east end of the roadcut. Note the panorama view of the Mohawk Valley and the southern Adirondacks to the north.

STOP 1. Chestnut Street Roadcut

This outcrop features the uppermost part of the Union Springs Member, an excellent exposure of the complete Cherry Valley Member, and the lowermost part of the Chittenango Member. Two thin zones of intensely deformed shale within the

Union Springs Member and a thrust fault that ramps up through the Cherry Valley Member can be observed at this locality. Bosworth (1984a, b) associated these deformation features with northwest-directed overthrusting that occurred during either Acadian or Alleghenian orogenic events.

The exposed 4.0 m of Union Springs Member shales contain several intervals of carbonate concretions at this locality. One of these concretion intervals commonly features the goniatite Cabrieroceeras pleibeforme and lies approximately 1.0 m below the base of the Cherry Valley Member. The Chestnut Street Beds form one 20 cm-thick ledge of skeletal wackestones and packstones around 17 to 20 cm below the base of the Cherry Valley Member. Although the individual Chestnut Street Beds are amalgamated and burrow-mottled, distinction of the uppermost darker gray, crinoid-rich packstone bed can be made on outcrop. A thin, silty, calcareous, gray to black shale interval between the Chestnut Street Beds and the Cherry Valley Member features the goniatite Agoniatites nodiferous. The clean weathered faces of this roadcut make it one of the best places to view internal stratigraphy of the Cherry Valley Member. The 1.2 m-thick section of Cherry Valley contains a 15 to 20 cm-thick lower massive packstone bed, a 60 to 65 cm-thick middle nodular packstone/marlstone interval, and a 37 to 40 cm-thick package of upper packstone beds. Concentrations of whole and partially preserved goniatites can be observed in the basal bed and upper packstone intervals. Orthocone nautiloids can also be observed in the base of the upper packstone interval, especially 30 cm below the upper contact of the Cherry Valley Member. Planolites traces are common on the bedding plane surfaces of fallen blocks of the Cherry Valley Member. Calcareous black shales with small brachiopods, dacryoconarids, and small orthocone nautiloids mark the transition from the Cherry Valley Member into the overlying sooty black shales of the Chittenango Member.

32.1

0.0

Proceed east on Otsego Co. Rte
54.

FIGURE 8.--Generalized geologic and locality map. Geologic map modified from Fisher et al. (1970). Explanation: (Don) Onondaga Limestone and lower units; (Dhm) lower part of the Marcellus Formation (Bakoven/Union Springs, Stony Hollow, and Cherry Valley Members), Mount Marion Formation, and Panther Mountain Formation to north (Hamilton Group); (Dhmr) Marcellus Formation (Hamilton Group); (Dh) Panther Mountain Formation and higher units; (Dhc) continental facies of the Hamilton group and higher units. Localities are listed in Appendix II.



32.2	0.1	Turn left (north) off Rte. 54 and then right (east) onto U.S. Rte. 20.
34.4	2.2	Note outcrops of Kalkberg Fm. along U.S. Rte. 20 west of Sharon Springs.
35.7	1.3	Enter village of Sharon Springs.
36.1	0.4	Cross intersection with N.Y. Rte. 10. Continue on Rte. 20.
39.2	3.1	Note outcrops of Onondaga Limestone.
40.0	0.8	Enter village of Sharon.
41.2	1.2	Turn right (south) onto N.Y. Rte. 145.
45.0	3.8	Note exposures of the Union Springs Mbr. of the Marcellus Fm. and the underlying Onondaga Limestone in the drainage ditch on the right (west) side of the road for the next 0.4 miles.
48.6	3.6	Note roadcut in Onondaga Fm. on the right (west) side of the road.
48.7	0.1	Enter village of Lawyersville.
49.0	0.3	Turn left (east) at stop sign, remaining on Rte. 145.
50.0	1.0	Enter village of Cobleskill.
51.1	1.1	Continue straight through the intersection with N.Y. Rte. 7 (at stop light) onto South Grand St.
51.6	0.5	Proceed under overpass of I-88.
51.8	0.2	Turn left (east) onto Mineral Springs Rd. (Schoharie Co. Rte. 1).
53.3	1.5	Turn right (south) onto Green Hill Rd.
53.4	0.1	Turn left into vacant lot and park. Walk down into the ravine at the back of the lot and proceed upstream to outcrops.

STOP 2. Mineral Springs Section.

This stop exposes the upper 4.5 meters of the Union Springs Member, a complete section of the Cherry Valley Member (1.4 m-thick), and the lowest part of the Chittenango/Berne Member. Calcareous dark gray shales a meter above the base of the section contain small brachiopods and bivalves; these include the brachiopod Leiorhynchus and the large bivalve Panenka, along with nautiloid and goniatite cephalopods. A 2 m-thick interval of tectonized shale occurs in the upper part

of the Union Springs Member above these fossiliferous shales. The Chestnut Street Beds form a 20 cm-thick package of two skeletal wacke/packstone beds separated by gray calcareous shales. The basal Chestnut Street bed directly overlies a 5 cm-thick dark, argillaceous concretionary lime mudstone layer with pyritized burrows. The internal stratigraphy of the Cherry Valley Member at this locality is similar in most ways to that of STOP 1. However, individual packstone beds of the upper massive interval increase in thickness and are separated by shaly partings.

53.4	0.0	Return to junction with Mineral Springs Rd.
53.5	0.1	Turn right (east) onto Mineral Springs Rd.
54.5	1.0	Note hillside exposure of the Chittenango Mbr. of the Marcellus Fm. on the south side of the road.
55.4	0.9	Turn left (north) onto N.Y. Rte. 145.
55.5	0.1	Turn right onto I-88 eastbound at Exit 22.
55.8	0.3	Note Carlisle Center and Esopus Fms. in roadcuts.
56.1	0.3	Note Oriskany and Becraft Fms. in roadcuts south of I-88.
56.8	0.7	Note Becraft and Kalkberg Fms. in roadcuts south of I-88.
57.2	0.4	Note Coeymans Fm. in low roadcuts on the south side of the highway.
59.2	2.0	Note exposures of the Manlius, Rondout, and Brayman Fms. in large roadcut to the south of I-88.
61.1	1.9	Leave I-88 eastbound at Exit 23.
61.5	0.4	Turn right (south) onto N.Y. Rte. 30A.
62.3	0.8	Rte. 30A ends. Veer right and continue southbound on N.Y. Rte 30.
63.8	1.5	Turn left (east) onto N.Y. Rte. 443.
64.0	0.2	Enter village of Shutters Corners.
67.1	3.1	Note exposures of Onondaga Limestone in roadcuts and in adjacent Fox Creek for the next 1.5 miles.
69.1	2.0	Cross Albany County line.
69.5	0.4	Enter village of West Berne.

71.7	2.2	Note Onondaga Limestone exposures behind Highway Dept. Building (south of Rte. 443).
71.8	0.1	Enter village of Berne.
72.5	0.7	Continue on Rte. 443, through the intersection with N.Y. Rte. 156 (around 2 sharp bends).
75.3	2.8	Cross junction with Cole Hill Rd. Note that large roadcuts on Cole Hill Rd. feature the type-Berne and the complete Otsego Mbrs. of the Mount Marion Fm. (= proximal marine facies of the upper part of the Marcellus Fm.).
76.0	0.7	Cross junction with N.Y. Rte. 157A. Continue on Rte. 443.
76.1	0.1	Enter village of East Berne.
76.5	0.4	Turn left (east) onto Long Rd.
78.0	1.5	Cross intersection with Saw Mill Rd. Continue on Long Rd.
78.7	0.7	Note small quarry in the Berne Mbr. (south of the road).
79.05	0.35	Park on the side of Long Rd. Walk down into the deep, heavily wooded ravine directly north of the road.

STOP 3. SECTION AT LONG ROAD RAVINE (THOMPSON'S LAKE SECTION OF RICKARD, 1952)

This section illustrates the eastward appearance of coarse-grained siliciclastics in the lower part of the Marcellus Formation. The stop exposes a relatively thick section of the Bakoven Member, a 4.5 m-thick section of the Stony Hollow Member, and a 1.4 m-thick section of the Cherry Valley Member.

The Bakoven Member (= Union Springs Member) is exposed downstream from and within the lowermost waterfall. The shales contain carbonate concretion horizons and thin-bedded limestones. Rickard (1952) recognized the true concretionary Cabrieroceras bed near the base of the lowermost waterfall. A 1.75 m-thick interval of tectonized shale occurs in the face of this waterfall.

A 2.0 cm-thick bed of the Lower Proetid Unit occurs at the base of the Stony Hollow Member, just below the crest of the lowermost waterfall. The overlying 1.8 meters of buff-weathering, pyrite-rich, calcareous siltstones and shales are equivalent to the massive sandstone unit near the top of the Stony Hollow in the Hudson Valley (STOPS 4 and 5b). The

overlying Upper Proetid Unit consists of a package of coarsely crinoidal packstone and grainstone beds that display relict cross-stratification. Quartz silt and sand are common in these limestone beds at this locality, in contrast to previous stops.

The Cherry Valley Member is exposed within and caps the uppermost waterfall. The lower and upper Cherry Valley intervals are heterolithic at this locality and contain thin interbeds of terrigenous siltstone/sandstone with skeletal packstone and grainstone beds. The middle nodular interval consists of a few large, sharply bounded concretions in dark gray shale. Coarse crinoidal beds with finely comminuted brachiopod valves are common in the uppermost Cherry Valley.

79.2	0.15	Turn right (south) onto Elm Dr.
81.2	2.0	Turn right (west) onto Stage Rd. (Albany Co. Rte. 303) at stop sign.
81.6	0.4	Veer left at fork near the junction of combined N.Y. Rte. 443/85 and Stage Rd. Turn left (east) onto Rte. 443/85. Note sandstone at the top of the Berne Mbr. (Mount Marion Fm.) on right past the intersection.
82.3	0.7	Note Helderberg Lake on left (north) side.
82.5	0.2	Cross junction with Duck Hill Rd. Note exposures of the Berne Mbr. behind the house at the corner.
82.9	0.4	Note the large parking area on the north side of the road, which provides parking for access to exposures of the lower part of the Marcellus Fm. in and below the falls on Onesquethaw Creek, directly to the north.
83.9	1.0	Continue on Rte. 443 as Rte. 85 turns to the left (east).
85.2	1.3	Note exposure of Onondaga Limestone in roadcut on north side.
85.3	0.1	Enter village of Clarksville.
85.4	0.1	Turn right (south) onto Clarksville South Rd. (Albany Co. Rte. 312). Continue on this route past the intersection with Bennett Hill Rd.
87.5	2.1	Note quarry in the Otsego Mbr.

91.3	3.8	Turn left (east) onto N.Y. Rte. 143 in the village of Dormansville. Note outcrops of the upper part of the Mount Marion Fm. on the south side of the intersection.
91.5	0.2	Turn right (south) onto N.Y. Rte. 32 at the intersection with Rte. 143.
91.8	0.3	Note quarry in the upper part of the Mount Marion Fm. on the right (west) side of the road.
97.2	5.4	Enter village of Greenville. Continue on Rte. 32.
97.8	0.6	Cross junction with N.Y. Rte. 81. Continue on Rte. 32.
99.4	1.6	Note outcrops of the Plattekill Fm. along the road for the next 0.4 mile.
101.3	1.9	Note scenic views of the northern Catskills for the next 0.5 mile.
101.9	0.6	Enter village of Freehold. Continue on Rte. 32.
105.6	3.7	Cross Catskill Creek.
106.7	1.1	Rte. 32 joins with N.Y. Rte. 23 and heads east. Continue on combined Rte. 32/23. Note exposures of Plattekill Fm. red beds and fluvial sandstones in roadcuts.
107.7	1.0	Rte. 32 veers right (south). Continue east on Rte. 23.
108.4	0.7	Note additional outcrops of the Plattekill Fm. for the next 2.4 miles.
112.0	3.6	Note outcrops of the Mount Marion Fm. over the next 0.4 mile.
113.1	1.1	Turn left (north) onto Cauterskill Rd.
113.4	0.3	Turn right (east) onto Old Rte. 23 (N.Y. Rte. 23B). Cross old stone bridge over Catskill Creek.
113.6	0.2	Turn left (north) onto Greene Co. Rte. 49 in the village of Leeds.
114.1	0.5	Cross intersection with Sandy Plains Rd.
114.9	0.8	Note scenic view of Potic Mtn. to the left (west).

115.5	0.6	Note outcrops of the Onondaga Limestone in roadcuts for the next 0.2 mile.
115.8	0.3	Turn left (west) onto Buttermilk Falls Rd.
116.4	0.6	Turn vehicles around and park in the parking area on the south side of Buttermilk Falls Rd. Follow dirt trail southward to waterfalls.

STOP 4. BUTTERMILK FALLS

This locality exposes approximately 41 m of the Stony Hollow Member and 3.7 m of the terrigenous sand-rich facies of the Cherry Valley Member. Strata at the base of the lowest falls lie approximately 12 m above the Bakoven/Stony Hollow Member contact, which is exposed in a ravine 2.1 km to the north (Locality 8).

A 7 m-thick interval in the lowest falls features a series of thin dolomitic beds (ca. 2-22 cm-thick). This interval, which is best seen in the high bank north of the lowest falls, correlates with a similar package of thin dolomitic beds in the lower part of the Stony Hollow Member at Kingston (Locality 13/Stop 5b). Fine-grained resistant sandstones forms the caprock of the lowest falls.

A second falls 4 m upsection is capped by 1.6 m of highly bioturbated, argillaceous sandstone. The lower part of the unit appears medium bedded, and the upper part is massive. Prominent subhorizontal to vertical Zoophycus traces occur in the upper 0.9 m. This unit is also traceable to Kingston (Locality 13, STOP 5b), where it is represented by 0.9 m of fossiliferous, bioturbated fine sandstone.

The main upper waterfall at Buttermilk Falls is capped by the massive sandstone (3.3 m-thick) near the top of the Stony Hollow Member. At this locality, the massive sandstone unit is highly bioturbated and displays a prominent slaty cleavage. A 0.3 m-thick recessed interval of sandy shale separates the massive sandstone from the underlying Lower Proetid Unit. This highly fossiliferous unit is composed of 2-3 separate beds that total 0.6 m in thickness at Buttermilk Falls.

The massive sandstone that caps the main falls at Buttermilk Falls is overlain by siltstones and silty shales in the upper part of the Stony Hollow Member. The Upper Proetid Unit is covered at STOP 4. A 0.6 m-thick sandstone that forms a small cascade upstream of the main falls may correlate with a similar thin unit that overlies the Upper Proetid Unit or the Chestnut Street Beds at most localities.

The Cherry Valley Member forms a 2 m-high falls at the top of the outcrop. The argillaceous sandstone of the Member is highly cleaved and has several recessed carbonate-rich intervals with numerous small brachiopods. The sandstones appear to be highly bioturbated. A small outcrop of sandy shales that is exposed approximately 5 m upstream is apparently part of the Cherry Valley Member. An abandoned quarry in the south bank of the creek exposes the lowermost black shales of the overlying Berne Member.

116.4	0.0	Retrace route (east) on Buttermilk Falls Rd.
117.0	0.6	Turn right (south) onto Greene Co. Rte. 49 and return to the village of Leeds.

TO RETURN TO ONEONTA:

119.2	2.2	Turn right (west) onto N.Y. Rte. 23b.
119.4	0.2	Turn left (south) onto Cauterskill Rd.
119.7	0.3	Turn right (west) onto N.Y. Rte 23 and follow highway to Oneonta.

TO OPTIONAL STOP 5: ROUTE 28 EXPOSURES, KINGSTON

119.2	2.2	Turn left (east) onto N.Y. Rte. 23b.
120.3	1.1	Turn left (north) at entrance to N.Y. State Thruway.
120.5	0.2	Stop and get ticket at tollbooth. Enter southbound ramp toward New York City. Note outcrops of the Lower Devonian New Scotland and Becraft Fms. for the next 1.2 miles.
121.8	1.3	Cross Catskill Creek.
122.1	0.3	Note outcrops of the Tristates Group (Esopus, Carlisle Center, and Schoharie Fms.) and the Onondaga Fm. for the next 8.9 miles.
123.9	1.8	Cross Kaaterskill Creek.
131.9	8.0	Note exposures of the Glenerie Fm. and the underlying upper part of the Helderberg Group (Becraft, Alsen, and Port Ewen Fms.) for the next 0.6 miles.

132.9	1.0	Note exposures of the Schoharie and Onondaga Fms. for the next 1.1 miles.
133.2	0.3	Exit 20 (Saugerties).
134.4	1.2	Mount Marion visible to the right of the Thruway. Note large quarry at the north end of the ridge which exposes the Berne and Otsego Mbrs. of the Mount Marion Fm.
137.5	3.1	Note exposure of Stony Hollow Mbr. on left (east) side of highway.
140.5	3.0	Note dark to rusty shales of the Berne Mbr. exposed on right (west) side of highway.
142.2	1.7	Note outcrops of Stony Hollow Mbr. for the next 0.7 miles.
142.9	0.7	Exit N.Y. State Thruway at Kingston.
143.6	0.7	Pay toll at tollbooth.
143.7	0.1	Enter traffic circle.
143.8	0.1	Turn right (northwest) to exit traffic circle onto N.Y. Rte. 28 West.
144.6	0.8	Turn right (northeast) onto Forest Hill Drive, then immediately turn right (southeast) onto City View Terrace.
144.65	0.05	Park on right (southwest) side of road.

STOP 5a. CITY VIEW TERRACE ROADCUT

This outcrop exposes the upper 10 m of the Bakoven Member and the lower 23 m of the Stony Hollow Member. The transition between the members is gradational at this locality, and it is underlain by a 1-3 m-thick zone of tectonized shale. Calcareous nodules within this interval have yielded Cabrieroceras and another unidentified goniatite (G. Kloc, 1991, personal commun.). The lower strata of the Stony Hollow Member at this locality are thinly laminated and exhibit little to no burrow-mottling (chiefly small Planolites traces). Body fossils are rare and are chiefly small tentaculids (Nowakia?) and rare small brachiopods and bivalves. The upper part of this outcrop is exposed along the adjacent road to the northwest, where thin (ca. 3-10 cm) dolomitic beds appear in the section.

144.65	0.0	Turn around and return to N.Y. Rte. 28.
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144.7	0.05	Turn right (northwest) onto Rte. 28.
144.8	0.1	Stony Hollow Mbr. exposed in roadcut.
145.1	0.3	Park at the end of the roadcut. Walk back along the highway to the beginning of the outcrop.

STOP 5B. LARGE ROUTE 28 ROAD CUT

This large roadcut exposes approximately 60 m of the Stony Hollow Member. The base of the outcrop lies approximately 11 m above the contact with the underlying Bakoven Member (see STOP 5a). The thinly laminated character of the unit is visible on many of the rock surfaces, and the low degree of burrow-mottling (chiefly small Chondrites burrows) is also notable. These features characterize much of the Stony Hollow Member at Kingston. A series of thin (ca. 3-17 cm-thick), buff-weathering dolomitic beds occurs 11-21 m above the base of the outcrop. Two thicker, buff-weathering units are visible farther upsection (27 and 33 m above the base of the outcrop, respectively). The lower bed (ca. 0.8 m-thick) is underlain by a layer of rusty-weathering burrows and concretions. The upper unit (ca. 0.9 m-thick) features an upper bioturbated sandstone (with Planolites and Teichichnus traces and small rugose corals) and a lower fossiliferous unit featuring hyoliths, coleolid tubes, gastropods, and cephalopods. Small bivalves may also be found in this interval. This unit is correlatable with the lower massive sandstone at Buttermilk Falls (Locality 9, Stop 4).

The next key unit is a thick, massive, light buff-weathering unit (ca. 5-6 m-thick) that is traceable northward along the outcrop belt as far as Catskill. Auloporidae corals are scattered throughout the unit, and two horizons feature small streptelasmid rugose corals. The overlying interval (ca. 12 m-thick) is characterized by darker, blocky-weathering, calcareous shale-rich strata.

The top of the outcrop is marked by the resistant, thin-bedded to massive sandstone near the top of the Stony Hollow Member. The base of this interval is marked by the Lower Proetid Unit and an underlying brachiopod-rich bed. The upper surface of the sandstone marks the base of the Upper Proetid Unit at outcrops in the Kingston area.

The overlying transition into the Cherry Valley Member is not well exposed along Route 28, but a complete section through this interval may be seen 1.7 km to the east along Route 209. At the latter outcrop, the top of the thin-bedded to massive sandstone unit is overlain by a 3.5 m-thick interval of silty shales which feature a series of thin,

richly fossiliferous beds with proetid trilobites. These beds may have small calcareous nodules or thin limestone lenses. This interval represents the Upper Proetid Unit in the Kingston area. An overlying thin, calcareous sandstone bed contains numerous brachiopods, which include Productella, Kayserella, and Leptaena. The brachiopod bed is capped by a prominent, 60 cm-thick, bioturbated sandstone that lies approximately 5 m below the top of the Route 209 outcrop. The two lower beds of the Cherry Valley Member are present in the upper 2.7 m of the Route 209 cut.

145.1	0.0	Continue northwest on Rte. 28.
145.2	0.1	Park on the right (northeast) side of Rte. 28 opposite a rock exposure and walk across the highway.

STOP 5C. CHERRY VALLEY MEMBER ALONG ROUTE 28 AND ADJACENT RAILROAD CUT

This roadcut and the adjacent railway cut expose a 10 m-thick section of the terrigenous sand-rich facies of the Cherry Valley Member. At this locality, the member is composed of five highly bioturbated arenaceous units separated by sandy shale intervals. These units range from 0.7-1.4 m-thick. The sandstones display prominent cleavage, especially in the railroad cut. (Note that the upper sandstone is missing in the highway cut and the lower sandstone is exposed downsection from the railway cut.) Body fossils are relatively uncommon in the sandstones, though carbonate-rich nodules feature shelly to styliolinid-rich hashes with abundant quartz sand. Leiorhynchus, other small brachiopods, and auloporid corals may be present near the tops or bases of the sandstone units. Uncommon to rare nautiloid and goniatite cephalopods may also be found. Teichichnus is the most prominent trace in the sandstones. The intervening sandy shales feature numerous limonitic burrows, accompanied by small brachiopods and bivalves.

145.2	0.0	END OF TRIP. PROCEED ON N.Y. RTE. 28 WEST TO RETURN TO ONEONTA.
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