TRIP B-8

ALLUVIAL AND TIDAL FACIES
OF THE
CATSKILL DELTAIC SYSTEM

by

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INTRODUCTION

Within the uppermost Middle Devonian and lowermost Upper Devonian rocks of eastern New York State there occurs a remarkably complete spectrum of ancient sedimentary facies (Johnson and Friedman, 1969; Johnson, 1970, 1972, 1976). These beds, which evolved during a transgressive pulse in the building of the great Catskill deltaic system, are part of a 3000 meter sequence that constitutes the standard for the Devonian System of North America (Figs. 1 and 2). They are exposed at the northeastern end of the Allegheny Synclinorium, are essentially undisturbed and, for the most part, very fossiliferous. Laterally transitional between those beds that are clearly of marine origin and those that are clearly non-marine are sandstones and shales that have sedimentary structures, lithology, geometric relationships with adjacent units and biogenic structures that indicate that they evolved in tidal environments generally similar to those of the modern Wadden Sea.

The purpose of this trip is to outline evidence for assigning depositional environment interpretations to these non-marine and transitional clastics and to offer their associated characteristics as recognition criteria for rock units developed in other tectonic delta complexes (Friedman and Johnson, 1966) at other times in the geologic past.

LITHOFACIES
of the
MIDDLE AND UPPER DEVONIAN

Three general lithofacies are recognized in the Devonian deltaic system of New York State (Fig. 2). The Catskill lithofacies, which consists of non-marine red and green-gray shales, sandstones and conglomerates, overlies and interfingers westward with littoral and shallow marine, very fossiliferous, gray sandstones and shales of the Chemung lithofacies. The Chemung, in turn, overlies and interfingers westward with deeper-water, sparsely fossiliferous, black shales of the Portage lithofacies.

The rocks of interpreted alluvial origin on which this trip focuses are best exposed along the Catskill Front between Palenville and Haines Falls and, farther northwest, at East Windham. They constitute the northwest Catskill lithofacies (Fig. 2). Rocks of interpreted tidal origin are exposed near Gilboa Dam in the Schoharie Valley, within the easternmost part of the Chemung lithofacies (Fig. 2). These rocks stratigraphically comprise the uppermost part of the Hamilton Group and the basal part of the Genesee Group (Cooper and Williams, 1935).

The interfingering relationship of the Catskill and Chemung rocks is best displayed just east of Schoharie Reservoir. Exposures there consist of interbedded gray, variably fossiliferous, cross-bedded, very fine-grained sandstones and red and green siltstones and mudstones. In places the contact between these two divergent lithologies is marked by a very thin conglomerate zone.

During this field trip, we will briefly examine the characteristics of the Catskill lithofacies between Palenville and Hunter (Stops 1-3). At Hardenburg Falls (Stop 4) we will study the Chemung lithofacies. Along Rt. 30, north of Grand Gorge (Stop 5), we will see both Catskill and Chemung rocks, at Gilboa Dam (Stop 6) Chemung rocks and, finally, at East Windham (Stop 7) a thick section of Catskill beds.

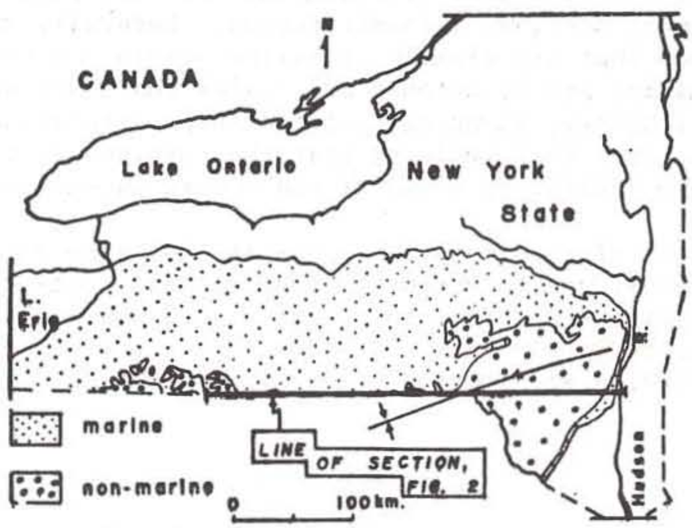


Figure 1 - Devonian bedrock of New York State (after Rickard, 1964).

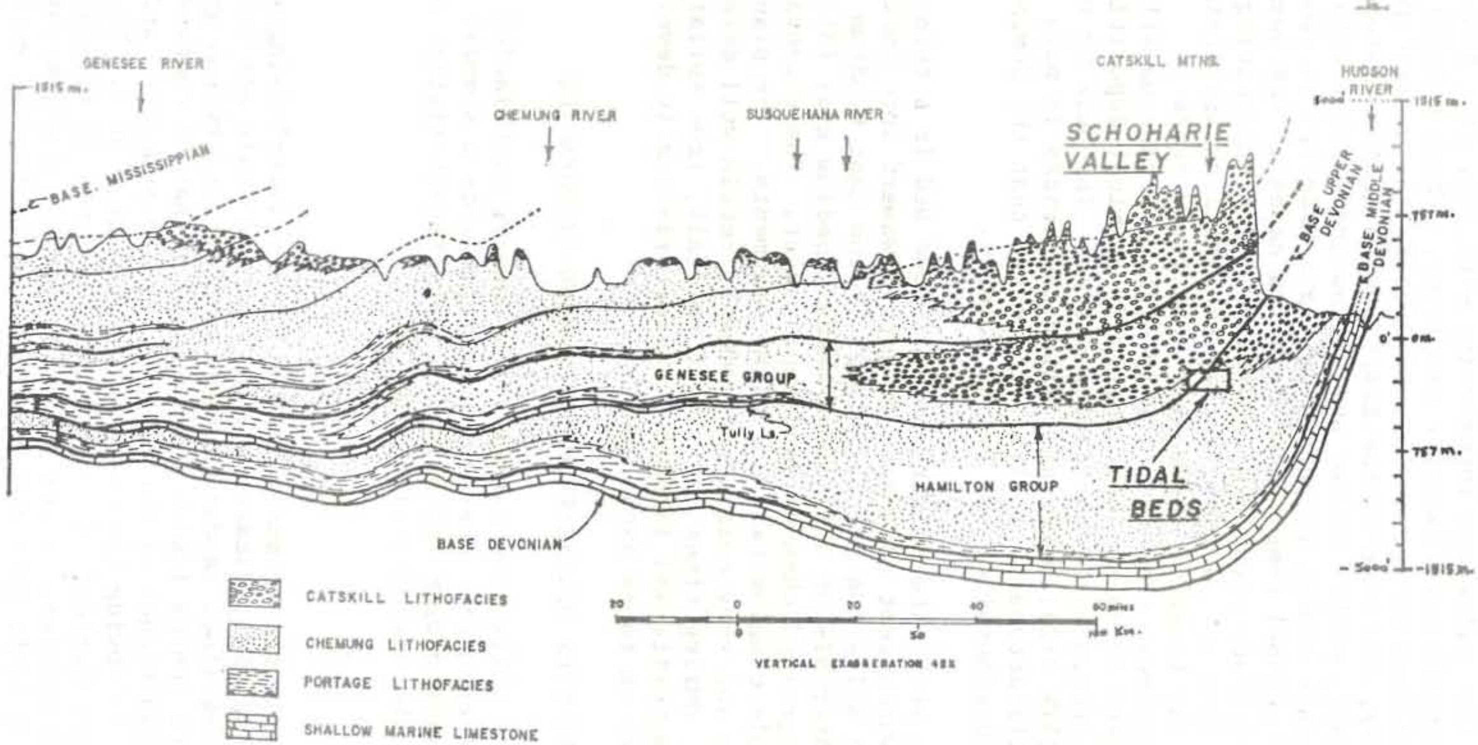


Figure 2 - Cross section of Devonian System along New York-Pennsylvania border (modified after Fig. 17, Broughton and others, 1962), showing geographic and stratigraphic location of Schoharie Valley tidal beds.

CHARACTERISTICS OF CATSKILL LITHOFACIES

Basal Upper Devonian rocks in the eastern part of the Catskill lithofacies consist for the most part of grayish red (5R 4/2) and grayish brown (5YR 3/2) siltstone interbedded with gray (N5) fine to medium-grained, texturally very immature sandstone. Green coloration in these fine-grained beds is not as extensive as in the western part of the lithosome. Near the base of the East Windham section (Stop 7) a large complex channel, mostly of red and yellow-green color with some dark gray highly organic zones, is present. Plant material is abundant in some parts of the channel complex and in a few cases it has been altered to a vitreous black bituminous substance. Two interesting features of the red beds are also present in the section some distance above the channel. The lower of these is a relatively dense bed of persistent thickness composed of very highly calcareous siltstone. The bed appears to be at least partly of chemical depositional origin and is shot through with dessication cracks. The bulk of the rock is pale brown (5YR 5/2); material filling the cracks is pale olive (10Y 6/2). X-ray diffractometer analysis indicates that the dominant constituent carbonate mineral of the bed is calcite.

About one meter above the calcareous siltstone bed is a thin gray (5G 6/1) zone from which root stigmaria project downward into underlying grayish red (5R 4/2) siltstone. Still higher in the East Windham section, numerous intervals of well cross-bedded, medium gray (N5 and N4), fine to medium-grained channel sandstones occur. These contain lenses of shale-pebble conglomerate and plant fragments. The plant fragments are coarse and very coarse and commonly retain well developed cellular structure. During times of slight rainfall, iron sulfate mineralization (melanterite and jarosite) characteristically develops on the organic lenses in these sandstones.

CHARACTERISTICS OF EASTERNMOST CHEMUNG LITHOFACIES

In the Schoharie Valley the Catskill and Chemung lithofacies are interbedded and well exposed. The following represents a summary of the lithologic, sedimentologic and paleontologic characteristics of the Chemung beds in the vicinity of Gilboa Dam.

Lithology

Lithologies within the Chemung lithofacies are interlensing medium gray (N4) to dark gray (N3), micaceous siltstone and shale and medium gray (N5), very fine-grained sandstone with subordinate, medium gray (N5 and N6) coquinite lenses (color terminology is that of Goddard, 1951). All of the sandstones of the lithofacies are submature and immature graywackes following the usage of Folk (1954, 1965). They contain sporadic accumulations of shale pebbles as well as moderately common, small pyrite nodules. A few polymictic pebble conglomerates containing pebbles of light gray and greenish gray quartzite, medium gray slate, red and olive siltstone, and subordinate medium gray limestone are present. Siltstones and shales of the lithofacies are dark gray in color due to a high content of fine organic material. They are very micaceous and variably thinly cross-laminated to occasionally fissile.

The coquinites, or in most examples more correctly coquinoid sandstones, occur as elongate lenses ranging from a few centimeters thick by 1 or 2 m long to 15 to 45 cm thick by lengths of up to some 15 meters. Thickness within a given lens is variable and they rest in channelled contact on underlying beds. Shell material in the lenses consists mostly of large spiriferid brachiopods, which in most fresh exposures are composed of calcium carbonate. Some of the lenses also contain pelecypod fragments as well as red siltstone pebbles. No preferred orientation of valves is apparent in the lenses, although some valves suggest imbrication.

Inorganic Sedimentary Structures

Bedding thickness of sandstones ranges from medium to thick and very thick (terminology after Ingram, 1954). Virtually all of the strata in the lithofacies, with the exception of the fissile shales, are cross-bedded or cross-laminated. Even the very thick-bedded sandstones, which in some cases appear homogeneous, are well cross-laminated. Interference, oscillation and current ripple marks are common. Interference ripple marks are expressed as a low-amplitude unevenness on bedding surfaces. The current and oscillation ripple marks, which have wave lengths of several centimeters and amplitudes of only 2 centimeters or less, provide reliable and plentiful evidence of sedimentary strike and direction of transport. Cross-bedding is of both planar and trough types and in most cases the inclination of foresets is well in excess of the 10 degree lower limit used by Pettijohn (1962) to denote high-angle cross-bedding.

Dessication cracks are well developed in the uppermost part of the Hamilton Group in the Schoharie Valley. Most of these occur as polygonal patterns of medium gray, very fine-grained sandstone infill on bedding surfaces of dark gray shaly siltstone. In one instance numerous sandstone infills extend some 15 cm perpendicular to bedding into a shale ledge.

Biogenic Structures

Biogenic structures in the Chemung lithofacies of the Gilboa Dam area are of three general types - (1) brachiopod and pelecypod body fossils, (2) ichnofossils and (3) fossil seed-ferns.

Brachiopods and pelecypods occur in both sandstones and shales as isolated specimens and as concentrations that appear to be allochthonous. Those found in allochthonous arrangements were considered, for purposes of this study, as biological sedimentary particles occurring in lithified sediment not necessarily that of their life environments. Ichnofossils in the Chemung lithofacies of the Schoharie Valley occur on bedding planes of sandstone as shallow, generally circular and ovoid depressions, which are slightly darker in color than the enclosing lithology. These occur in two sizes; those only about 1 cm in diameter, and those 2.5 cm or more in diameter. The smaller of the two extend downward perpendicular to bedding a distance of up to some 15 cm.

At one locality abundant vertical burrows are 30 cm in length. A few of the burrows have a Y or U pattern.

Fossil seed-fern stumps are present at three stratigraphic levels in the upper Hamilton beds near Gilboa Dam. Over two hundred stumps were taken from the lowest of these levels during quarrying operations just north of the dam (Goldring, 1924, 1927). They occur in light olive-gray (5 GY 6/1), tabular and trough cross-bedded, fine-grained sandstones some of which contain abundant vertical burrows up to 30 cm long. The beds are thick and very thick bedded, are in part slightly calcareous and, at certain levels, contain abundant casts of large spiriferid brachiopods.

ALLUVIAL DEPOSITIONAL SYNTHESIS

During late Middle and Late Devonian time, the Catskill Mountain region was occupied by a very extensive alluvial plain which was composed of sediment derived from a highland or highlands to the east. The general environmental significance of these strata was recognized during early investigations of the Catskill Mountain region and was summarized by Barrel (1913, 1914). The strata interpreted as representing alluvial deposition are all within the Catskill lithofacies.

As a result of intensive study during the last 30 years (Fisk, 1944, 1947, 1952; Allen, 1965a), present-day meandering stream deposits have been found to consist of relatively coarse-grained point bars, channel bars, and alluvial islands that are built in stream channels by lateral sedimentary processes, and of relatively finer-grained levee and flood-basin deposits that accumulate in interfluve areas by vertical sedimentary processes. Cut-off channels, channel fills, and crevasse-splay deposits accumulate by combinations of these two types of sedimentary processes. Subdivision of rocks of the alluvial facies incorporates recognition of the distinction between (1) the coarser, lateral accretion sediments of channel origin and (2) the finer, vertical accretion sediments of overbank origin.

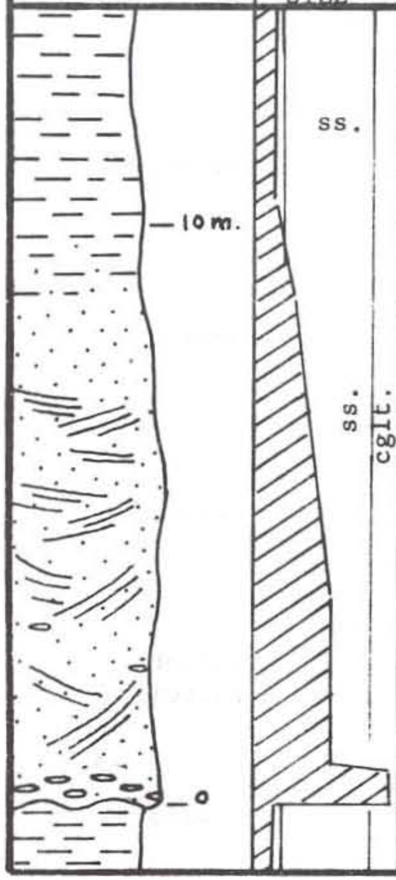
Alluvial Channel Facies

A summary of diagnostic characteristics of rocks of the channel facies is given in Table 1. None of the individual characteristics which are noted is inherently diagnostic; the value of each of them lying only in its being part of a set of characteristics which, in total, is unique to alluvial deposits.

In addition to the beds that will be seen along Route 23A between Palenville and Haines Falls, excellent examples of the channel facies are present in the East Windham section (Stop 7). Here the facies is represented by "multi-story" sandstone bodies that are inter-stratified with red beds of the overbank facies (Fig. 3). At the base, each body (channel) truncates overbank red beds, with the upper contact being one of gradation into red siltstone. This type of cyclic occurrence has been observed to occur commonly in rock sequences of alluvial origin

	Channel	Overbank
Lithology	Gray and greenish gray, fine to medium-grained, immature graywacke with abundant carbonaceous debris and green shale pebbles, especially in lower few feet of sandstone body.	Red and green, locally mottled siltstones, mudstones and shales with sporadic dark gray, locally bituminous lenses and very sparse thin, greenish tan, highly calcareous siltstone beds.
Texture	Variable; poorly sorted with abundant "fines" commonly becoming finer-grained upward in sandstone body.	Silt and clay grain-size with very small admixtures of very fine sand grains.
Sedimentary structures	Cross-bedding ubiquitous, commonly with decreasing foreset thickness and inclination upward in sandstone body. Parting lineation common. Current ripple marks locally well developed.	Very thin parallel laminations which generally are obscure on even slightly weathered outcrops; locally bedding is shaly. Local occurrence of mud-cracks.
Geometry	Truncates strata of underlying unit; upper contact gradational into overbank facies. Sandstone may interfinger with overbank facies or may be lenticular. Many bodies are laterally extensive	Occurs interbedded with channel sandstones. Basal contact with sandstone gradational; upper contact a sharp channelled disconformity. Interfingers with channel facies.
Associations	Sandstone bodies of facies occur as cyclic, "multistory" interbeds in red and green and locally dark gray and black, highly organic siltstones and shales of overbank and marsh facies.	See Geometry. Green coloration occurs in red siltstones and mudstones as mottles, lenses and very thin, persistent layers.
Miscellaneous	Outcrop surfaces commonly iron-stained. Iron sulfates frequently occur on organic, pyrite-rich lenses. Only fossils are plant material, sparse freshwater bivalves and fish plates.	Only fossils are plant material. Locally burrows, green burrow mottling and yellow-green, very slightly calcareous plant stigmaria are abundant.

TABLE 1. Summary of diagnostic characteristics of alluvial channel and overbank facies.



COLOR		LITHOLOGY	STRUCTURES	SEDIMENTARY PROCESS	ENVIRONMENT	
5R 4/2 with 10Y 6/2 mottles 5R 4/2	RED	Micaceous silty mudstone and shale; locally very calcareous Micaceous siltstone	Local burrows, plant stigmaria and mud-cracks Horizontal lamination to massive	Vertical sedimentation	Flood basin Levee	OVERBANK
N5 N4	GRAY	Immature graywacke shale pebble conglomerate	Parting lineation	Upper Flow Regime	Point bar Lag concentrate	CHANNEL
			Trough and Tabular cross-bedding: Low angle High angle	Lateral sedimentation: Low intensity Lower Flow Regime High intensity Lower Flow Regime		
5R 4/2		micaceous silty mudst.& sh.	Truncation		OVERBANK	

Figure 3. Alluvial Cycle - Physical characteristics, hydrodynamic zones and environments.

(Bersier, 1959; Allen, 1962, 1964, 1965b; Beerbower, 1964), and Allen has referred to such alluvial successions as "fining-upwards cycles".

Near the base of the East Windham section, a large asymmetric compound channel is well exposed. The compound channel consists of a lower channel sandstone, which truncates overbank siltstone, and an upper channel sandstone, which truncates both the lower sandstone body and laterally adjacent overbank siltstone. A shale-pebble conglomerate in the base of cross-bedded point bar sandstone marks the trough of the oldest (lower) channel element. The bar sandstone can be traced laterally toward the slip-off slope of the channel where it truncates dark, highly organic pyritic lenses of the marsh facies. These lenses contain very abundant, very coarse plant fragments. On the opposite (cut-bank) side of the channel an interval of some 4.5 m of red overbank siltstone is truncated.

In the sandstone bodies higher in the section, foreset thicknesses and inclinations are greater than in the compound channel described in the preceding paragraph, and grain size is fine to medium. Basal shale-pebble conglomerates are very common, as are highly organic, pyrite-rich lenses that during dry periods are commonly encrusted with iron sulfate mineralization. Shale-pebble, or clay gall, accumulations are also scattered through the point bar cross-beds. These have been observed in modern environments to result from (1) undercutting of mudflats on channel-margin point bars and (2) dessication of the surface of mud flats into subangular, flat, disc-shaped plates that were later carried downstream more or less intact and deposited with sand (G. D. Williams, 1966). Although clay galls have been observed to develop in modern marine environments (Trefethan and Dow, 1960), the presence of abundant shale-pebble conglomerate in sandstone is highly suggestive of fluvial deposition. A "fining-upwards" is noted in virtually all of these sandstone bodies and parting lineation was found to be common in the upper, more shallowly cross-bedded portion of the units.

Alluvial Overbank Facies

A summary of diagnostic characteristics of those alluvial rocks of overbank origin is given in Table 1. Rocks of this facies are well exposed at East Windham (Stop 7) and just north of Grand Gorge (Stop 5).

In addition to their very fine grain-size and very thin horizontal bedding, the most striking characteristic of rocks inferred to be of overbank origin is their red and green color. At Stops 5 and 7 the predominant color of the facies is red, with local development of green coloration occurring as thin beds, mottles, and lenses. In places, thin dark gray or black, highly organic zones of limited lateral extent were noted. Just east of the Schoharie Reservoir, green coloration is much more common and is present in some 50 percent of the overbank facies.

The origin and environmental significance of red beds is controversial and has been variously ascribed to (1) color of soil in the source terrain (Krynine, 1949), (2) in place oxidation of iron-bearing minerals in a hot arid climate (Walker, 1967), and (3) variation in oxidation-reduction values at the site of deposition with resultant development of zones in which constituent iron oxides are either in an oxidized (red) or reduced (green or gray) state.

Van Houten (1964) has emphasized that there is no simple explanation for red beds. He points out that they are fundamentally a sandstone, siltstone, or mudstone composed of detrital grains set in a reddish-brown mud matrix or cemented by precipitated reddish-brown ferric oxide, and that there are two basic red bed types: (1) first cycle and (2) second cycle. First cycle red beds are derived from source material weathered deeply enough to supply free ferric oxide, either in chemical solution or colloidal suspension, to the side of deposition. Second cycle red beds are colored by pigment and grains inherited from a pre-existing red deposit.

Friend (1966) who studied the clay fractions and colors of alluvial cyclothems of the Catskill front, which represent the inland flood plain rocks that are generally correlative with the alluvial plain rocks of the present study area, concluded that:

(1) The essential difference between the red overbank rocks and the associated non-red fluvial sandstones is the presence in the red beds of fine-grained hematite that occurs as coatings on silt grains.

(2) The redness developed in place by oxidation of a pre-existing iron oxide, and did not result directly from the presence of red soils in a lateritic source area.

(3) The red/non-red differentiation occurred in the sedimentary environment, as a result of differences in oxidation-reduction potential determined by the position of the ground-water table.

On the basis of the characteristics of rocks in the study area assigned to the overbank facies and the observations of Friend in the generally correlative rocks farther east, it is clear that the beds evolved as interfluve vertical accretion deposits during stream high-water stages. In the areas between channels, oxidizing conditions prevailed in those places where the water table lay some distance below ground level. Here it was possible for any hematite in the sediment to remain in the oxidized state and for any constituent pre-existing iron oxide to be altered to hematite. Plant material included in the sediment was destroyed by oxidation. Where drying at certain times of the year was excessive, desiccation cracks developed, and in local, shallow pans extremely thin accumulations of "evaporites" evolved. In other parts of the interfluve, where the ground water table intersected the surface, reduction of organic material resulted in green or, where organic content was very high, in dark gray or black coloration of the sediment. The westward increase of green coloration within the overbank facies appears to be mainly an expression of environmental change from predominantly oxidizing (well drained) to reducing (poorly drained) conditions.

TIDAL DEPOSITIONAL SYNTHESIS

Although it has long been known that the interbedded Catskill and Chemung lithofacies in the Schoharie Valley are a record of medial and late Devonian shoreline oscillation at the margin of the Catskill deltaic system, it has not been noted that some of the Chemung lithofacies units have characteristics that quite clearly indicate tidal-flat and tidal-channel depositional processes.

Modern tidal sediments accumulate along the margins of protected coastal water bodies such as lagoons, estuaries and bays, and are for the most part alternately submerged and subaerially exposed. They may be subdivided into (1) tidal flats and (2) tidal channels. Most modern tidal-flat sediments consist of material of silt and mud grade-size which is deposited by vertical sedimentary processes, and of somewhat coarser sediment which is deposited by lateral sedimentary processes in channels or creeks that cut across the tidal flats. The lower part of the channel deposits is not necessarily completely exposted during low-tide stage.

In Recent environments, two general types of tidal-flat sedimentation have been recognized (Klein and Sanders, 1964; Klein, 1967): (1) Wadden-type tidal flats and (2) Fundy-type tidal flats. The type area of the first of these is in the Wadden Sea, a part of the Rhine-Ems-Scheldt delta system of northwestern Europe. Van Straaten (1954) subdivided the intertidal sediments of the Wadden Sea into salt marshes, high tidal flats, low tidal flats and tidal channels. Fundy-type tidal flats, which have been studied by Klein (1963, 1964) in the intertidal zone of the Bay of Fundy, have a more complicated association of sediments, attributed to large coastal relief, bedrock cliffs and large tidal ranges. The dominant environment is a wave-cut bench on which a thin veneer of locally derived sediment is being reworked by waves and rising and falling water.

Although modern tidal deposition has been intensively studied in areas of both clastic and carbonate sedimentation, studies of rocks of tidal origin in the geologic record have been for the most part of carbonate sequences (Klein, 1965; Matter, 1967; Braun and Friedman, 1968; LaPorte, 1967, and others). Detailed descriptions of clastic tidal rocks are not well represented in the literature. However, beginning in the last decade a number of papers marked an initiation of considerable interest in ancient clastic tidal sediments.

Tidal Flat Facies

Van Straaten (1950, 1954) subdivided the Wadden Sea tidal flats into (1) a lower seaward part, where meandering tidal creeks cut across and into mud and muddy sand deposits, and (2) a higher landward part composed dominantly of sand. Well-developed incised tidal channels are not present in the high tidal flats and structures in the sediment are lacking due to bioturbation by enormous numbers of sand and mud-dwelling worms and crustaceans. In the lower tidal flats, where sedimentation proceeds at a faster rate, destruction of sedimentary features by organisms is not nearly as complete and fine cross-lamination and flaser bedding is preserved. The origin of interlaminations of sand cross-laminae and mud (flaser bedding) in the Recent tidal flats of the German Bay in the southeastern part of the North Sea has been attributed by Reineck (1967) to alternating current activity and slack water conditions. The lenticular interstratification of mud and very fine sand described by Reineck and Van Straaten appears to be the modern counterpart of the lithological and sedimentological features of those rocks of the Schoharie Valley assigned to the tidal flat facies. These rocks consist of medium dark gray (N4), cross-laminated, muddy siltstone that in most cases contains subordinate medium gray (N5), very fine-grained sandstone. Flaser bedding is commonly well developed, oscillation ripple marks are locally present, plant fragments are abundant, very faint, fine vertical burrows are common, and brachiopods occur sporadically throughout and in lenses. The lenses contain admixtures of pebbles and coarse plant material. In most places the tidal-flat rocks are truncated by over-lying tidal-channel sandstones (Fig. 4). The very close association of these rocks with sandstones of inferred tidal-channel origin indicate that they are of lower tidal-flat derivation. Characteristics of the tidal-flat rocks that are considered diagnostic for recognition of depositional environment are listed in Table 2.

Tidal Channel Facies

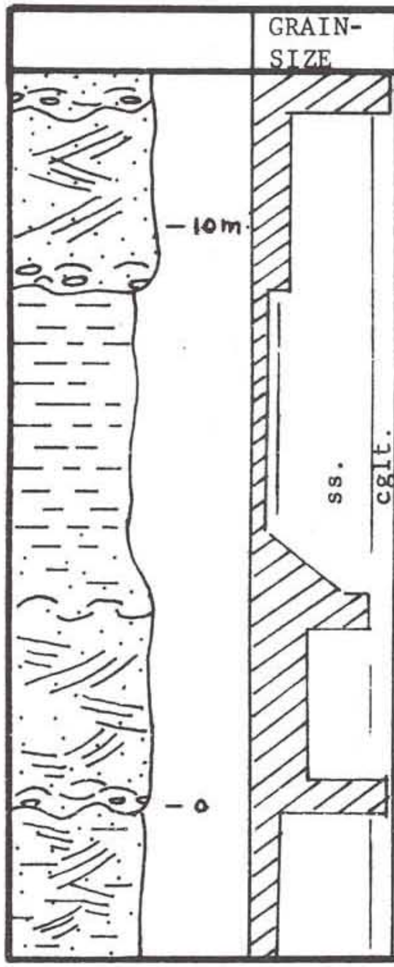
The sedimentary processes operative in modern sinuous tidal channels (Oomkens and Terwindt, 1960) are essentially the same as those found in meandering alluvial channels. In both types erosion cuts back outer (concave) meander banks and sediment is carried downstream and deposited in slack water along the inner (convex) banks of meanders. By this combination of erosion and sedimentation, cross-bedded channel deposits are built laterally and vertically. In the closing stages of channel filling, as flow slackens, parallel laminae of fine sediment are deposited. Thus, virtually all of the sedimentary structures of rocks of alluvial channel origin are found in rocks of tidal-channel derivation.

There would be, of course, a general tendency for Wadden-type channel sandstones to be somewhat finer than equivalent alluvial channel sandstones, and in at least one modern example (Terwindt and others, 1963, Fig. 7) a distinct difference in grain-size has been noted between tidally influenced estuarine sands and adjacent much coarser fluvial sands. This distinction, however, might not be immediately apparent in the geologic record.

Two important characteristics of the tidal type of channel sand body that permit recognition of the facies in the geologic column are (1) close association with strata of marine origin and (2) the unique character of the basal channel lag concentrate. The basal lag concentrates of the Schoharie Valley tidal channel facies consist of a polymictic pebble assemblage and abundant large spiriferid brachiopod valves of subtidal derivation. This type of allochthonous organic sedimentary accumulation has been noted in modern tidal flats and channels of the Wadden Sea, Easter Scheldt (Netherlands), and Bay of Arcachon (France), where the shells are typical open-sea species that are washed into the tidal-flat areas by flood tides (Van Straaten, 1956).

	FLAT	CHANNEL
Lithology	Medium dark gray (N4) finely micaceous, mudy sltst and very subordinate medium gray (N5) very fine-grained ss.	Medium gray (N5) fine-grained immature graywacke containing abundant plant material; coquinoid ss and coquinite with spiriferid brachiopods; polymictic cglt with pebbles of gray, light green, and olive sltst, greenish gray qtzt and red sltst and sh.
Texture	Very fine to fine grade sizes.	Grain-size decreases upward in rock unit from cglt lenses in base to very fine-grained ss at top. Sorting is generally poor.
Sedimentary structures	Featureless to very fine cross-laminated (flaser and ripple bedding). Local well developed polygonal mud-cracks and oscillation ripple marks.	Tabular and trough cross-bedding ubiquitous in basal part of ss, grading upward to generally horizontal bedding at top. Parting lineation common in upper part of body.
Geometry	Basal contact gradational from ss of inferred tidal or nearshore bar origin. Upper contact disconformable with overlying tidal channel ss or nearshore bar ss.	Basal contact truncates strata of underlying inferred tidal flat facies. Upper contact gradational into fine-grained rocks of tidal flat or other facies. In cross section may be lenticular or interfinger with tidal flat facies. In modern environments long axis of sand body generally perpendicular to shoreline.
Associations	Interbedded with ss of inferred nearshore bar and tidal channel origin.	Ss bodies occur as channel deposits in tidal flat facies. Basal lag concentrate is commonly coquinite or coquinoid ss.
Miscellaneous	Contains abundant plant material common allochthonous brachiopods and bases of in situ fossil seed-ferns.	Sedimentary structures same as that of alluvial channel facies. Ss contain local large burrow structures, allochthonous marine fossils and trunks of fossil seed-ferns.

TABLE 2. Summary of diagnostic characteristics of tidal flat and channel facies.



COLOR		LITHOLOGY	STRUCTURES		SEDIMENTARY PROCESS		ENVIRONMENT	
5Y 6/1		coq.pebble cglt.	Truncation	Cross-bedded	High intensity Lower Flow Regime	Lat. Sed.	Lag deposit	CHANNEL
N4	Gray	Immature graywacke	High angle-					
		coq.pebble cglt.	Truncation				Lag deposit	
5Y 4/1	Olive gray	Micaceous siltstone	Flaser bedding			Vertical Sedimentation		FLAT
N5	Gray	coquinoid ss	Current ripple marks & sparse burrows	Cross-bedded	High intensity Lower Flow Regime	Lateral Sedimentation	Lag deposit	CHANNEL
		Immature graywacke						
		coq.pebble cglt.	Low angle- Truncation				Lag deposit	
N5		Silty sandstone			Low intensity Lower Flow Regime			

Figure 4. <u>Tidal Cycle</u> - Physical characteristics, hydrodynamic zones and environments.

The best examples of the tidal-channel facies in the Gilboa Dam area consist of medium gray (N4) and olive gray (5Y6/1), tabular and trough cross-bedded, fine to medium-grained, immature graywacke. The sandstone bodies truncate medium gray, shaly siltstone of the tidal-flat facies and contain well-developed basal lag accumulations, most of which are very rich in large spiriferid brachiopods. In several places vertical burrow structures are present in the uppermost part of cross-bedded sandstone ledges. The tidal channel sandstone bodies occur in cyclic association with the tidal flat facies, in some instances as "fining-upwards cycles" (Fig. 4). Characteristics of the tidal channel rocks that are considered diagnostic for recognition of depositional environment are listed in Table 2.

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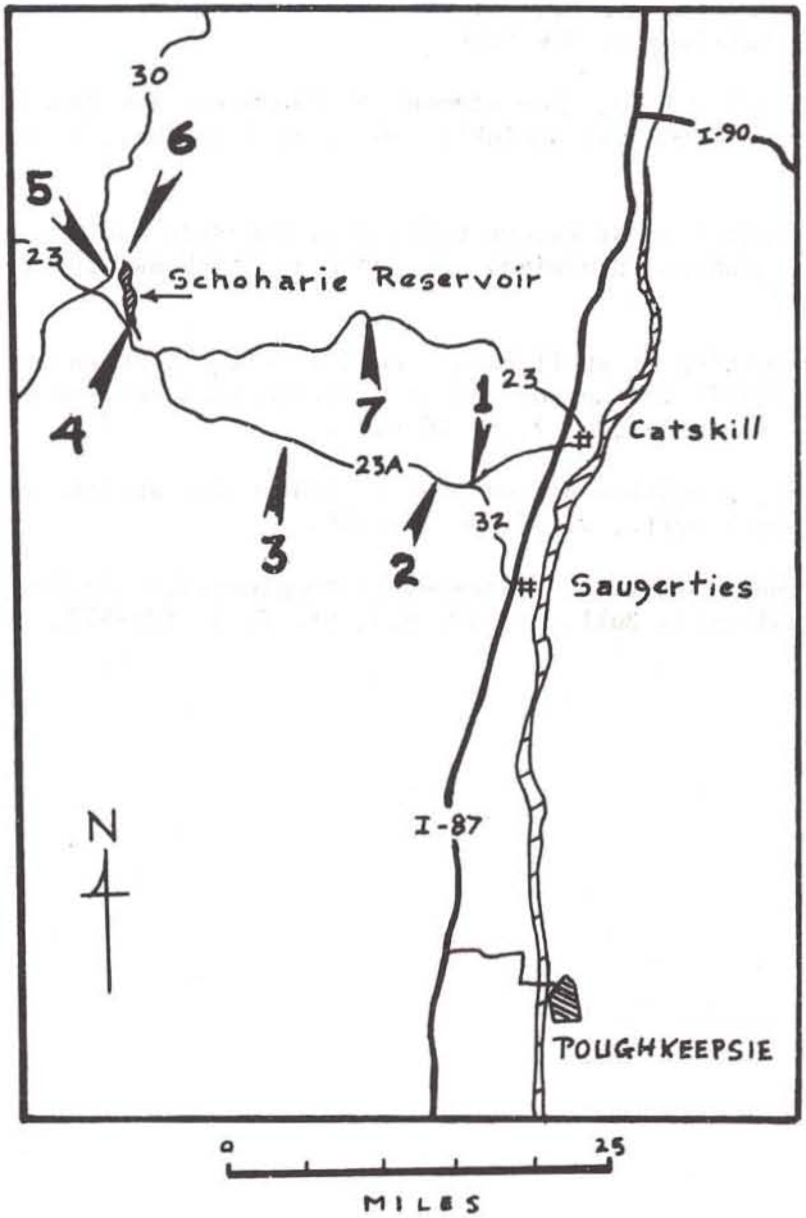


Figure 5. Field trip stop locations.

TRIP B-8

ALLUVIAL AND TIDAL FACIES

OF THE

CATSKILL DELTAIC SYSTEM

ROAD LOG

For purposes of this trip, the intersection of Routes I-87 and 32 at Saugerties are considered the mileage zero-point.

Mileage

0 LEAVE New York State Thruway (I-87) and proceed north on New York Route 32.

0.6 ON LEFT - colonial house, construction material Lower Devonian limestone.

Cherty Onondaga Limestone exposures.

2.2 Deep roadcut in Onondaga cherty, fossiliferous limestone. AHEAD-view of Catskill Front. The Front marks the eastern margin of the Catskill Mountains. It is cut by several narrow stream valleys (cloves) in which there are excellent exposures of Middle and Upper Devonian Catskill lithofacies. We will climb Kaaterskill Clove and observe rocks along the Rip Van Winkle Trail (Route 23A).

3.8 Roadcut in cross-bedded, blue-gray sandstone. Local term for this rock type is Bluestone.

5.1 ON LEFT - Old, inactive quarries in Bluestone.

5.5 ON LEFT - In distance, view of Kaaterskill Clove.

6.4 ROAD FORKS - Bear left on Route 32A.

7.4 Enter PALENVILLE.

7.9 Cross small creek. Rapids and low waterfalls in bed of creek due to well developed, horizontally bedded Bluestone ledges.

8.3 JUNCTION of Routes 32A and 23A (Rip Van Winkle Trail). Proceed west on Route 23A.

8.6 ON LEFT - Gloria Dei Church (Episcopal) STOP 1
This church, constructed in the late 19th Century, was built of fieldstone, most of which is of local bedrock lithologies. The most significant of these are (1) polymictic pebble conglomerate, (2) grayish green, immature, medium-grained, sandstone, and (3)

(3) dark red, very fine grained sandstone and siltstone. In some respects this is as good an outcrop as any that you will see today.

PROCEED west on Route 23A.

9.3 Cross Kaaters Kill and begin climbing clove. Just downstream from this bridge are very well developed pot holes and water falls, where the stream flows over Bluestone ledges.

9.4 Enter Catskill State Park.

9.6 ON RIGHT, across Kaaters Kill - interbeds of red and green Catskill lithofacies.

11.7 ON LEFT, up clove - Twilight Park, a private preserve that was very fashionable in the late 19th and early 20th Centuries. It is still private, but less fashionable. The preserve is the type locality of the Twilight Park Conglomerate, the coarsest of the Catskill lithofacies rocks. The conglomerate appears to represent an ancient mountain front, braided stream deposit. You will see it in outcrop at Stop 3.

11.8 Road swings sharply left. Cascade on right formed where tributary of Kaaters Kill flows over sandstone ledges.

12.0 ON LEFT - Forest Preserve Access Parking Area. STOP 2. From this point it is possible to look east down Kaaterskill Clove. The cross-sectional profile is typical of high-gradient streams that are engaged in active vertical erosion. The Kaaters Kill is considered to be an excellent example of a short, high gradient stream that has managed to capture the headwaters of a longer lower-gradient stream flowing in an opposite direction. The elbow of capture is at Haines Falls, just west of this observation point.

CONTINUE UP CLOVE on Rt. 23A.

13.0 Enter HAINES FALLS

13.2 ON RIGHT - Green County Route 18 leading to North Lake Campsite, former site of Catskill Mountain House. The Mountain House, a resort hotel, was situated near the top of the Catskill Front, some 700 meters above the Hudson River. Exposures of cross-bedded, gray, conglomeratic sandstone and conglomerate may be seen on the trails around North Lake Campsite.

CONTINUE WEST ON Rt. 23A.

14.8 Enter TANNERSVILLE.

AHEAD - Hunter Mountain ski area.

18.9 Enter HUNTER

20.9 JUNCTION Rts. 23A and 296. STOP 3. Outcrop of cobble conglomerate at base of one of Catskill lithofacies alluvial channels. This basal lag concentrate was apparently deposited quite near its source area. It is by far the coarsest exposure that you will see today.

PROCEED WEST ON Rt. 23A.

22.2 Enter SOUTH JEWETT

23.5 JEWETT CENTER

33.5 ON RIGHT - Catskill lithofacies.

34.5 ON RIGHT - Catskill red beds.

35.1 JUNCTION Rts. 23A and 23.
PROCEED west on Rt. 23.

35.7 Pratt Rock Park on outskirts of PRATTSVILLE.

36.6 Cross Schoharie Creek. Leave Prattsville.

36.8 Enter Delaware County.

38.3 ON LEFT - Small power substation. PARK HERE. STOP 4. Walk northeast along unsurfaced side road to Hardenburg Falls. At this point Bear Kill flows into Schoharie Reservoir. Beds here are assigned to the tidal channel and tidal flat facies. The tidal channel facies is represented by gray, cross-bedded, fossiliferous sandstones and the tidal flat facies by very dark gray, very thin-bedded, in part conglomeratic, shales. Lag-concentrates in both facies are rich in shallow marine brachiopod shells.

PROCEED west on Route 23 to Grand Gorge.

41.4 Junction of Rts. 23 and 30 in Grand Gorge. TURN RIGHT AND PROCEED NORTH ON ROUTE 30.

42.4 Enter Schoharie County.

42.9 Top of long hill. PARK ON LEFT. STOP 5A. On east side of road, exposure of alluvial channel sandstone resting on red overbank shale.

PROCEED DOWN HILL.

43.6 PARK ON RIGHT. STOP 5B. On east side of road, exposure of gray, cross-bedded sandstone of tidal channel facies with lag-concentrates of shallow marine spiriferid brachiopods. BE VERY CAREFUL. THIS IS A NARROW SPEEDWAY WITH POOR VISIBILITY.

CONTINUE NORTH ON RT. 30.

43.9 On right, in distance - large quarry from which much of stone for Gilboa Dam was taken. Completion of dam impounded waters of Schoharie Creek, forming Schoharie Reservoir, a part of New York City water supply system.

44.5 Turn right on road to Gilboa.

44.9 View north down Schoharie Valley. Note even crest of hills flanking valley, a result of stream dissection of nearly horizontal Devonian strata.

45.7 Gilboa Bridge across Schoharie Creek. PARK on right at west end of bridge.

STOP 6 - Display of seed-fern stumps taken from quarry just to southwest. Some 200 specimens were found during the quarrying operation. These seed-ferns are thought to have grown to heights of some 18 meters in swamps along the seaward margin of the Catskill alluvial plain during late Medial Devonian time. They were buried during a minor oscillation of the marine shoreline in tidal channel or bar sand deposits.

RETURN TO JUNCTION OF RTS. 23 and 23A VIA GRAND GORGE and PRATTSVILLE.

56.8 Junction of Rts. 23 and 23A. PROCEED EAST ON RT. 23, following Batavia Kill Valley.

58.4 ON RIGHT - Red Falls.

61.1 Enter ASHLAND.

66.1 Enter WINDHAM.

69.4 Enter CATSKILL PARK.

69.9 ON RIGHT - alluvial channel sandstone on overbank shale. Note irregular erosion surface at base of sandstone ledge.

71.9 ON LEFT - Catskill lithofacies, mostly red.

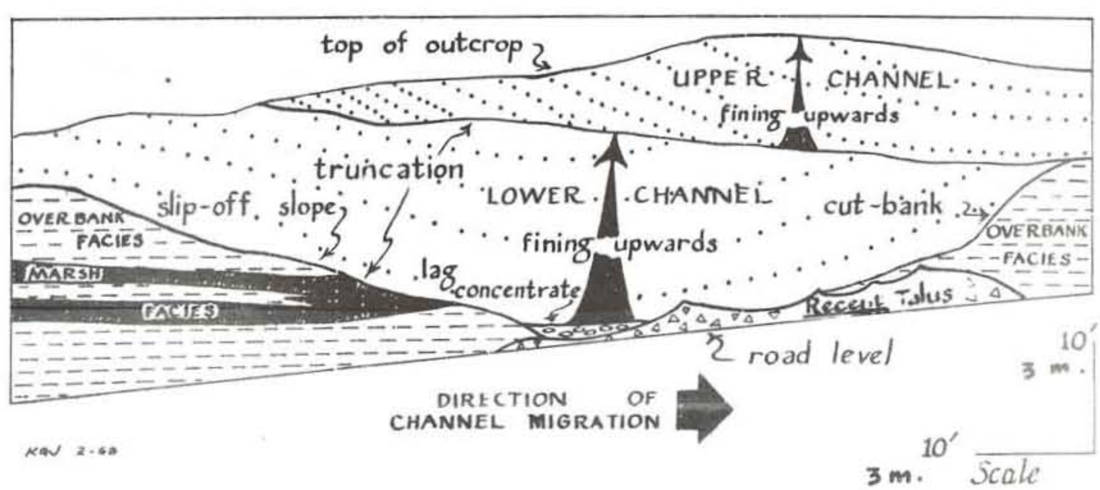
72.6 PARK ON RIGHT SHOULDER, STOP 7A. These alluvial channel sandstones mark the top of an excellent section of some 185 meters, consisting almost entirely of rocks of alluvial origin. Many of these sandstone ledges show an interesting upward progression of change in texture and sedimentary structures.

CONTINUE EAST ON RT. 23. On right - East Windham Post Office. To left (north), in distance, dip slopes of Hamilton Group strata.

74.0 ON RIGHT - high on outcrop - tan sandstone, much lighter in color than sandstone in remainder of exposure, assigned to tidal channel facies.

74.2 Mobil gas station on right.

74.5 Driveway on right. PARK ON RIGHT SHOULDER. STOP 7B. At the driveway are alluvial overbank facies root stigmaria and a highly calcareous overbank "evaporite" bed. A short distance downhill is a compound alluvial channel and laterally equivalent overbank siltstones.



PROCEED EAST ON RT. 23 TOWARDS LEEDS AND NEW YORK STATE THRUWAY (I-87).

82.4 JUNCTION Rts. 23 and 32. CONTINUE EAST On Rt. 23.

82.7 Beginning of series of roadcuts in Catskill lithofacies channel and overbank rocks.

88.9 TURN LEFT on Cauterskill Road.

89.2 TURN RIGHT on Green County Route 23B and cross limestone bridge into village of LEEDS.

90.5 TURN LEFT to NEW YORK STATE THRUWAY toll booths. PROCEED SOUTH on Thruway.

99.0 Thruway Interchange 20 at Saugerties (zero-point for this field trip).

End Road Log