New York State Geological Association 67th Annual meeting & Eastern Section of the American Association of Petroleum Geologists 26th Annual meeting, Union College, Schenectady, NY, October 13-15, 1995

Field Trip A4: October 14th

Lithofacies & Structure Of The Taconic Flysch, Melange, & Allochthon In The New York Capital District

W.S.F. Kidd, A. Plesch, and F.W. Vollmer

This trip will cover the full width of the deformed belt of Medial Ordovician flysch that outcrops adjacent to the Taconic Allochthon. It will include examination of the flatlying flysch bordering the western side of the deformed belt, and of the western part of the Taconic Allochthon, which confines the eastern margin of the deformed flysch belt. Locally, excellent exposures show the structural transition from the undeformed to the folded and thrust flysch, and the further deformation to melange associated with shearing on thrust fault zones. The large-scale domainal structure of the deformed flysch belt, with intercalated belts affected by greater (melange) and lesser (folding) deformation, and by some of the melange containing 'exotic" clasts, will be illustrated by several stops, including Cohoes Gorge along the Mohawk River. One of the very few exposures of the fault that places the western edge of the Taconic Allochthon against melange will also be visited. The trip aims to demonstrate a structure of the deformed flysch belt of the Hudson Valley dominated by faults, including a significant contribution from out-of-sequence imbrication of older faults, and with most of the flysch and melange being very considerably allochthonous. This picture is similar to that established for the same belt of rocks in southern Quebec, but differs fundamentally from the interpretation shown on recent published geological maps of the Hudson Valley.

W.S.F. Kidd, A. Plesch, and F.W. Vollmer, 1995. Lithofacies and Structure of the Taconic Flysch, Melange, and Allochthon, in the New York Capital District. pp. 57-80 in Garver, J.I. and Smith, J.A. (eds), Field Trip Guide for the 67th Annual Meeting of the New York State Geological Association, Union College, Schenectady, N.Y.

Note: This pdf version is reconstructed from source materials; the pagination and format does not match the original publication. One factual error has been noted and a statement inserted in this version to correct it; this correction is not in the published document. Otherwise, the text and figures are the same content as in the original.

From:
Field Trip Guidebook for the 67th Annual Meeting of the New York State Geological Association
Edited by John I. Garver and Jacqueline A. Smith
For the combined meeting of the 67th Annual meeting of the New York State Geological Association & 26th Annual meeting of Eastern Section of the American Association of Petroleum Geologists, October 13-15, 1995
Sponsored by New York State Geological Survey/State Museum and Union College
Hosted by Geology Department, Union College, Schenectady, NY

Lithofacies and structure of the Taconic Flysch, Melange, and Allochthon, in the New York Capital District

William S.F. Kidd[1], Andreas Plesch[1], and Frederick W. Vollmer[2]
[1]Dept of Geological Sciences, University at Albany, Albany, NY, 12222
[2]Dept of Geological Sciences, SUNY College at New Paltz, New Paltz, NY, 12561

Introduction

The Taconic Allochthon of eastern New York is bordered to the west by a zone of mid-Ordovician shale and greywacke turbidites, which are appropriately characterised by the term “flysch”. These synorogenic deep-water clastics are now interpreted to represent the fill of the migrating flexural basin created by the advance of the Taconic thrust sheets onto the Cambro-Ordovician passive margin of easten North America (Rowley and Kidd, 1981; Bradley and Kusky, 1986). The flysch is markedly diachronous, with a thick basal carbonaceous shale unit, the Utica Shale, and extends many hundreds of kilometres west of the present margin of the Taconic Allochthon. The Allochthon consists almost exclusively of sedimentary rocks that represent a sample of the continental rise part of the Cambro-Ordovician passive margin, and of the latest Precambrian-earliest Cambrian clastics of the late-stage rift fill, and rift to passive margin transition; all are strongly folded and have been transported westward on a complex system of thrusts at least 150 to 200 km relative to the North American craton (Bradley, 1989). In the New York Capital District, a zone about 16-20 kilometers wide of the Ordovician flysch adjoining the western margin of the Allochthon has also undergone strong deformation, including widespread conversion of once stratified rocks to melange, associated with the later stages of the Taconic Orogeny. It is the purpose of this guide and field trip to examine these rocks, to attempt to illuminate the structures which they contain, to try to roll back at least some of the nomenclatural and stratigraphic confusion they have suffered, and to place them in the larger regional context of the Champlain Thrust system.

General geological setting of the field trip

Before confusing readers and trip attendees with the “stratigraphic” terminology, we set out the distribution of basic rock types and their structural condition (refer to Figures 1 and 2, the geological maps). West from a NNE-trending line through a point on the Mohawk River in Niskayuna, just east of Schenectady, regionally flat-lying [very gently-dipping] Paleozoic strata are exposed, which consist, in the immediate area of the field trip, of the medial Ordovician flysch, that is greywackes and shales, in varying proportions. East of this boundary, the western limit of Taconic deformation, deformed medial Ordovician rocks occur in a zone 16-20 kilometers wide, bounded to the east by the [also] NNE-trending western border fault of the Taconic Allochthon, the Taconic Frontal Thrust. The deformed rocks of this zone dominantly consist of highly disrupted shales and greywackes, and these are appropriately termed shale-matrix melange. The western side of the deformed zone consists of a belt about 5-6 kilometers wide of folded and internally faulted rocks that are still largely bedded (we term this the Vischer Ferry Zone), and which can be interpreted as expressing a zone of increasing strain transitional from the undeformed flat-lying strata in the west to the highly-strained, disrupted melange in the east. Within the melange, there are lens-shaped belts of less-deformed material, both of shale-dominated, and of greywacke-dominated protolith, and ranging in structural condition from merely folded, to "broken formation", transitional to melange. These less-deformed lenses range up in size to regionally mappable; the most prominent in the area of the field trip is the bedded greywacke and shale of the Halfmoon Greywacke Zone (see Figures 1 and 2). South of the Capital District, along the Hudson valley as far as Kingston, most of the exposed width of the flysch and melange belt is occupied by two of these bedded belts, with a narrow melange belt separating them, and another bordering the eastern side (Figure 1). The change of structural style, from melange-dominated in the north, to "fold/thrust"-dominated to the south, was probably controlled by the change from shale-rich to greywacke-rich strata, which in turn must have been a product of sediment supply and local basin geometry.

Previous work

Detailed and systematic studies of the medial Ordovician rocks of the Hudson River Valley are contained in Ruedemann’s reports of mapping and stratigraphic and structural studies, *Geology of Saratoga Springs and vicinity* (Cushing and Ruedemann, 1914) and *Geology of the Capital District* (Ruedemann, 1930), which even now include the most detailed published maps of this area.

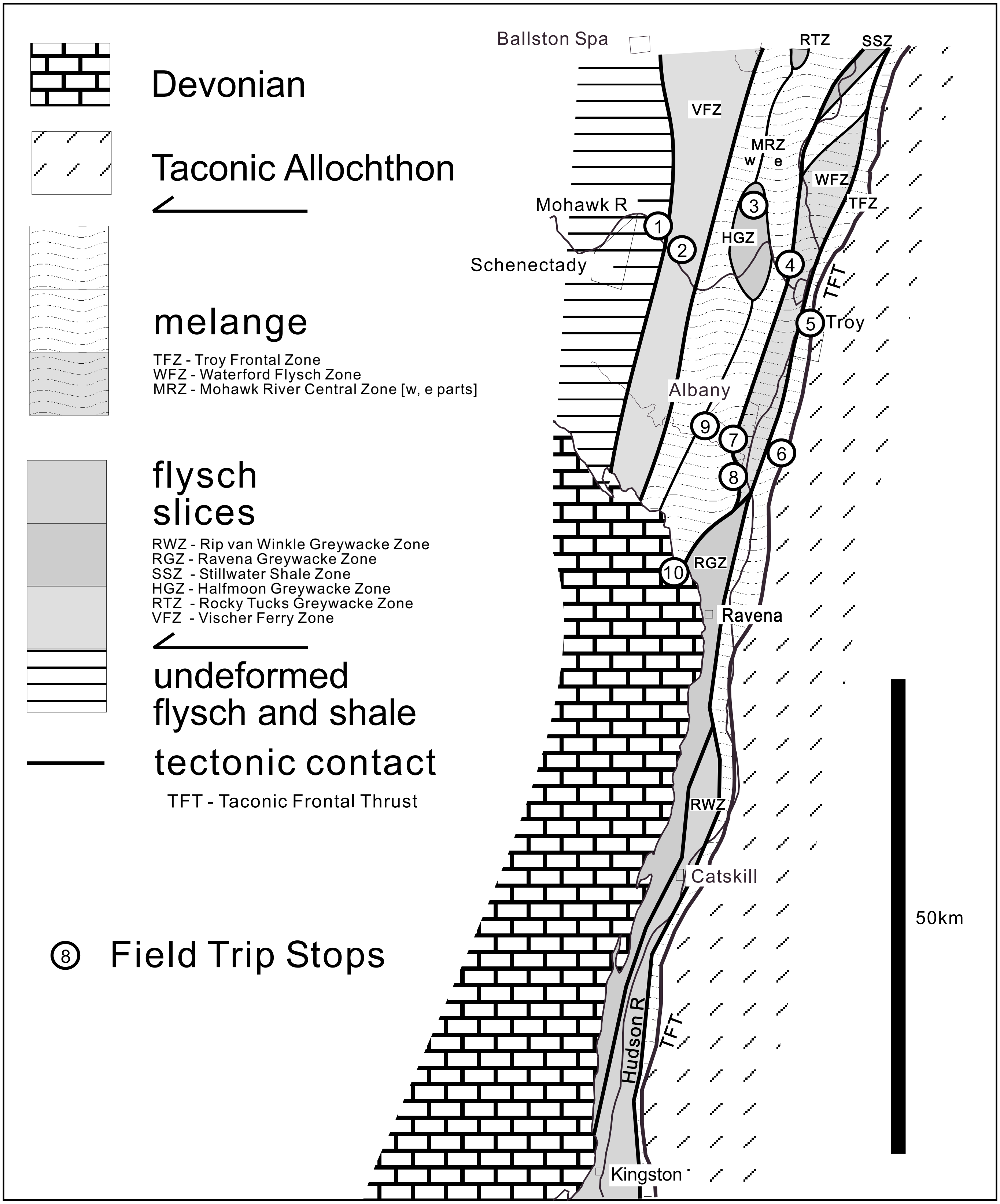


Fig 1. Tectonic units in the Saratoga Lake - Capital District - Kingston segment of the central Hudson Valley

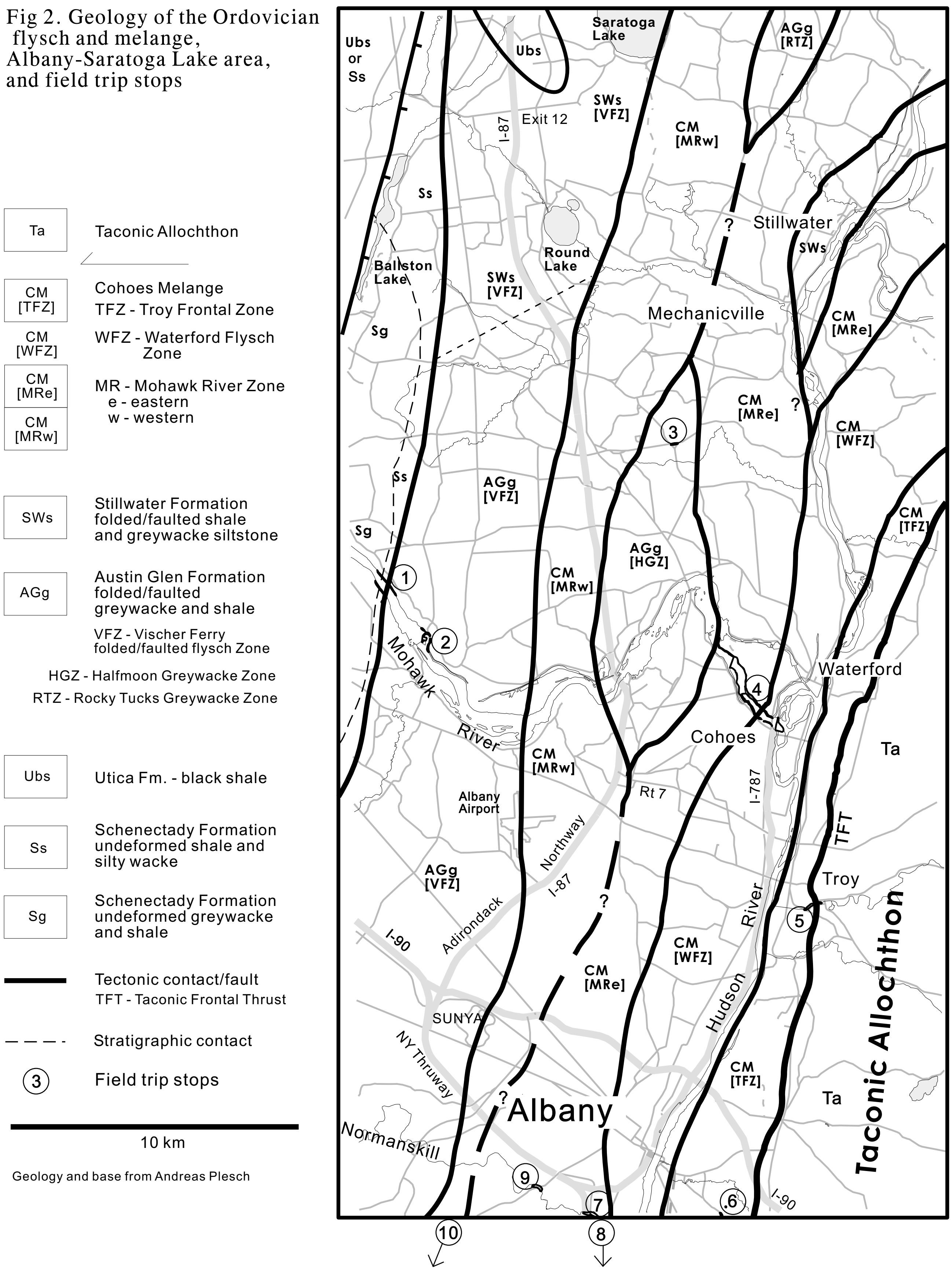
Ruedemann identified, and marked on his maps, the western limit of deformation in the medial Ordovician flysch, meaning folding and pervasive faulting and melange formation, and devoted considerable space in his text to the structural condition of the deformed zone, which occupies most of the width of the exposure of these rocks in the Hudson River lowlands in this area. It is unfortunate that this pioneer structural work has been submerged by the choice of the compilers of the last several geological maps of New York State (Fisher et al., 1970, Rogers et al., 1990) and of the Albany County area (Fickes, 1982) not to indicate that the medial Ordovician flysch in most of this area is significantly deformed, in strong contrast to these strata further west, and to have continued use of a stratigraphic nomenclature that, among other defects, actively works to obscure this fact. It is ironic that Ruedemann himself remains responsible for creating much of the stratigraphic nomenclature and confusion in the first place! Bird (1963, 1969) first clearly documented the regional extent of the melange, and its general structural significance in its relation to the emplacement of the Taconic Allochthon, although we reject the then-prevalent notion of gravity sliding for the emplacement mechanism of the Allochthon and the formation of the melange. More recent work in the Hudson Valley flysch by Vollmer (1981a), Bosworth and Vollmer (1981), Vollmer and Bosworth (1984), and Plesch (1994) includes detailed mapping of the area between Ravena and Saratoga Lake, and compilation of outcrop mapping farther south to the area of Middletown (in Plesch, 1994). This work reveals, more clearly than that of previous workers, the abundance of melange in the Capital District (see Figure 1), and that this is a product largely of subsurface shear strain, not of superficial slumping, and that the shearing was accommodated by significant brittle fracturing, largely on a small scale, besides more ductile behaviour. These melange zones of the Hudson Valley are a part of the southern extension of the Champlain Thrust and its subsidiary faults. Vollmer (1981a) and Vollmer and Bosworth (1984) pointed out that melange produced by this thrusting is unconformably overlain in the southern Capital District of New York by the earliest Devonian Helderberg Group carbonates. The unconformable contact constrains the formation of the melange, and the thrusting which produced it, to be a product of the Taconic Orogeny, and hence a purely Ordovician event. This unconformable relationship applies to the deformation in the westernmost (and hence youngest) part of the Taconic fold and thrust belt, implying that similar melange now east of the outcrop of the unconformity is also a product of Ordovician tectonism. The Champlain thrust system links the deformed flysch of the central Hudson Valley to similar sections in southern Quebec; it is a purpose of this guide and field trip to point out that there is much greater similarity between the marginal zone of the Taconic fold and thrust belt in these two areas than might be inferred from the existing published maps which, despite similar poor outcrop, clearly indicate the importance of melange and the extent of the marginal deformed zone in Quebec (St. Julien and Hubert, 1975; St. Julien et al. , 1983; Avramtchev, 1989), but do not in New York.

Stratigraphic terms

Names and assigned ages of rocks in the deformed belt of the Ordovician flysch of New York are badly confused, both because of the structural complexity and because of the application, by Ruedemann and subsequent workers, of biostratigraphic names to inadequately defined lithic units. To the west of the deformed belt, where strata are close to flat-lying, the black shales of the basal part of the foreland basin sequence are termed Utica shale [Canajoharie shale has been biostratigraphically distinguished as slightly older than the type Utica, but is lithologically not distinguishable from it]. This shale is overlain by rapidly coarsening-upward flysch, which is termed Schenectady Formation in the eastern Mohawk Valley. West of the central Mohawk Valley this is replaced by the Frankfort Formation which is not that different lithologically, although on average containing somewhat thinner-bedded greywackes, and in part somewhat younger because of the westward-younging diachronous flysch fill of the axis of the foreland basin (Rowley and Kidd, 1981). While it is probably least disruptive, and partly justified by historical practice, to continue to have separate names for these two areas of equivalent and similar strata, it is not justified to place Frankfort under Schenectady, a practice started by Fisher (1977, 1980), because the maps (Fisher, 1980) and the outcrops show them to be lateral equivalents with each starting directly on the Utica shale. Also, thin-bedded, shale-rich sections indistinguishable from the Frankfort are found within the Schenectady Formation, and coarser greywacke-bearing sections indistinguishable from the Schenectady are found in the Frankfort. As soon as one enters the deformed belt of flysch near Schenectady along the Mohawk River, things get (for stratigraphic terms) much worse!

The greywacke turbidite-shale flysch strata, when they are encountered in a structurally undisrupted but folded condition in the deformed zone of the Hudson Valley, are at present commonly known as Austin Glen Member [of the Normanskill Formation] [or Austin Glen Greywacke] from a definition by Ruedemann (1942) using a locality near Catskill (Figure 1). Regrettably, no section is available that shows the stratigraphic base or top of these strata. Furthermore, they are not distinguishable, despite the claim to the contrary by Rickard and Fisher (1973), from the coarser parts of the Schenectady Formation, which does have a defined base, and top (albeit erosional). Identical strata where they are unquestionably in the stratal sequence of the Taconic Allochthon, stratigraphically overlying the Mount Merino chert, are termed Pawlet Formation in northern New York and adjacent Vermont (Shumaker, 1967; Rowley et al., 1979), but have been termed Austin Glen farther south, towards and beyond the Capital District.

Fig 2. Geology of the Ordovician flysch and melange, Albany-Saratoga Lake area, and field trip stops



Ruedemann (1901a; 1930) was previously responsible for starting use of the term Normanskill Formation mostly [judged by outcrop area] to describe identical rocks, using a type locality to be seen on this trip (Stop 8; Figure 2), in the southern part of the City of Albany. This term has become so biostratigraphically and chronostratigraphically ensnared, and applied indiscriminately by Ruedemann, and by others (e.g. Ruedemann, 1942; Rickard and Fisher, 1973; Berry, 1962, 1963; 1977) to rocks which are utterly different lithologically [specifically the red Indian River Slate, and the black and green Mount Merino chert, both of the Taconic Allochthon stratigraphic sequence] that it should be abandoned by those wishing clearly to identify still stratified greywacke-shale rock units in the deformed zone. Thus Austin Glen Greywacke, at least specified as a member of the Normanskill "Formation", is a term also contaminated by this association, and unwanted attendant biostratigraphic implications.

It might be less confusing to most geologists, not natives to the area, to use Schenectady Formation for the greywacke-shale flysch, whether these strata are folded or not. The alternative, besides creating yet another name, is to elevate the Austin Glen to separate Formation status for the folded greywacke-shale facies of the flysch, as long as this is understood to include explicit and complete divorce from Normanskill biostratigraphic and age associations. We favour the latter proposal, and use it below, because it will allow clear separation of deformed from undeformed rocks on future maps. We acknowledge that this promotes continued use of one nominally redundant lithostratigraphic name, and that the Austin Glen cannot, because of its structural setting, be given a "proper" type section with base and top both included.

Shale-dominated rocks in the deformed belt are mostly in the form of melange. Intact or nearly intact stratified shale and thin-bedded silty to fine sandy greywacke, and these rock types in the form of "broken formation" transitional to melange, are found also, forming lens-shaped belts. These rocks, including the melange, have been inflicted with various stratigraphic terms indiscriminately, without regard to their structural condition. We think it is important, in order to understand them, to distinguish between still-bedded strata and the melange; for that reason alone we reject the application to the areas of melange of stratigraphic terms based on stratified type sections.

One term, Snake Hill Shale, has perhaps been most widely applied to the shaly rocks of the deformed belt, although we regard it as particularly inappropriate because, at the type locality, on Saratoga Lake, the rocks consist of medium-bedded greywackes, some quite calcareous and containing abundant brachiopod fauna, with lesser shales interstratified. Apart from the presence of the fauna, the arenites are otherwise very similar to those in the Schenectady Formation, and the Austin Glen Formation. The unusual lithology is only seen at a few other places in the area, and the fact that is is unusual, besides the fact that the stratified, fossil-bearing part of the section at Snake Hill is not dominantly shale, makes Snake Hill an entirely unsuitable term for the large areas of shaly rocks forming the bedrock of the deformed flysch zone of the Capital District, whether they are in the form of bedded strata or in the form of melange. Another term used by Ruedemann (1930) is Canajoharie shale [now designated the basal Utica shale], which is not appropriate because of the widespread presence of thin greywackes in these rocks, where they are not melange, in all but one area, and the fact that they consist, in all but the same one area, of grey shales, significantly unlike the black, carbonaceous shales of the Utica Formation at Canajoharie, and elsewhere. There are localities where black graptolitic shales occur in the belt of melange and highly deformed flysch, including one just southeast of Snake Hill, but these are slivers and blocks in grey shale matrix melange. We suggest that neither of these terms is appropriate for even the minority of bedded shale and thin silty greywackes in the deformed belt, and certainly not for the melange. There is one area where black, non-greywacke-bearing shale occurs in the western belt of folded and faulted flysch, between Ballston Spa and Saratoga Lake, and including a very prominent outcrop of flat-lying black shale in the median of Interstate 87 about a mile north of exit 12 (see Figure 2). Poor overall outcrop prevents determination of whether this area of Utica Shale is exposed due to updoming of Utica from beneath the grey shales and wackes of the Stillwater and Austin Glen of the folded and faulted flysch Zone, or due to local overthrusting of the Utica over those grey shales and wackes.

The Schenectady Formation contains sections that are thin-bedded and shale-dominated, and this unit, with a facies designation (shale facies, as opposed to greywacke facies) might be an appropriate way to designate the areas of little-disrupted shale-dominated flysch in the deformed belt. Alternatively, in keeping with the proposal to formalize Austin Glen Formation for the folded greywacke-shale facies, a separate [and new] name would be needed; we favour this alternative and suggest Stillwater [Shale] Formation for the good exposures of this unit around that town (Figure 2), and specifically along Schuyler Creek, up to about 1.5km west of the Hudson River. We propose that the term Snake Hill be restricted to occurrences of the brachiopod-rich wacke/shale facies seen at Snake Hill, and that it be specifically designated Snake Hill facies of the Austin Glen Formation, because of the rarity of the occurrences, and the inclusion of most of them as blocks or slices in melange.

Melange

Specific lithounit terms for parts of the melange have only been given by two authors. Zen (1961) proposed "Forbes Hill Conglomerate" for a very specific pebbly olistostromal unit only found (as originally defined) adjacent to the northernmost Taconic Allochthon. This conglomerate in its type area and location is not at all a typical occurrence of the melange, and also has a poorly exposed type locality. Bird (1969) used this term to apply to the melange in general; we think that this usage ought to be dropped for this context, since most of the melange is emphatically not conglomerate. Bird (1963, 1969) also used the informal lithological descriptive term “wildflysch” to characterise the melange; this term is not at all inappropriate. Fisher (1977) introduced “Poughkeepsie Melange”, based on a few outcrops that are still not adequately understood in terms of relationships to their surroundings (i.e. not mapped in detail). Because we think that these two names have significant defects, we propose a new lithostratigraphic name, the Cohoes Melange, for the melange of the deformed flysch belt of the Hudson Valley. We propose as a type locality the excellent cliff and riverbed outcrop on the north bank of the Mohawk River from Cohoes Falls to the end of outcrop in the riverbed below the dam and spillway east of the Waterford-Cohoes Route 32 highway bridge (to be seen at Stop 4; Figures 2 and 5). This section contains both "exotic" and "non-exotic" types of melange (see below). Because the melange is a product of disruption of stratified rocks by structural processes, it is not feasible to define a type section that includes top and base; for that reason it is not appropriate to define it as a conventional "Formation". However, it is possible to specify a well-exposed, accessible type locality, and to define clearly the lithologic characteristics and contents. We base these on the mapping and detailed descriptions of Plesch(1994), and Vollmer (1981a).

The detailed mapping of Plesch (1994) identified two main varieties of melange in the Capital District. One contains only greywacke blocks in grey phacoidal shale matrix, both components being ultimately derived from the bedded flysch. The other variety has a more complex derivation, with blocks that are "exotic", at least in comparison with the exclusively mundane greywacke blocks of the first-mentioned variety, and with at least two types of shale for the phacoidal matrix. We emphasise that the term "exotic" is used in a relative sense, and that no blocks in the New York Taconic melange are exotic in the sense that term is often used elsewhere, for example to denote blueschist and eclogite blocks in the Franciscan of California. With the single exception of the basaltic pillow lava of Stark's Knob [near Schuylerville], all known "exotic" blocks in the Taconic melange are sedimentary rocks, and most of the types can be matched with lithic units of the Taconic Allochthon stratigraphic sequence. In the melange belt of the Capital District, exotic blocks are seen in the largest [and best] exposures to be arranged in distinct zones, often in a systematic assemblage. However, it is impractical to distinguish on maps all the zones with exotic blocks versus those without such blocks, partly because of the generally poor outcrop, and because many of the alternating zones are too narrow too show; because of this, we do not propose separate lithostratigraphic names for exotic-bearing and non-exotic-bearing melange.

Within the exotic melange, there are several distinctive block/slice lithologies, some of which have (in some places) been given specific names. The most widespread of these lithic types are cherts of dark grey, black, and green aspect, and which are identified confidently as samples of the Mount Merino (chert) Formation, a unit native only to the Taconic Allochthon stratigraphic sequence (Rowley et. al., 1979). These cherts, to be seen at Stop 8 (Figure 9), and closely related black argillites/slates, contain the most prolific and best preserved graptolite faunas (of *Nemagraptus gracilis* age) obtained in the belt of deformed flysch and melange. Unfortunately, it has been presumed by Ruedemann (1930), who described the faunas, and by others (e.g. Berry 1963, 1977; Rickard and Fisher, 1973) that the Mount Merino chert was a lithostratigraphic member of the flysch of the Hudson Valley, a notion propelled by the inclusion of the chert in the Normanskill “Formation”. We maintain that the contacts of these black cherts and slates are everywhere tectonic within the belt of deformed flysch greywackes, shales, and melange. Given their origin from the allochthonous strata of the Taconic Allochthon, they are evidence for out-of-sequence and structurally late formation of at least some of the melange; Taconic slices were emplaced over flysch and then both were mixed together by out-of-sequence thrusting and melange formation.

The other unit given a specific name in this area is the Ryesdorph Hill conglomerate of Ruedemann (1901b, 1930). This carbonate conglomerate/breccia, to be seen at stop 6 (Figure 7), also has suffered the presumption that it was part of the stratigraphic sequence of the flysch. We are of the opinion that it is a block in the exotic melange, and that the youngest fauna in this block is only a constraint on the maximum age for the formation of the melange in which it is contained. Other occurrences of carbonate blocks, mostly breccias, are not known to contain faunas with the exceptional age range Ruedemann painstakingly extracted from the Ryesdorph Hill locality. Other rock types found in the exotic melange include distinctive rusty-weathering sideritic carbonate mudstone, whose source is unknown, but which is unlikely from comparison to be the Burden Iron Ore found south of Hudson within the Taconic Allochthon stratigraphy (Hofmann, 1986). In the melange matrix, bright green shale, which is not found in the melange that bears only greywacke blocks, is also an “exotic” lithotype; it always (reliably) accompanies other exotic lithotypes. A few occurrences of brachiopod-rich wackes, like those seen in stratified rocks at Snake Hill on Saratoga Lake, also occur in the exotic melange, particularly in Cohoes Gorge where (Riva, J., pers. comm, 1983) they also contain the trilobite *Cryptholithus tesselatus*, and in part of the western long road cut on the new Route 7 in Latham.

Discussions of age relations of the flysch and melange, from fossils (Berry, 1962, 1963, 1977; Rickard and Fisher, 1973), derived either from within blocks in melange, or from bedded sequences in the deformed flysch belt, have not been particularly conclusive, partly because of a failure to establish a clear lithostratigraphic framework, and partly because the highly tectonised condition and structural complexity of this belt of rocks was not sufficently recognised. We suggest in particular that the Hudson Valley flysch and melange is not as old as previously inferred, because *N. gracilis* faunas only occur in blocks of Taconic Allochthon-derived black chert and slate. Also we suggest that none of the presently known faunas <u>in the greywackes</u> necessarily demand (but do not rule out) out-of-sequence thrusting or deposition in basins (“lower slope basins”) stratigraphically upon previously deformed flysch and melange.

Several major belts of melange occur in the Capital District (Figures 1 and 2), based on the outcrop maps of Plesch (1994) and Vollmer(1981a). We term these belts "zones", not slices, because they are highly likely to contain significant faults, and are not just bounded by faults. The widest zone occupies the center of the deformed flysch belt; we term this the Mohawk River Central Melange Zone. It is divided by the Halfmoon Greywacke Zone (intact folded Austin Glen Formation) into eastern and western parts. It is impossible to separate these parts or to locate the boundary precisely where the Halfmoon Greywacke Zone is not present, but we think there is good evidence (see Plesch, 1994) that this boundary is a fault that must continue to north and to south of the Halfmoon Greywacke Zone, in particular to link with the Rocky Tucks Greywacke Zone along strike to the north. The Central Melange Zone contains significant occurrences of exotic fragments, across the full width of its outcrop. The zone of bedded shaly rocks around Stillwater appears to further divide the eastern Central Melange zone in the northeastern portion of Plesch's map. The western margin of the Central Melange adjoins the belt of less-deformed folded and faulted flysch (Figure 2). The eastern margin is formed by the 1-2 kilometer-wide belt of mixed broken formation, small intact bedded blocks, and melange, mostly formed of, or derived from, shaly to fine arenite flysch, and which lacks "exotic" components; this belt we term Waterford Flysch Zone. The other mappable melange belt is the one that is clearly localized adjacent to the Taconic Frontal Thrust, and which truncates some zones of the bedded flysch and melange to its west. This melange we term Troy Frontal Melange Zone, for its well-exposed section in the gorge of the Poestenkill in Troy (to be seen as Stop 5). The Troy Frontal melange is prominently "exotic"-bearing, although there appears to be an exotic-poor, greywacke block-dominated zone in the hundred meter width adjacent to the Taconic Frontal Fault, at least in the two exposures of this interval to be seen on the trip [Stops 5 and 6]. The melange at Poughkeepsie noted by Fisher is possibly equivalent, at least in part, to this one.

Structure of the melange and flysch and its origin

Structural features of the Taconic melange in eastern New York have been most recently studied by Vollmer (1980, 1981a, 1981b), Bosworth and Vollmer (1981), Vollmer and Bosworth (1984), Bosworth (1989), and Plesch (1994). The melange formed by the progressive deformation of synorogenic flysch as an accretionary thrust wedge advanced over the Ordovician North American continental margin, creating, and supplying sediment to an active submarine foreland-type basin. The flysch was derived from, and was progressively accreted to and overridden by the Taconic Allochthon, resulting in the formation of belts of tectonic melange.

Three principal mechanisms are believed to have operated to form the melange: folding, boudinage and disruption of graywacke-shale sequences due to viscosity and ductility contrasts; imbrication and out-of-sequence thrusting resulting in intercalation of sedimentary units; and tectonization of olistoliths, and possibly slumps, derived from exposed fault scarps. Exotic clasts in the melange are probably both of sedimentary and of structural origin. In some locations pebbly mudstones are preserved without extensive deformation, suggesting that some of the exotic melange could have formed by later deformation of such deposits. In other cases exotic fragments appear to have been introduced by structural imbrication.

The state of consolidation of the rock during melange formation may have varied considerably, but it is thought that melange formation was dominated by lithified rock tectonic processes. Folded veins, brittle failure at fold hinges, axial plane cleavage cross-cutting veins, consistent orientation of axial planes, and a general absence of criteria indicating soft sediment deformation were found by Vollmer (1981a). In particular, steeply plunging isoclinally folded calcite veins suggest that much of the strain was accommodated after the rock was consolidated enough for extensional vein formation to occur (Vollmer, 1981a). Extensive veining is presumably related to high pore pressures, however, and only a limited degree of lithification may have been required for brittle failure to occur.

A progressive change in the orientation of fold axes was documented by Vollmer (1980, 1981a, Bosworth and Vollmer 1981, Vollmer and Bosworth 1984) in Albany County (stops 7-10). Away from the allochthon near-horizontal fold axes trend NNE. As the Allochthon is approached, fold axes swing 90 degrees to steep ESE plunges. This change is accompanied by increased fold tightness, stratal disruption, and development of a phacoidal fabric. The amount of rotation also appears to be lithology dependent, as folds in the presumably more viscous graywacke beds appear to have undergone less rotation. These observations suggest that fold rotation was progressive and was related to increasing strain (Vollmer 1981a).

The characteristic fabric of the melange is a phacoidal cleavage, which is intimately associated with high strain, bedding disruption, and fold rotation. The adjective “phacoidal” refers to the lensoid character of the shale chips and other fragments that define the fabric. Greenly (1919), who first applied the word melange to a rock body, used this term in his description of melange fragments. The term “scaly” is used to describe similar fabrics elsewhere (for example, Moore 1986), however, the term “phacoidal” more accurately describes the fragment shapes which define the fabric here (Caine, 1991). Studies of the Taconic melange fabric by Vollmer (1981b, Vollmer and Bosworth 1984), Bosworth (1989), and Caine (1991) show a complex three-dimensional network of anastomosing seams and conjugate shear planes. Although the development of this fabric is not fully understood, it appears to be only developed within high strain zones, and is considered to be a shear zone fabric. Similar fabrics are described from melanges worldwide. Outcrops at Normansville (Stop 9; Figure 10) show good examples of the phacoidal cleavage with associated stratal disruption and folding.

Some of the most complex deformation in the area was documented by Vollmer (1981a) within the Normanskill gorge (stop 7), the type locality of "Normanskill Formation". There, directly under the 9W overpass, a large rootless antiformal syncline is exposed (Figure 9). Flute casts clearly demonstrate its downward-facing character. Downward facing bedding/cleavage relationships can also be found. Vollmer (1981a) modeled the deformation there as either the refolding, or slumping, of a sequence of variably plunging folds with extensive stratal disruption. This location is clearly a singularly poor choice for a stratigraphic type section.

The upper limit to the age of melange formation is constrained by the unconformity exposed at Feuri Spruyt (Creek) near South Bethlehem (stop 10; Figure 11) which was described by Ruedemann (1930) and Vollmer (1981a). Here highly disrupted melange is unconformably overlain by carbonates of the lower Helderberg group. Although it could conceivably be argued that the contact at this locality is structural, the regionally extensive melange belt passing underneath the carbonates requires an unconformable relationship. Late quartz veins in the melange rather consistently show slickenside fibres plunging to 120°±15 (Plesch, 1994), which is an orientation clearly identified with the Champlain thrust (e.g. Stanley and Sarkisian, 1972); **~~in contrast, slickenside fibres on thrusts and flexural slip surfaces in the Devonian Helderberg Group between Ravena and Catskill, just south of the Capital District, trend 090 ±15, the local Acadian Orogen orientation. These data also suggests most of the structure in the melange belt was formed in the Taconic Orogenic event.~~

The belts of Taconic melange are thus envisioned as broad shear zones, with dominantly "hard-rock" structures, that formed thrusts within the synorogenic flysch during the emplacement of the Taconic Allochthon. The east to west decrease in deformation intensity at the western margin of the defomed belt of flysch might be interpreted as reflecting a progressive decrease in strain rate as the Taconic thrusting ceased, although this cannot be conclusively demonstrated. Because of the evidence for out-of-sequence thrusting in the Taconic belt, it could alternatively be a petrified representative sample of the progressive incorporation of flysch into the accretionary thrust complex, a rate inferred rather speculatively by Bradley and Kusky (1986) to have been of the order of 2 cm/yr.

***note added [not in original guide] Marshak (1986) shows that the slickenside fibres of (probable) Acadian age in Helderberg carbonates near Catskill average around a 120º orientation; thus the unreferenced statement about these given above is wrong, and it is not possible to distinguish Taconic from Acadian structures on this basis.*

References

Avramtchev, L., 1989. Cartes des gites mineraux des Appalaches, region des Basses-terres du Saint-Laurent et Estrie-Beauce, 1:250,000. Ministere de l'Energie et de Ressources, Quebec; DV-87-19.

Berry, W.B.N., 1962, Stratigraphy, zonation, and age of Schagticoke, Deepkill, and Normanskill Shales, eastern New York, Geol. Soc. Amer. Bull., **73**, p.695-718.

Berry, W.B.N., 1963, Ordovician correlation in the Taconic and adjacent regions, in Guidebook for field trip three. Stratigraphy, structure, sedimentation and paleontology of the southern Taconic region, eastern New York, GSA meeting 1963, Albany, NY., p.23-31.

Berry, W.B.N., 1977, Ecology and age of graptolites from greywackes in eastern New York. J. Paleontol., **51**, p.1102-1107

Bird, J.M., 1963, Sedimentary structures in the Taconic sequence rocks of the southern Taconic region, in Guidebook for field trip three. Stratigraphy, structure, sedimentation and paleontology of the southern Taconic region, eastern New York, GSA meeting 1963, Albany, NY., p.5-21.

Bird, J.M., 1969, Middle Ordovician gravity sliding - Taconic region, in M. Kay (ed.) North Atlantic - Geology and Continental Drift, Amer Assoc. Petrol. Geologists Mem. **12**, p.670-686.

Bosworth, W., 1989, Melange fabrics in the unmetamorphosed external terranes of the northern Appalachians, Geol. Soc. Amer. Spec. Pap. **228**, p.65-91.

Bosworth, W., and Vollmer, F.W., 1981, Structures of the medial Ordovician flysch of eastern New York: deformation of synorogenic deposits in an overthrust environment, J. Geol. **89**, p. 551-568.

Bradley, D.C, 1989, Taconic plate kinematics as revealed by foredeep stratigraphy, Appalachian Orogen, Tectonics **8**, p. 1037-1049.

Bradley, D.C., and Kidd, W.S.F., 1991, Flexural extension of the upper continental crust in collision foredeeps, Geol. Soc. America Bull. **103**, p. 1416-1438.

Bradley, D.C., and Kusky, T.M., 1986, Geologic evidence for rate of plate convergence during the Taconic arc-continent collision, J. Geol. **94**, p. 667-681.

Caine, J.S., 1991, Melange fabrics of the northern Appalachians [MS thesis]: New Paltz, State University of New York, 208 p.

Cushing, H.P., and Ruedemann, R., 1914, Geology of Saratoga Springs and Vicinity, New York State Mus. Bull. **169**, 177 p.

Fickes, R.H., 1982, Generalized bedrock geology of Albany County, New York, 1:125,000. New York State Museum/Geological Survey Educational Leaflet 25.

Fisher, D.W., 1977, Correlation of the Hadrynian, Cambrian and Ordovician rocks in New York State, New York State Mus., Map and Chart Ser. **25**, 75 p.
Fisher, D.W., 1980, Bedrock geology of the central Mohawk valley, New York, New York State Mus., Map and Chart Ser. **33**, 44 p.
Fisher, D.W., Isachsen, Y., and Rickard, L.W., compilers, 1970, Geologic Map of New York State, 1:250,000. New York State Mus., Map and Chart Series **15**, 6 sheets.
Greenly, E., 1919, The geology of Angelsey: Great Britain Geological Survey Memoir, 980 p.
Hofmann, P.M., 1986, Dolomitization of the Hatch Hill Arenites and the Burden Iron Ore. Msc. thesis, State University of New York at Albany, 188 pgs.
Marshak, S., 1986. Structure and tectonics of the Hudson Valley fold-thrust belt, eastern New York State. Geol. Soc. Amer. Bull., 97, 354-368.
Moore, J.C., 1986, editor, Structural fabrics in deep sea drilling project cores from forearcs: Geological Society of America Memoir **166**, 160 p.
Plesch, A., 1994, Structure and Tectonic Significance of Deformed Medial Ordovician Flysch and Melange between Albany and Saratoga Lake and in the Central Hudson Valley, N.Y., M.S. thesis, University at Albany, State University of New York, 299 p.
Rickard, L.V., and Fisher, 1973, Middle Ordovician Normanskill Formation, eastern New York: age, stratigraphic and structural position, Am. J. Science **273**, p. 580-590.
Rogers, W.B., Isachsen, Y.W., Mock, T.D., and Nyahay, R.E., compilers, 1990, New York State Geological Highway Map, New York State Mus., Educational Leaflet **33**.
Rowley, D.B., and Kidd, W.S.F., 1981, Stratigraphic relationships and detrital composition of the medial Ordovician flysch of western New England: implications for the tectonic evolution of the Taconic Orogeny, J. Geol. **89**, p. 199-218.
Rowley, D.B., Kidd, W.S.F., and Delano, L.L., 1979, Detailed stratigraphic and structural features of the Giddings Brook slice of the Taconic Allochthon in the Granville area, in Friedman, G.M., ed., New York State Geol. Assoc. and N.E.I.G.C. Guidebook, p. 186-242.
Ruedemann, R., 1901a, Hudson river beds near Albany and their taxonomic equivalents, New York, New York State Mus. Bull. **42**, p. 489-596.
Ruedemann, R., 1901b, Trenton conglomerate of Ryesdorph Hill, Rensselaer County, New York, New York State Mus. Bull. **49**, 114pp.
Ruedemann, R., 1930, Geology of the Capital District, New York State Mus. Bull. **285**, 218 p.
Ruedemann, R., 1942, Cambrian and Ordovician geology of the Catskill quadrangle, New York State Mus. Bull. **331**, p. 7-188.
Shumaker, R.C., 1967, Bedrock geology of the Pawlet Quadrangle, Vermont: part I, central and western portions, Vermont Geol. Survey Bull. **30**, p. 1-64.
Stanley, R..S., and Sarkisian, A., 1972, Analysis and chronology of structures along the Champlain Thrust west of the Hinesburg synclinorium, in B.L. Doolan and R.S. Stanley (eds.) Guidebook for Field Trips in Vermont, N.E.I.G.C. 64th Annual Meeting, p. 117-149.
St. Julien, P., and Hubert, C.,1975, Evolution of the Taconian orogen in the Quebec Appalachians, Am. J. Sci. **275A**, p. 337-362.
St. Julien, P., Slivitsky, A., and Feininger, T., 1983, A deep strucutral profile across the Appalachian of southern Quebec, Geol. Soc. of America Mem. **158**, p. 103-111.
Vollmer, F.W., 1980, Progressive deformation, fold rotation and melange formation in Middle Ordovician flysch near Albany, New York: Geological Society of America Abstracts with Programs, **12**, p. 542-543.
Vollmer, F.W., 1981a, Structural studies of the Ordovician flysch and melange in Albany County, New York, M.S. thesis, State University of New York at Albany, 151 p.
Vollmer, F.W.,1981b, Signifcance of small scale structures for the deformation history of the Taconic melange, eastern New York: Geological Society of America Abstracts with Programs, **13**, p. 574.
Vollmer, F.W., and Bosworth, W., 1984, Formation of melange in a foreland basin overthrust setting: example from the Taconic Orogen, *in* Raymond, L. A., [ed.], Melanges: their nature, origin and significance, Geol. Soc. America Spec. Paper **198**, p. 53-70.
Zen, E-An, 1961, Stratigraphy and structure at the north end of the Taconic Range in west-central Vermont, Geol. Soc. Amer. Bull., **72**, p. 293-338.
Zen, E-an, 1964, Stratigraphy and structure of a portion of the Castleton Quadrangle, Vermont Geol. Survey Bull. **25**, 70 p.
Zen, E-an, 1967, Time and space relationships of the Taconic allochthon and autochthon, Geol. Soc. of America Spec. Pap. **97**, 107p.

Field trip stop descriptions

Stop 1 - View of flat-lying Schenectady Fm. flysch and shale outcrop on south bank of Mohawk River from end of Brian Drive. Outcrops are scarce in the belt of flat-lying to gently dipping greywackes and shales [flysch] east of the trace of the Saratoga-Ballston Lake normal fault. The best are in the south bank of the Mohawk River, and are not readily accessible to large groups. At this stop (see Figure 2 for location) a shaly unit of the Schenectady Formation flysch can be seen across the river underlying medium-bedded greywackes and shales with gentle west dips and no signs of internal deformation.

These rocks are autochthonous and have not been transported by thrusting during the Taconic Orogeny. About 300 meters to the east of this location, along the southern shore, there is an abrupt contact of these flat-lying strata with significantly folded and faulted thin-bedded greywackes and shales, defined by the first thrust fault encountered in a west-to-east transect. This is not clearly apparent from this viewpoint, but a representative outcrop of the folded and faulted flysch is seen at the next stop.

Stop 2 - Folded and faulted flysch of Vischer Ferry Zone - outcrop along north shore of Mohawk River near Vischer Ferry power plant/Lock 7

The rocks here form part of the Vischer Ferry Zone of folded and faulted flysch (Figures 1 and 2). Thin-bedded greywackes and shales, with subvertical dip, are exposed in the discontinuous roadcut going down the paved road and branching off onto the dirt track down to the shore of the river. At the shore, similar thin-bedded flysch and shale comprises the outcrop extending west from the path to the abutment of the power plant (Figure 3). This outcrop displays asymmetrical folds and small faults connected with east-over-west thrusting. A detailed description of this outcrop appears in Bosworth (1989), who pointed out the incipient development of a melange-type fabric in the fault zone (Figure 3), mainly through fracture development and incremental slip on the fracture surfaces. Farther down the dirt track to the south-east, a small hillock and its shoreline on the river under the power transmission line exposes more subvertical, west-younging thin to medium-bedded greywackes and shales.

While the strata here are in part shale-dominated, enough arenaceous greywacke occurs here and in the surrounding areas for the Vischer Ferry Zone to be mapped as Austin Glen Formation across the Mohawk River. To the north, however, near Round Lake (Figure 2), the Zone changes to largely shale, lacking significant arenaceous wackes, and there it is specified to consist of Stillwater Shale. This change is gradational, and thinning and fining of the arenaceous component of the flysch is occurring, within the Zone, across the Mohawk River; we choose for consistency to include anything containing arenaceous greywackes within the Austin Glen Formation.

Stop 3 - Thick-bedded Austin Glen Formation flysch of Halfmoon Greywacke Zone, folded, with melange on small thrust fault - road cut on north side of Route 146 east of Clifton Park

This outcrop (Figure 4) mostly exposes structurally intact medium to thick-bedded greywackes and lesser shales in a broadly antiformal structure, hence the popular name for this locality, Clifton Park Anticline. However, in the center of the outcrop there is a thrust fault, which can be identified from the zone of overturned steeply-dipping thinner greywackes and shales that form the lower limb of a close fold in the immediate hanging wall of the fault.

This fold might be a tightened hanging wall ramp anticline. To the west [structurally below] this fold structure, there is an approximately 3 meter wide zone consisting of broken blocks of greywacke in a disrupted shale matrix, which is melange derived from the adjacent materials, and defines the fault zone. We think that this fault is an excellent example that shows in miniature how the larger zones of melange formed.

This outcrop is part of a large structural slice, which we term Halfmoon Greywacke Zone (HGZ), that consists of relatively intact, medium-thick bedded greywackes like these, surrounded both to east and west by highly disrupted melange, including some materials exotic to the immediate greywacke-shale association. This HGZ slice consists along the Mohawk River of a disrupted large-scale synform; however we do not favour the klippen interpretation shown for it on the New York State Geological Survey

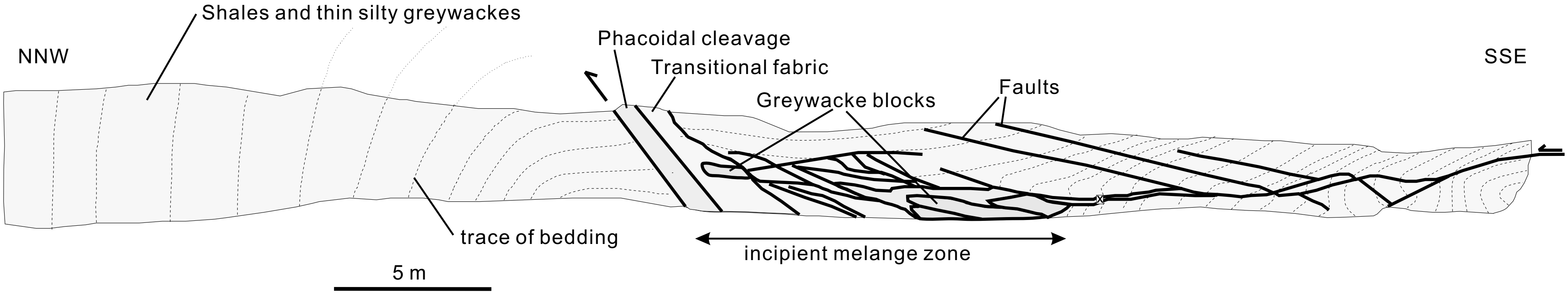


Fig. 3. Sketch section of outcrop [stop 2] adjacent to Vischer Ferry power station, north bank of Mohawk River (after Bosworth, 1989).
Melange developing on small thrusts in thin-bedded shaly flysch facies.

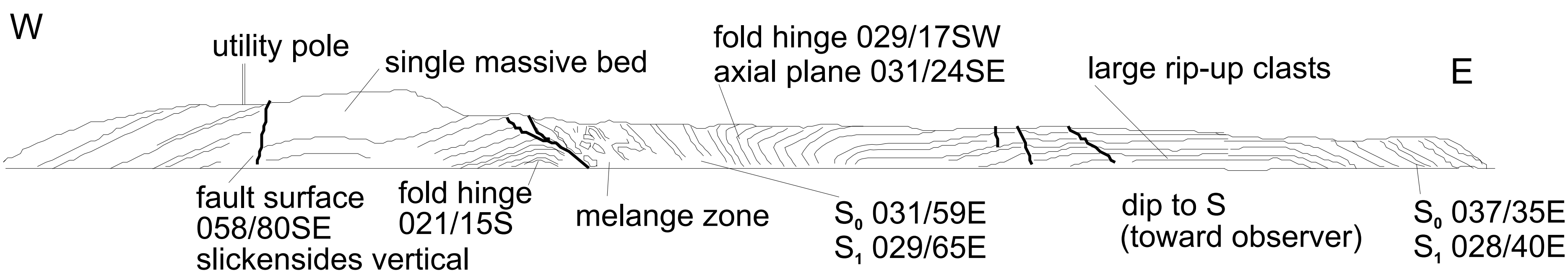


Fig. 4. Sketch section of road cut [Stop 3] on north side of Route 146, Clifton Park; folded Austin Glen Fm. with small melange zone on thrust.

maps since 1970; in particular there is no evidence for a westerly dipping, nor a relatively west-downthrown fault/fault zone on its eastern side.
Excellent sedimentary structure assemblages may be seen in the greywackes in this outcrop indicating deposition by turbidity currents, and local reworking by bottom currents [beds completely occupied by climbing cross-laminations], perhaps the tails of turbidity current events. Claims of the existence of shallow water sedimentary structures, particularly mudcracks, have occasionally been made for the Schenectady Formation , and for greywackes of the same structural slice as this outcrop near the Mohawk river (Rickard and Fisher, 1973); we think that these reports are mistaken, and the structures are probably either syneresis cracks, or tectonic structural features. All greywacke-bearing outcrops we have seen in the Hudson Valley and in the Schenectady Formation have turbidite characteristics, certainly deposited below wave base, and likely in substantially deep marine water given the analogy with modern arc-passive margin collisions, such as Timor-Australia.

Stop 4 - Cohoes Melange outcrop [eastern Mohawk River Central Melange Zone], cliff on Waterford side of Mohawk River below Cohoes Falls
This outcrop and its continuation up and downstream constitutes the best, and most continuous section through the melange of the Hudson Valley. Structural features seen here, and elsewhere in this belt indicate a "hard-rock" origin for the melange, particularly the striations visible on many of the characteristic "phacoidal" or lenticular splinters of the shale, and the polished nature of these surfaces in places when freshly exposed. Clear evidence of olistostromal origin of units with blocks in matrix is found in a few places, but the large majority of the melange in the region does not show features that require a surficial mass-wasting origin. As long as shear strains were high, imbrication and mixing of materials could be achieved in large ductile thrust fault zones, as long as some of these were out-of-sequence thrusts, in order to introduce originally overthrust materials [from the Taconic Allochthon] among the medial Ordovician flysch-derived melange matrix. The latest structures here and elsewhere in the melanges consist of quartz veins, some fibrous, and slickensided, which in many places, including here, show a consistent 120° plunge; this orientation is known to be associated with the Champlain Thrust in Vermont, which is an along-strike continuation of the faults defined by the Hudson Valley melange zones. This fault displacement direction contrasts with the ~090° plunge of thrust-related slickensides in the Devonian Helderberg Group to the south between Ravena and Catskill.
The section here consists (figure 5) of alternating zones of exotic-containing and less- to non- exotic-bearing melange. A large isolated wacke block is seen part-way down the cliff path; lower down, several large carbonate breccia blocks are exposed, possibly derived from a Taconic Allochthon source, or from normal fault scarps in the outer trench slope prior to arrival of thrusting and melange formation. Just east of the bottom of the path is a large block of black argillite, which is in our opinion derived from the allochthonous strata of the Taconic Allochthon, specifically from the upper Mt. Merino-basal Pawlet Fm. interval, which contains, regionally, black graptolitic argillites with *Nemagraptus gracilis* faunas like the one collected and identified by Riva [pers. comm., 1981] from this block. Smaller blocks of chert, also originally from the Mt. Merino Fm. of the Taconic Allochthon, occur at the base of, and above Cohoes Falls. The remaining materials in this part of the section consist dominantly of greywacke and shale [flysch], although there is also a persistent occurrence of greenish shale seams and films in all areas where the exotic melange occurs, as well as scattered small blocks of sideritic mudstone whose stratigraphic source is unidentified, and both of which are not seen in areas just containing greywacke and shale and their melange derivatives. Farther east in this outcrop than the black argillites, there are a few occurrences of blocks/lenses of a fossiliferous wacke, very similar to that exposed in a partly-disrupted bedded section at Snake Hill on Saratoga Lake.
This brachiopod/trilobite fauna contains *Cryptolithus tesselatus* [Riva, pers. comm, 1981]. Because of its local occurrence, we suggest that this lithology represents input to the flysch trough from a local across-axis source, unlike the majority of the flysch, which clearly has a southerly derivation and along axis transport, from the paleocurrent evidence.
If the water level is very low, excellent exposures of incipiently to strongly disrupted shales and silty wackes of the Waterford Flysch Zone may be seen just below the dam located east of the Waterford-Cohoes road bridge; these represent a discontinuous belt of in part less-deformed rocks forming a slice, or set of imbricate slices, on the eastern margin of the Mohawk River Central Melange. Access to this outcrop, at low water, may be obtained from either the north or south side of the Mohawk River, east of the bridge.

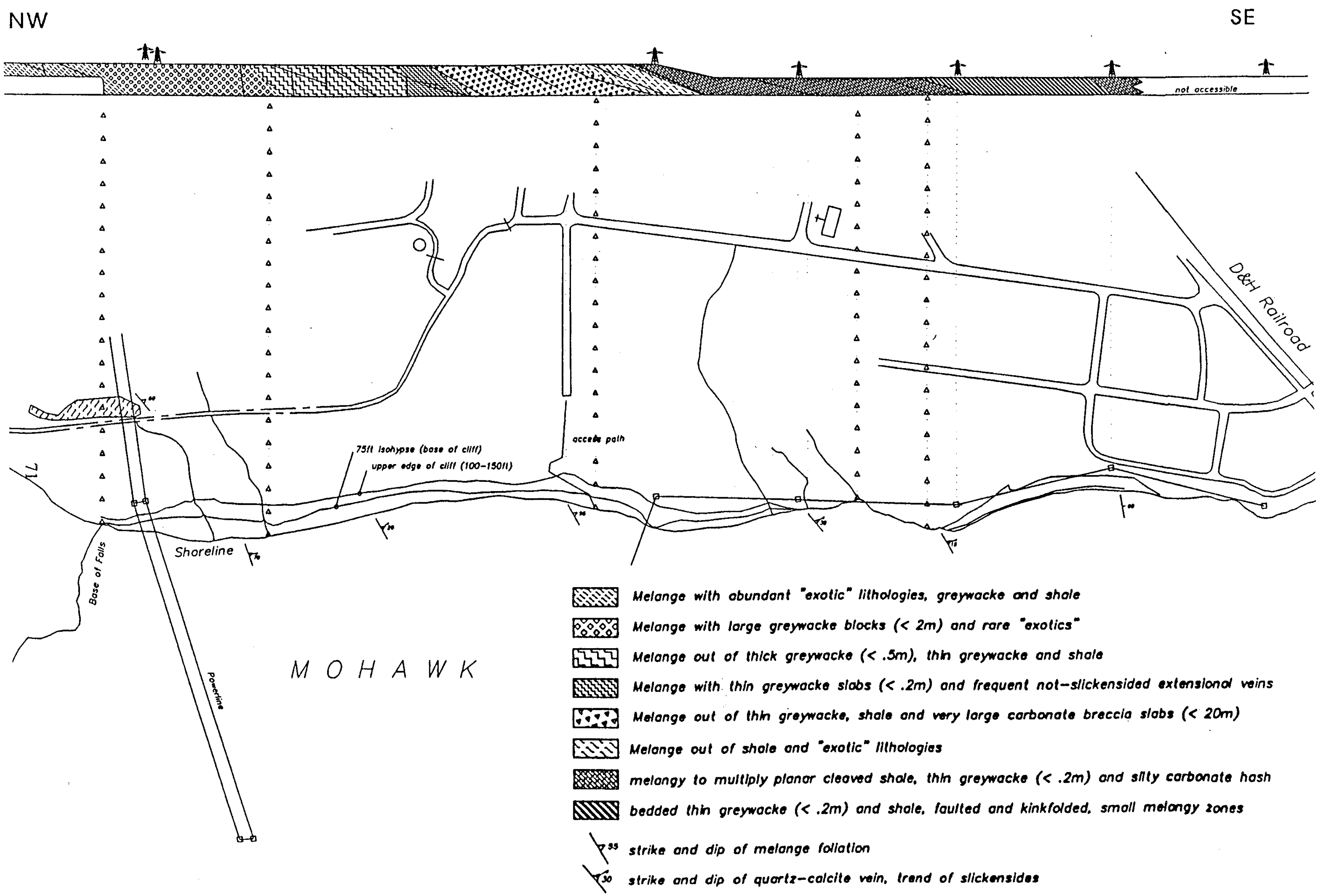


Fig. 5. Sketch section and location map from Plesch (1994) of north cliff of Mohawk River downstream from Cohoes Falls (Stop 4). Type section for Cohoes Melange, including "exotic"-clast facies, in Mohawk River Central Melange Zone.

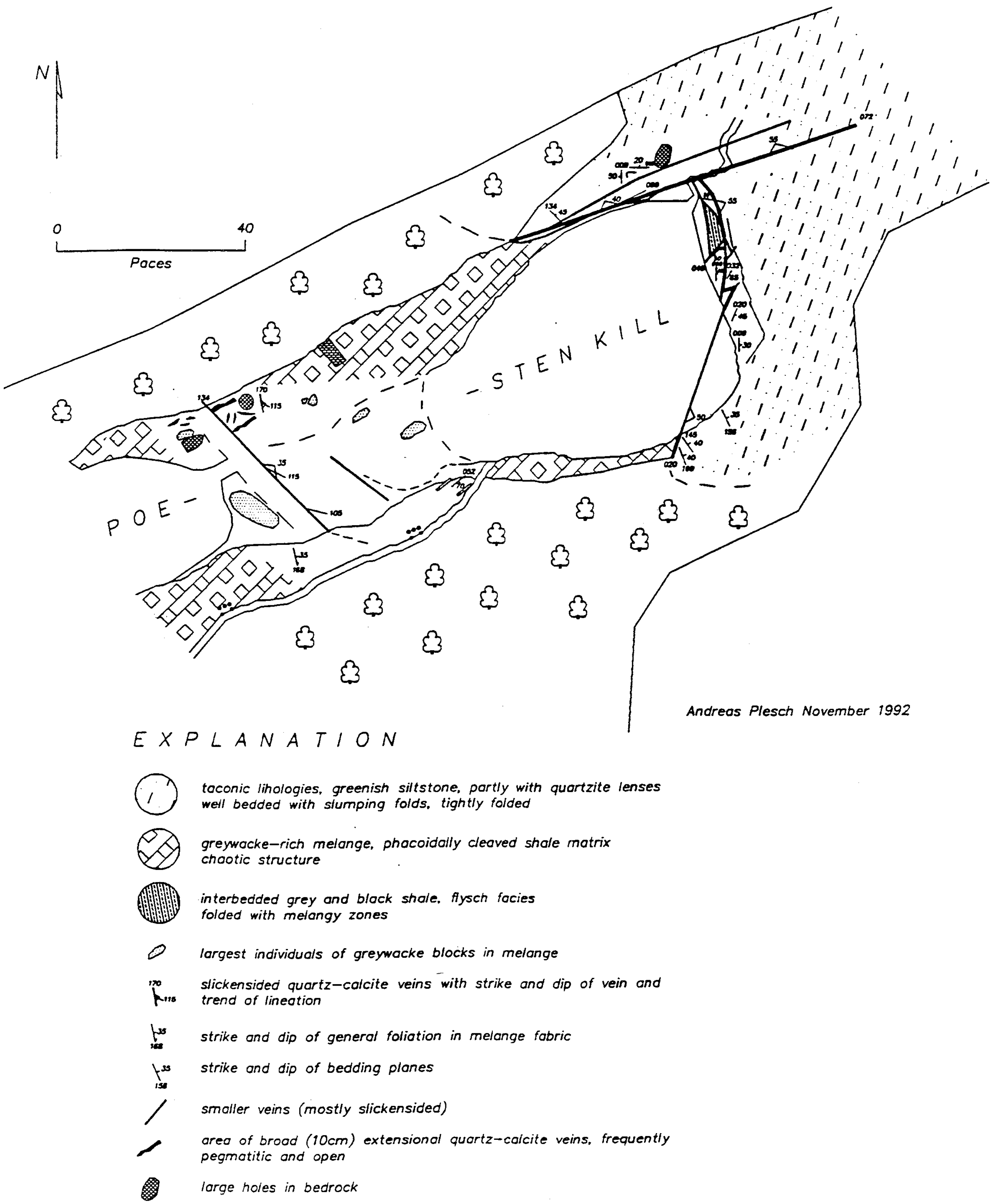


Fig. 6 Sketch geological map of Poestenkill Falls, City of Troy (Stop 5).
Exposure of Taconic Frontal Fault and Troy Frontal Melange Zone.

Stop 5 - Poestenkill Gorge, Taconic Frontal Fault and Troy Frontal Melange Zone
This is one of the few exposures, and certainly the best (Figure 6), of the Taconic Frontal Fault anywhere along its ~200km length. Green arenites and silty wackes and slates of the Bomoseen Formation are in fault contact here with greywacke block-rich grey shale melange of the Troy Frontal Melange Zone. The original (presumed thrust) fault contact has been cut and displaced by a later steep strike-slip fault at this locality, so that most of the exposed length is of the latter; the thrust may be seen under and to the south of the waterfall. It dips quite steeply [~55°], as is also the case at the few other exposures of this fault; a possible reason for this includes [back] rotation by later thrust ramps. It is the case that outcrop evidence of thrust sense of shear for this fault, here and at the few other localities where it is exposed, is not overwhelmingly convincing. An alternative explanation for the steep dip, also lacking convincing outcrop evidence, is that the fault is extensional, or has a component of late normal displacement, and formed late in, or long after, the Taconic orogenic event. Even if extensional, this in no way contradicts the regional relationships demonstrating the overthrust origin for the Taconic Allochthon and the belt of melange and deformed flysch.

Stop 6a - Troy Frontal Melange Zone in road cut on Rte 151 west of Couse Corners
This cut (for location, Figure 7) exposes in all the north side and most of its length on the south side a similar greywacke block-rich shale matrix melange as seen at stop 5, the Troy Frontal Melange Zone. The exposure lies a few hundred meters west of the [here unexposed] trace of the Taconic Frontal Fault. It is close to a unique locality first investigated by Ruedemann (1901b), the carbonate conglomerate of Rysedorph Hill [see below, stop 6b] which is the main reason for stopping here in addition to stop 5.
Within the greywacke-shale melange here, late quartz veins like those seen earlier cut all other structures. One block of wacke about 20 meters from the east end of the cut on the north side shows a slate with cleavage oblique to bedding on part of one margin, and this cleavage is clearly cut by the lenticular phacoidal melange matrix fabric. Some of the wacke blocks in this cut have angular, fracture-controlled margins, others have a more rounded and smoothed appearance, possibly indicating they were not fully consolidated upon incorporation. The westernmost outcrop along the south side of Rte 151 here shows a quite different assemblage, with both dark grey/black and green shale melange matrix, and only modest-sized [~10-40cm] sideritic mudstone blocks; it is identical to parts of the exposure in Cohoes Gorge, seen at stop 4. The contact with the greywacke block-rich melange to the east is not exposed, but is inferred to be a significant fault. This melange type forms the matrix on the west side of the exposure of the Rysedorph Hill conglomerate, located a few hundred meters to the north.

Stop 6b - Rysedorph Hill Conglomerate. ASK PERMISSION at the house on the west side of Olcutt Lane BEFORE entering this property. Please do NOT hammer this outcrop.
A limestone conglomerate, from which Ruedemann obtained a fauna ranging in age from the Cambrian through the medial Ordovician, forms a unique exposure on part of this hill. Walk up the slope within the woods from the unsurfaced Olcutt Lane, starting before the first bend to the east (Figure 7). Dark and green shale melange with small sideritic mudstone blocks is found, mostly as loose shale chips and fragments, on the slope. The limestone conglomerate and breccia is found forming a knoll, and also as loose fragments, near the top of the first slope. Much written about this famous [notorious?] locality presumes it to be in stratigraphic arrangement with the surrounding shales and greywackes. As you have seen from the roadcut, this is an untenable hypothesis, and the conglomerate/breccia must form a large block, in the exotic matrix melange, or on the contact of this melange with the block-rich greywacke melange to the east. Nonetheless, the large age range of the fauna in this small occurrence of limestone conglomerate needs explanation, even though it is now contained in a block within melange. We suggest that the limestone conglomerate/breccia may be explained by talus accumulation below a normal fault scarp produced by flexural extension in the outer trench slope of the Taconic foredeep basin [Bradley and Kidd, 1991], and the subsequent picking up of a sample of this breccia into the advancing accretionary thrust wedge bordering the Taconic Allochthon. Strata containing physically similar carbonate conglomerates/breccias do occur within the intact stratigraphic sequence in the Taconic Allochthon, but they nowhere have extended faunal age ranges, and none are known with ages younger than early Ordovician.

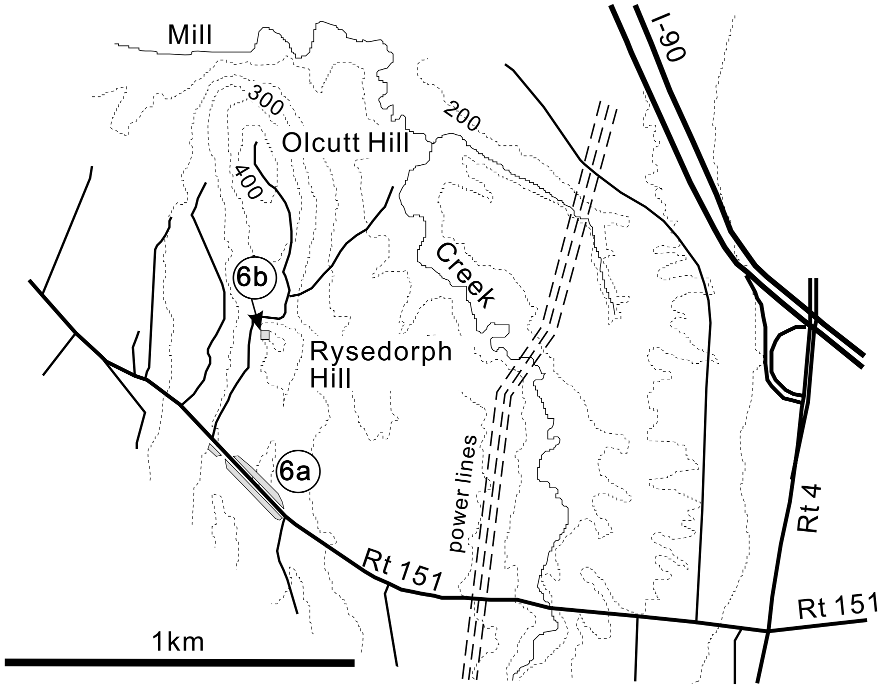


Fig 7. Location map for stop 6a and 6b, Route 151 and Rysedorph Hill

Stop 7 - Outcrops of melange and flysch in old railroad cut and bed of Normanskill [Ruedemann's "type" section]
These outcrops form the "type locality" of Ruedemann for the "Normanskill Formation", mainly because of the fauna he obtained here at Kenwood, and "nearby", including Stop 8 at South Glenmont. As you can see, structural disruption is prominent, and the bedded sections seen between faults have no defined, or definable, top or base. In addition, the use and abuse of the term Normanskill since Ruedemann, especially as a time-stratigraphic term, makes it inappropriate to use it for the general lithic assemblage of flysch greywacke and shale, which is, despite the structural disruption, quite well exposed here. In the creek bed, if the water level is not too high, a downward-younging bed in the crest of an antiform may be seen (Figure 8), with the turbidite sole structures exposed on a surface defining the fold hinge. This structural complexity is unusual for the bedded greywacke-shale sections in the Hudson Valley; Vollmer suggested that the stratigraphic inversion represented by the downward-facing nature of this fold may have been produced by slumping, with the fold being the regional set later superimposed on the already inverted section. This outcrop maps near the eastern margin of the Mohawk River Central Melange Zone (Figure 2).

Stop 8 - South Glenmont locality of allochthonous Mt. Merino Cherts
Black, grey, and green cherts, some with burrow mottling, as seen in this set of exposures, are characteristic small and large blocks in the exotic melanges. However, they are always blocks, or fault-bounded slices, in this context. Identical chert lithologies are found in stratigraphic sequence with other rock types only within the Taconic Allochthon. There they occur only at one position in the stratigraphic succession, at the top of varied continental rise-deposited sediments derived from the Cambro-Ordovician passive margin of North America, and immediately below black graptolitic shales with *N. gracilis* graptolite faunas, which are in turn overlain by greywacke-shale turbidites of the Pawlet Formation. This locality yielded to Ruedemann the most abundant fauna found in the greywacke-shale area of the "Normanskill", and has as a result strongly influenced the presumed age of the flysch of the Hudson Valley. We are of the opinion that all occurrences of these cherts are highly allochthonous, representing tectonically separated, and perhaps erosionally isolated, pieces originally emplaced as integral parts of the Taconic Allochthon. We think that all ages derived from the faunas in the cherts, and the related black graptolitic slates, are therefore older, by at least some small amount, than any of the greywacke-shale flysch of the Hudson Valley. Prominent down-dip plunging folds (Figure 9) are seen in several parts of this set of outcrops; these probably represent rotation of originally shallow-plunging folds by heterogeneous simple shear associated with thrusting, as indicated by Vollmer and Bosworth (1984) for the more strongly deformed flysch and melange generally. This locality maps close to the eastern boundary of the Mohawk River Central Melange Zone (Figure 1).

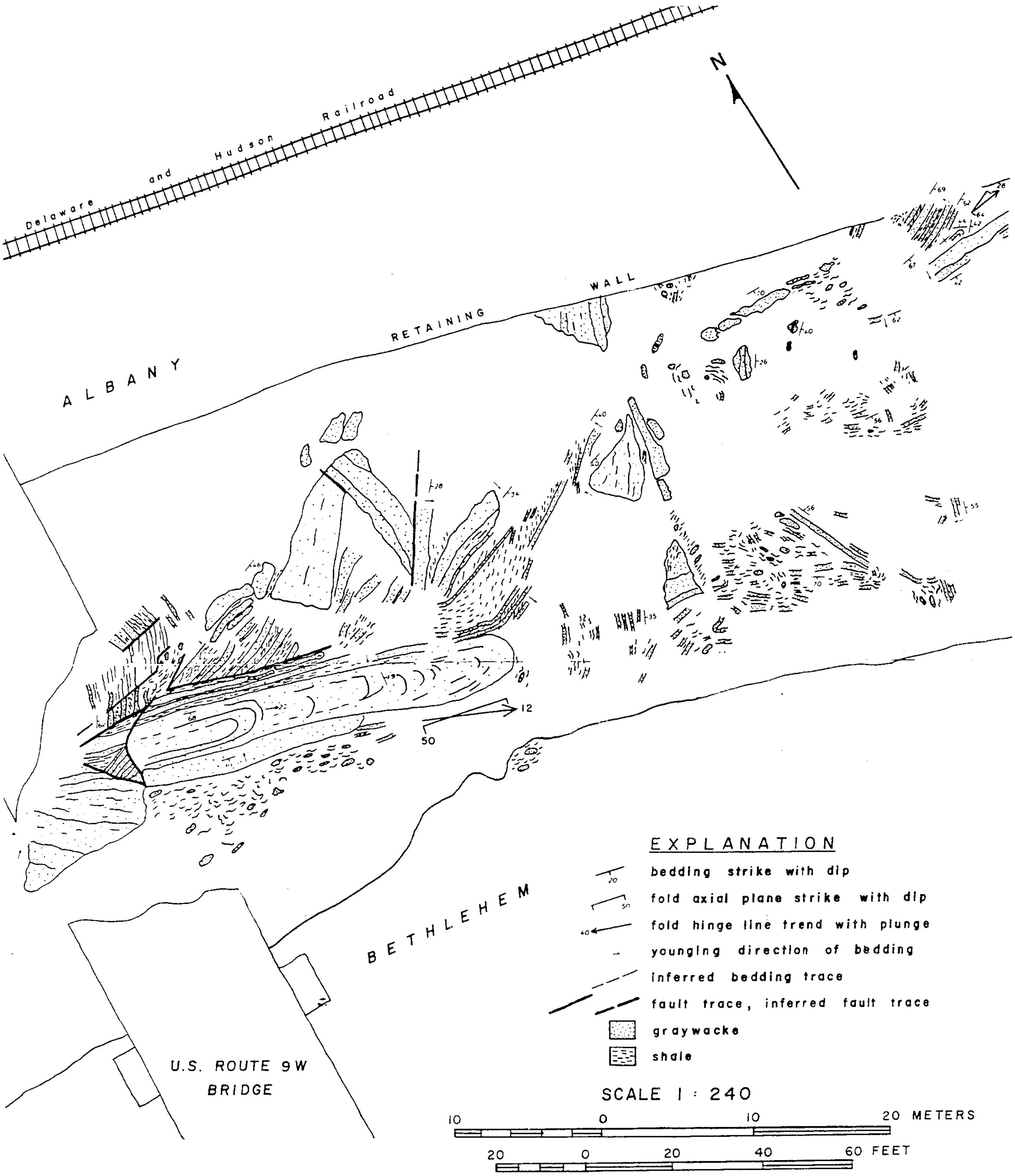


Fig. 8. Outcrop map (from Vollmer, 1979) of part of the Normanskill at Kenwood (Stop 7), Type locality of the Normanskill "Formation" of Ruedemann.

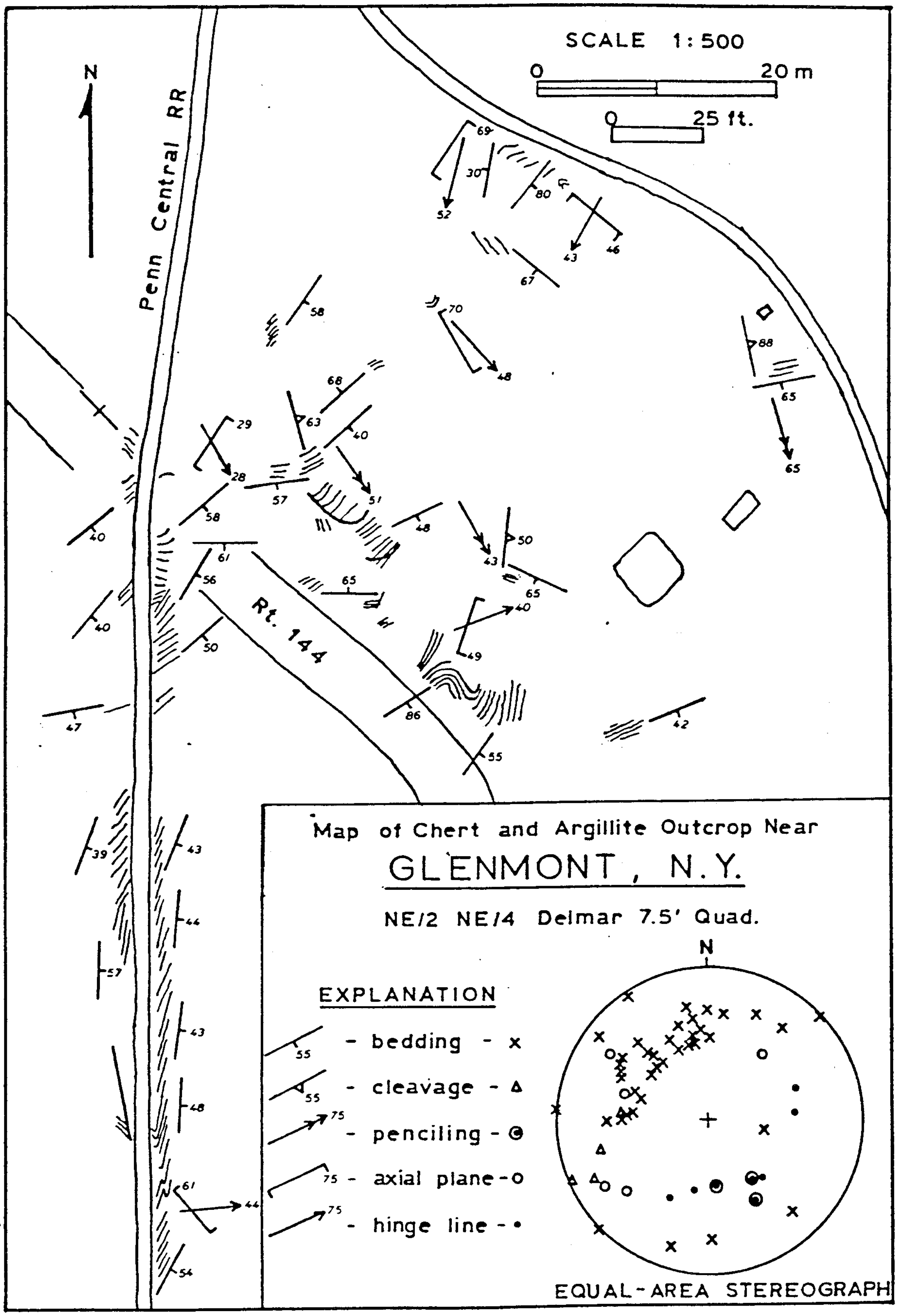


Fig. 9. Outcrop map of South Glenmont locality (Stop 8), exposures of Mount Merino Chert, part of a Large slice or block in Mohawk River Central Melange Zone (east part). From Vollmer (1979).

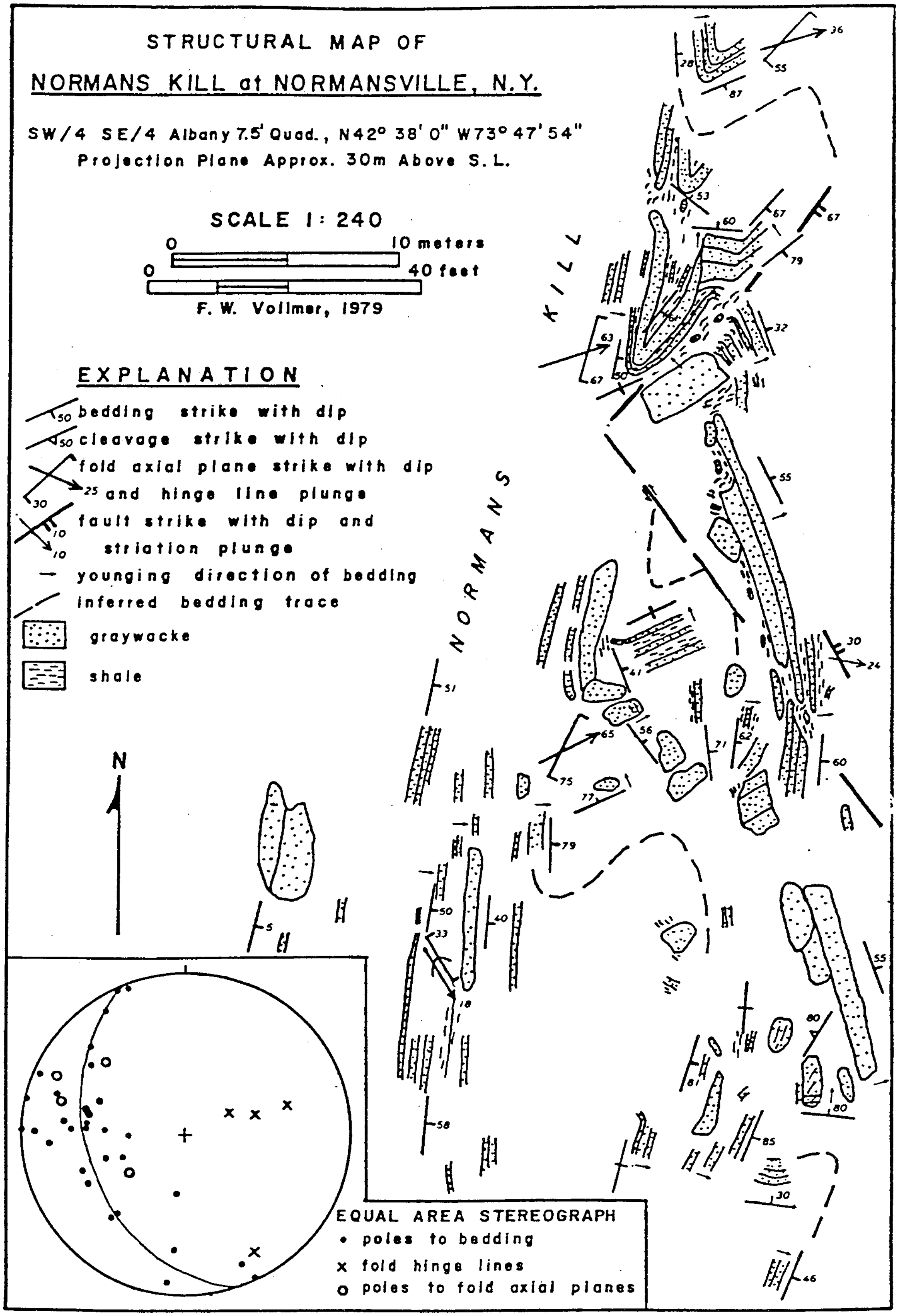


Fig. 10. Map of outcrop at Normansville on the Normanskill (Stop 9). Broken formation transitional to Melange; within Mohawk River Central Melange Zone (east part).

Stop 9 - Normansville melange and broken formation
This outcrop in the north bank of the Normanskill exposes shaly rocks with greywackes that can be demonstrated to be in part a broken formation (Figure 10), with partly traceable sedimentary layering , rather than a melange with completely disrupted layering. Additionally, this locality contains some folded quartz veins. The outcrop also maps within the Central Melange Zone.

Stop 10 - Feuri Spruyt and Callanan Quarry - unconformity with Helderberg Limestones overlying melange. PERMISSION REQUIRED - request permission in advance by calling 518-767-2222, or writing Callanan Industries Inc, Corporate Headquarters, South Street, South Bethlehem, NY 12161

This locality (Figure 11) shows carbonates of the basal Helderberg Group [early Devonian] unconformably overlying the folded greywackes and shales, and melange of the Ordovician.The boundary between the Ravena Greywacke Zone and the eastern side of the Mohawk River Central Melange Zone passes beneath the unconformity just west of the quarry (Figures 1, and 11). In particular, the unconformable relation to the melange demonstrates that the fault zone which created the melange is an Ordovician structure, and predates entirely, at this position, the Acadian structures that fold the overlying Devonian strata south of this place (Bosworth and Vollmer, 1981). The map relationships, and unfaulted structural condition of the Helderberg Group, west of this locality, shows that all the width of the melange belt comprising the western and eastern exotic melange, which goes beneath this unconformity, must also be an Ordovician, and Taconic-age structure.

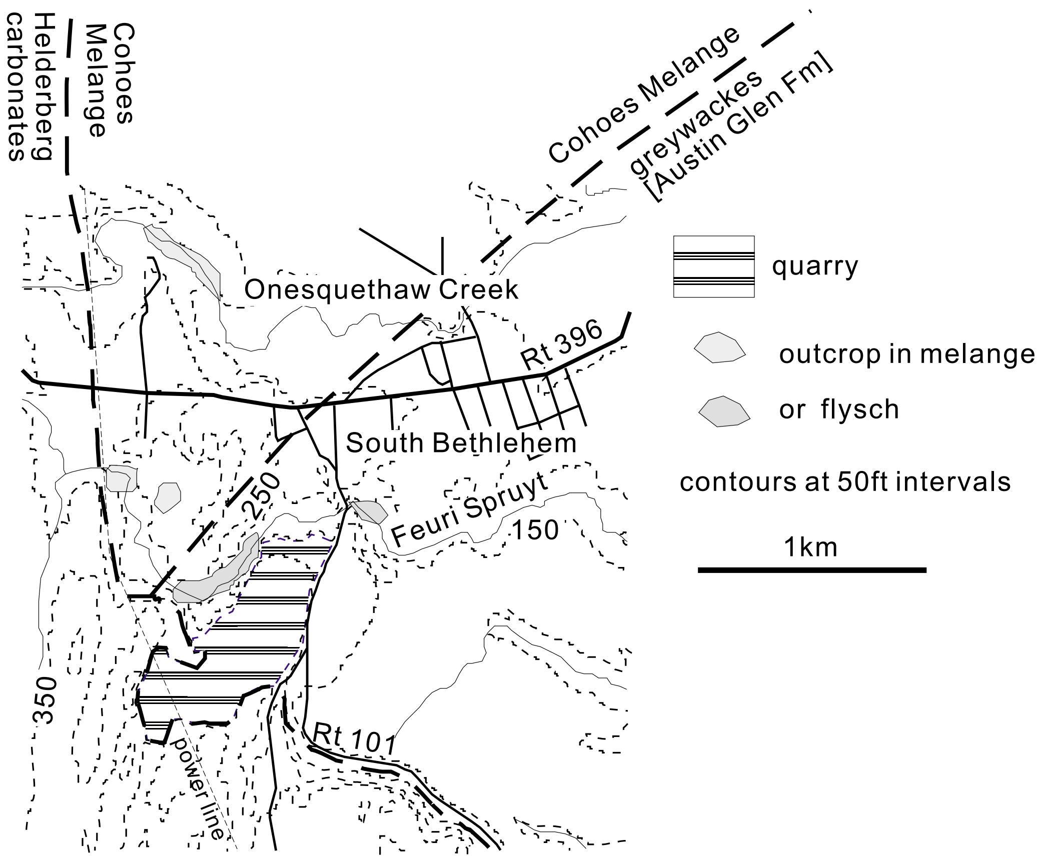


Fig 11. Sketch location map of Callanan Quarry, South Bethlehem and adjacent Feuri Spruyt Creek [Stop 10].

Field trip road log

From Union College, follow Union St east to Rte 146, or Lenox Rd and Nott St [6] or Rosa Rd/Providence Ave [8] east to Rte 146 and turn left to go north on Rte 146 Balltown Road

	Mileage Increment	Cumulative
Mohawk River bridge heading north on Rte 146	0	0
Junction 146 and River Road; turn right	0.4	0.4
view over Mohawk to flat Schenectady Fm in south bank [0.6]		
Junction with Grooms Road - keep right	1.3	1.7
Turn right onto Brian Drive	1.7	3.4
Park at end of road	0.15	3.55
Stop 1 - view of flat-lying Schenectady Fm. flysch and shale outcrop on south bank of Mohawk River		
Return to River Road, turn right	0.15	3.7
Crossroads at top of rise, turn right	1.4	5.1
Park in area on right before gate	0.2	5.3
- walk down road to **Stop 2 - folded and faulted flysch of Vischer Ferry Zone**		
Return to junction with River Road	0.2	5.5
Proceed straight across, north along Sugar Hill Road		
Turn right onto Rte 91, Grooms Road	1.8	7.3
Go east on Grooms Road to junction with Rte 9	5.5	12.8
[2.7 light; 3.8 cross over Northway]		
Proceed across Rte 9 following Rte91; turn left onto Rte 236	0.2	13.0
Turn left onto Fellows Road	1.3	14.3
Stop sign at Rte 146, go straight across and	1.2	15.5
Park on right just after crossing	0.05	15.55
- walk to east along Rte 146 inside the guard rail to roadcut **Stop 3 - thick-bedded Austin Glen Formation flysch of Halfmoon Greywacke Zone, folded, with melange on small thrust fault**	0.05	15.6
Turn around, take right at stop sign onto Rte 146 going west		
Turn left at light at junction with Rt 9	1.6	17.2
Proceed south on Rte 9 [Western Exotic Melange just to west near Sitterly Rd 1.2mi; 2.3 Grooms Road; 3.4 Crescent-Vischer Ferry Road; 3.6 center of Mohawk bridge]		
Turn left onto Cohoes-Crescent Road	3.9	21.1
Proceed along south bank of Mohawk River into Cohoes [0.4 view over river to outcrops of eastern Melange; 0.9 Crescent Dam and power plant; 2.5 Cohoes Falls on left; 3.0 Harmony Mills; 3.6 railroad crossing]; turn left at intersection with Rte 32	3.6	24.7
Cross Mohawk bridge [0.2]; take left turn at light Clifton St	0.4	25.1
Right turn onto Grove Street	0.1	25.2
Left turn onto Grace Street	0.1	25.3
Left turn onto Columbia Street	0.3	25.6
Park near end of street [turn around first]	0.1	25.7
walk south from end of street into open ground; angle 45 degrees right and cross main path along cliff top; find path down cliff close to where bushes start [distance to the top of this path from end of pavement on Columbia Street is less than 100m]- **Stop 4 - Cohoes Melange outcrop, eastern Mohawk River Central Melange Zone; down path and along base of cliff to Cohoes Falls.**		
Return to Rte 32 reversing directions above; turn right	0.6	26.3
Turn left at light onto Rte 787	0.3	26.6
[2.6 cross under Rte 7]		
Take exit for Rte 378 East	6.0	32.6
Cross Menands Bridge over Hudson River; curve to to left to light; go straight	1.0	33.6
Intersection with Rte 4. Fork left to follow Rte 4 north	0.1	33.7
[shallow right fork to follow Rte 4 at 0.3 and 0.6]		

Turn right at Canal Ave [currently not marked - just before small bridge, one way sign]	1.3	35.0
[if you miss this turn, take next available right; at intersection with Hill Street turn right, pick up log at bridge/Canal Ave]		
Turn half right onto Hill Street	0.3	35.3
Turn left onto Linden Ave	0.1	35.4
Turn left into parking lot next to road	0.2	35.6
walk down path to **Stop 5 - Poestenkill Gorge, Taconic Frontal Fault and Troy Frontal Melange Zone**		
Leaving parking lot, turn right		
Intersection with Hill Street; turn left	0.2	35.8
Go up hill to sharp intersection with Campbell Ave; turn sharp right	0.9	36.7
Intersection with Rte 4, Vandenburgh Ave, turn left onto Rte 4	1.1	37.8
at next light at top of hill, take center lane for straight ahead		
Proceed south on Rte 4 [2.0 RPI Tech Park; 3.7 Rte 43 enters from left; 4.4 Rte 43 leaves to right; 5.6 cross Interstate 90]		
Turn right at intersection with Rte 151 at Couse Corners	6.2	44.0
Park well off on hard shoulder near east end of large roadcut	1.0	45.0
Stop 6a - Troy Frontal Melange Zone		
Turn right onto Olcott Lane	0.1	45.1
Park on right- ask permission at house on west side of street	0.2	45.3
walk up slope to east to **Stop 6b, Rysedorph Hill, carbonate conglomerate block in melange**		
Return to Rte 151, turn right	0.2	45.5
Turn left onto Sherwood Ave	0.3	45.8
Turn right onto Columbia Turnpike,Rte 9 & 20	0.7	46.5
Proceed straight down hill into Rensselaer; last light before road curves to right is at:	1.5	48.0
Proceed ahead onto ramp to Dunn Memorial Bridge over Hudson River; at western side take exit marked for Interstate 787 South [0.7 from last light]		
South on I-787 to next exit, marked for Port of Albany [at 1.5]		
End of ramp, at light, joins Rte 32; turn left	1.8	49.8
South on Rte 32; at light turn part right onto Old South Pearl Street	0.6	50.4
Go to dead end of street, turn, and park	0.25	50.65
walk up path on left side of culvert at end of street to railroad embankment, turn right, and walk up trackbed 0.1mi to **Stop 7 - outcrops of melange and flysch in cut and bed of Normanskill [Ruedemann's "type" section]**		
Return to Rte 32, turn right	0.25	50.9
Proceed south; intersection with Rte 144; continue straight [onto 144]	0.6	51.5
Park at area on right just before road crosses bridge above railroad tracks as it curves to left and downhill	1.4	52.9
outcrop in road cut, by road and to east of bridge up to power line, [and along railroad tracks] **Stop 8 South Glenmont locality of allochthonous Mt. Merino Cherts**		
From parking area, return north along Rte 144 to intersection with Glenmont Road, Rte 910A - turn left	0.3	53.2
Intersection with Rte 9W; turn right onto 9W going north	1.5	54.7
[1.3 and 1.6 intersections with Rte 32; 1.9 cross Normanskill bridge;2.4 entrance to I-787; 2.5 entrance to NYS Thruway I-87]		
Light at junction with Southern Boulevard, go straight	2.8	57.5
[go straight at light where Rte 9W angles to right]		
Junction with Rte 443 Delaware Avenue; turn left	0.5	58.0
Turn left onto Mill Road	0.4	58.4
Park at old bridge	0.2	58.6
go down to east of old bridge to riverside outcrop **Stop 9 - Normansville melange and broken formation**		
Return to Rte 443; turn right	0.2	58.8
Turn right at light onto McAlpin Street	0.4	59.2

continue straight onto Southern Boulevard, and Rt 9W		
Go straight past Thruway and I-787 entrance	1.0	60.2
Follow Rte 9W to Beckers Corners, intersection with Rte 396, turn right	4.1	64.3
Turn left in South Bethlehem onto Rte 101	2.7	67.0
Park in visitor lot on right	0.5	67.5

ASK PERMISSION inside Callanan office building across road; it is preferable to request permission in advance by calling 518-767-2222, or writing Callanan Industries Inc, Corporate Headquarters, South Street, South Bethlehem, NY 12161

Stop 10 Feuri Spruyt and Callanan Quarry - unconformity with Helderberg Limestones overlying melange

Return to Rte 9W reversing directions above; go straight across continuing on Rte 396	3.2	70.7
Intersection with Rte 144; turn left	2.2	72.9
Entrance to NYS Thruway; turn left	0.4	73.3

End of road log

Albany I-787 exit 23; Albany exit 24 for I-87 Adirondack Northway and airport; Schenectady exit 25 to return to Union College area.