A STRUCTURE SECTION IN EASTERN NEW YORK SHOWING VARIATION IN STYLE OF DEFORMATION ACROSS THE TACONIC ALLOCHTHON: DISCUSSION [1]

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INTRODUCTION

The compilation of a structure section across the north-central portion of the Giddings Brook slice of the Taconic Allochthon by Steuer and Platt (1981) is a commendable and timely endeavor. Enough detailed surficial bedrock mapping has been completed in the northern Taconics over the last two-and-a-half decades to warrant a thorough analysis of both across- and along-strike stratigraphic and structural trends. As noted by Steuer and Platt (p. 135), maps and sections from adjacent field areas in the Taconics frequently show quite dissimilar interpretations of structural style and are accompanied by widely varying reconstructions of deformational histories. Our mapping to the south and in part overlapping with Steuer and Platt's field areas (Bosworth, 1980), as well as a short distance to the north (Jacobi, 1977; Rowley, et al., 1979; Rowley, 1980, Ph.D. in progress) (fig. 1) suggests to us structural and stratigraphic interpretations that both partially support and contradict those of Steuer and Platt. This journal provides a logical forum in which to air both points of agreement and differences.

Our discussion is in two sections, first a brief discussion of regional stratigraphy of the western Giddings Brook slice, and second, a more thorough discussion of structural relationships within the allochthon, which is the focus of Steuer and Platt's paper.

STRATIGRAPHY

Traditionally northern and central Taconic stratigraphy has included those units described by Steuer and Platt. The notable facets of this stratigraphy are: (1) a lower greenish sandy to silty mica-bearing unit (Bomoseen), lacking fossils; 2) a green/black boundary, the black slaty units (Hatch Hill-West Castleton) being early, medial, and late Cambrian in age; 3) early to medial Ordovician slates, silty slates, thin quartzites, and cherts (Poultney, Indian River, and Mount Merino); and 4) a flysch sequence (Pawlet or Austin Glen) of medial Ordovician age, at least locally unconformably overlying lower sequence units (Zen, 1961, 1964, 1967; Theokritoff, 1964; Potter, 1972; Fisher, 1977; among many others). Our recent mapping of several areas within the Giddings Brook slice (fig. 1) has led us to propose a somewhat different stratigraphy that can be reconciled with Platt (1960) and Steuer and Platt as shown in figure 2. The important differences with the traditional stratigraphy are: 1) the recognition of two distinct green slate units (Truthville and Mettawee); 2) the presence of two green/black boundaries within the Cambrian section; 3) the completely conformable nature of this stratigraphic sequence including the contact at the base of the Pawlet Formation (Rowley et. al., 1979; Jacobi, 1977; Rowley, 1980; Bosworth, 1980).

From our recent mapping, including a small map area in the Cossayuna area (Pindell, unpubl. ms., 1980) we believe that the lithostratigraphy orginally defined by Jacobi (1977) in the Granville, New York, area is applicable to at least western portions of the northern and central Giddings Brook slice. Significant variations are however recognized by us from west to east across the allochthon. These variations occur across major thrust faults within the areas that we have mapped (Rowley, et al., 1979; Rowley, 1980; Bosworth, 1980). Since Steuer and Platt did not publish a map to go with their cross-section it is difficult for us to assess the possible implications of applying our somewhat different interpretation of the stratigraphy, or for that matter structure to their area. We have however found that in other areas, for example west of Lake Bomoseen (Rowley, Ph.D. in progress), and in the Cambridge Quadrangle (Metz, 1967, 1980) (reconnaisance Bosworth) that significant changes may result from reinterpretation with our stratigraphic sequence.

STRUCTURE

Steuer and Platt focus primarily on the structure and variation in style across the Taconics. They discuss two generations of folds and associated axial surface foliations, thrust faults, lateral variability, and constraints on deformation timing. Although we agree with much of what they describe, we find several facets of their discussion to be inconsistent with our observations in regions adjacent to the south and partially overlapping with their area, as well as to the north near Granville, New York.

Folds

Steuer and Platt describe their early folds, referred to by them as P_1, as tight to isoclinal, overturned to the west, with half wavelengths of kilometer magnitudes. The P_1 folds have axial planes that vary from subvertical to sub-horizontal from west to east across the allochthon. A penetrative slaty cleavage, their Cl_1, is axial surface to these folds, and demonstrably developed in consolidated rocks. A second generation of folds, P_2 of Steuer and Platt, appear coaxial with P_1 folds, and range from open to tight, with subvertical to south-easterly dipping axial surfaces. P_2 folds achieve kilometer wavelengths, and are characterized by an axial surface crenulation cleavage, their Cl_2.

Steuer and Platt discuss these two generations of folds and associated cleavages in their sections on "lateral variability" and "constraints on deformation timing." In these sections they make the following statements: 1) Along the western edge of the alloch-

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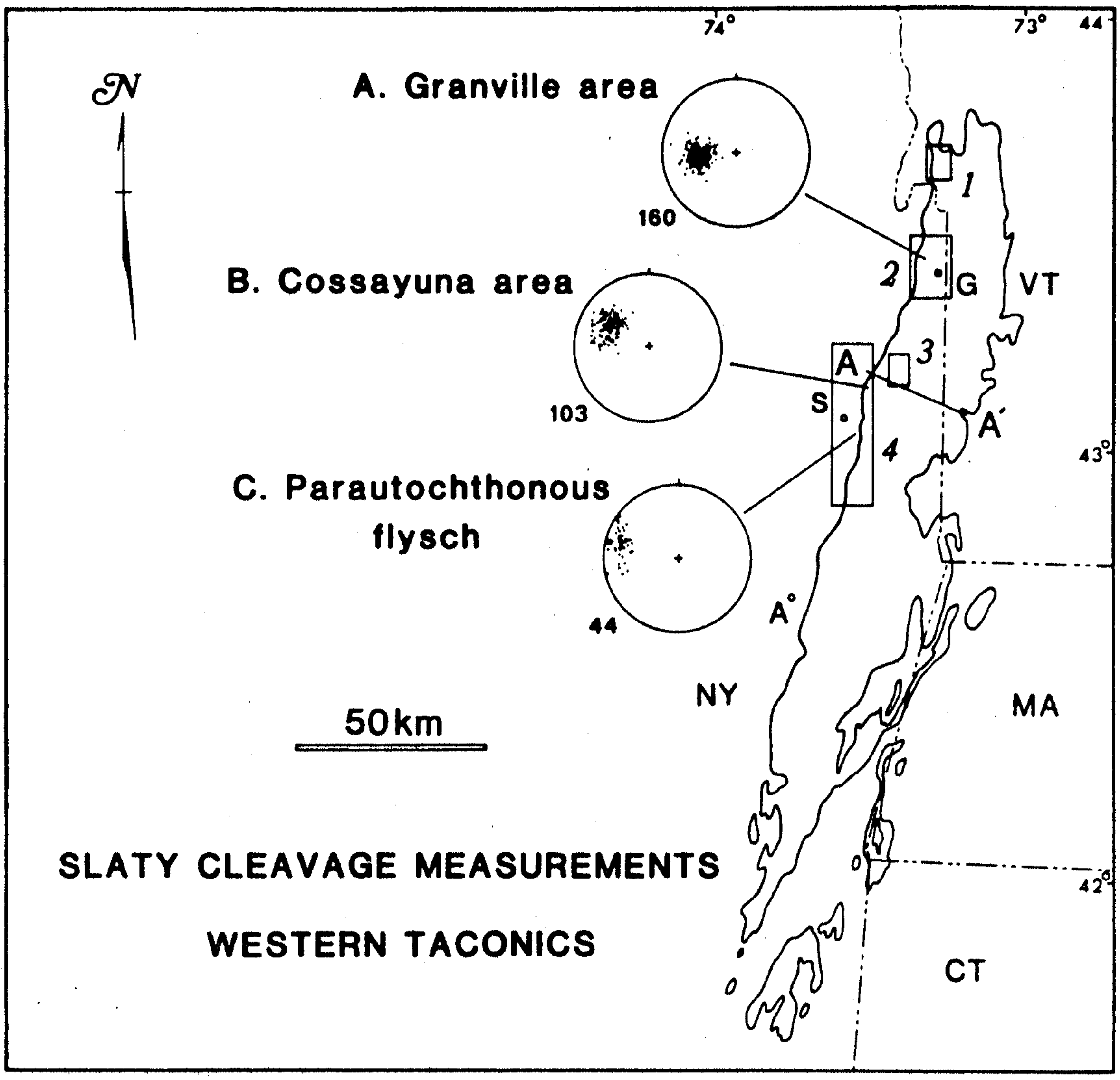

Figure 1. Location of field areas (numbered boxes) discussed and slaty cleavage measurements from representative subareas of the western Taconics. Stereoplots are poles to cleavage on equal-area Schmidt net projections. Number of points is given to the lower left of each plot. It should be noted that plot #3 is for measurements in the flysch immediately adjacent to the Taconic Allochthon (outlined). Field areas as follows: 1.) Lake Bomoseen area (Rowley, Ph.D., in progress), 2.) Granville area (Jacobi, 1977; Rowley, 1980), 3.) Cossayuna Lake area (Pindell, ms), 4.) Fort Miller, Schuylerville and Schaghticoke 7½' quadrangles (Bosworth, 1980). A - A' is approximate location of Steuer and Platt's (1981) cross-section. G = Granville, S = Schuylerville, A = Albany.

thon "The effect of a P_2 overprint . . . is difficult to assess. As P_1 folds in this area assume a very similar orientation to coaxial P_2 folds, separation of these structures is usually not possible." 2) "As initial folding (P_1) and attendant cleavage (Cl_1) are thought to be truncated at the allochthon edge, while P_1 folds deform all Taconic rocks at least below the Pawlet Graywacke, we propose that this deformation is synchronous with allochthon emplacement...." (p. 136-137). 3) "In the western portion of the klippe in the Cossayuna-Salem area, P_1 folds are nearly upright, assuming a similar orientation to P_2 folds. Cleavage which passes from allochthon to autochthon is thought to be Cl_2, as autochthonous shales were unlithified and unable to receive cleavage at the time of P_1 and allochthon emplacement." (p. 137).

Our mapping suggests somewhat different interpretations, and using the above summary of Steuer and Platt's discussion as a format we would like to outline some of the more salient points of difference.

We recognize both generations of folds and foliation described by Steuer and Platt, but take exception to some of their characterization of these structures, and in addition we recognize a more complicated history

STRATIGRAPHIC NOMENCLATURE OF THE WEST-CENTRAL TACONIC ALLOCHTHON

	Previous Stratigraphy: Southern Washington County; Platt, 1960; Metz, 1967		Principal Lithologies	Revised Stratigraphy: Southern Washington County; Bosworth, 1980		Revised Stratigraphy: Northern Washington County; Jacobi, 1977; Rowley, et al., 79	
ORDOVICIAN	Austin Glen Fm.		Intbdd. graywackes & dark gray shale	Austin Glen Fm.		Pawlet Fm.	
	Mt. Merino Fm.	* Middle	Graptoliferous black shale	Mt. Merino	Upper	Mt. Merino	Stoddard Rd. member
		Upper	Black chert & shale		Lower		Lower chert member
		Lower	Red and green slate	Indian River Fm.		Indian River Fm.	
	Poultney Fm.	Upper	Ribbon quartzites & gray-grn. slate	Poultney Fm.		Poultney Fm.	Crossroad member
		Lower	Thin limestones and dark gray shale				Dunbar Rd. member
CAMBRIAN	Hatch Hill Fm.		Intbdd. dolom. ss. and black shale	Hatch Hill/West Castleton Fm.		Hatch Hill/West Castleton Fm.	
	"unnamed green shale" of Platt		Green, purple and maroon slates	Mettawee Fm.		Mettawee Fm.	
	West Castleton Fm.		Thin ls., ls. congl., qtzt. & black shale	Browns Pond Fm.		Browns Pond Fm.	
CAMBRIAN?	Bull Fm.	Mettawee member	Micaceous grn. shale	Truthville Fm.		Truthville Fm.	
		Bomoseen member	Micaceous grn. wacke	Bomoseen Fm.		Bomoseen Fm.	

* Sequence misinterpreted

Figure 2. Proposed correlation between stratigraphy of earlier workers in west-central Taconics (Platt, 1960; Metz, 1967) and stratigraphy of the Granville area (Jacobi, 1977). Modified from Bosworth, 1980.

involving pre-cleavage, non-soft sediment folding, and at least one additional later deformation. The pre-P_1 (our F_1) generation of folds is at present only recognized locally in western portions of the Giddings Brook slice, as for example at Willard Mountain (Schuylerville Quadrangle, Bosworth, 1980), and south of South Poultney, Vermont (Wells Quadrangle, Rowley, 1980). These pre-P_1 folds appear to be relatively large, recumbent isoclinal folds with an unknown but greater than 100 meter wavelength, that lack an obvious axial surface foliation. P_1 generation folds (our F_2) fold the pre-P_1 fold axial surfaces and at least locally give rise to downward facing P_1 (F_2) folds. In fact it is the presence of these downward facing P_1 (F_2) folds that led us to recognize this earlier phase of folding. This raises the following question: are all of the P_1 folds mapped by Steuer and Platt demonstrably or only assumed to be upward (westward) facing? If they are only assumed to face upward, then significant modification of their cross-section may be necessary.

Steuer and Platt state that P_1 fold axial planes are subvertical in the west at several points in their paper (e.g. p. 135 and 137) but at another point (e.g. p. 136) suggest the P_1 axial surface dips 50 degrees to the east. We have made detailed observations of the attitude of slaty cleavage which is axial surface to P_1 (F_2) folds. Figure 1 shows some of this data plotted on equal area stereonets for several different areas along the front of allochthon. Our observations show that P_1 (our F_2) folds have a moderately inclined (35 to 50 degrees) axial surface orientation along the western edge of the allochthon, and not a subvertical attitude as contended by Steuer & Platt.

From our examination of the field relations along the western edge of the allochthon we feel, contrary to Steuer and Platt (statement 1) that it is possible to assess the effect of a P_2 overprint in the west and to distinguish these two generations where present. The stereonets (fig. 1) show that P_2 folding (our F_3) is not significant in the west. Poles to slaty cleavage define a tight point maxima in each of the different areas. This requires that either no significant refolding by P_2 has occurred, or that P_2 involves isoclinal folding of the slaty cleavage. We would expect to observe such folds, at least locally, if the second alternative was true. In addition, post slaty cleavage folds should be observed to invert the sequence, and produce downward facing P_2 (F_3) folds, which neither we nor Steuer & Platt have recognized.

As we consider P_2 folding to be insignificant along the western edge of the allochthon, we feel compelled to disagree with Steuer and Platt's statement (number 3 above) concerning which cleavage in the allochthon is correlative with the slaty cleavage observed in the "autochthonous" shales to the west.

First, we would prefer to consider these rocks as parautochthonous since they are highly deformed, and from age considerations clearly transported (see Rowley and Kidd, 1981, and Bosworth and Vollmer, 1981). Second, the rocks are dominantly interbedded greywackes and slates, with some interbedded pebbly and locally bouldery mudstones, not simply shales. These rocks are tightly folded with a moderately to well developed axial surface cleavage, commonly a slaty cleavage (Bosworth and Vollmer, 1981; Bosworth, 1980). As these structures record significant shortening and since P_2 folds are insignificant along the western edge of the allochthon, it appears to us that this cleavage must be essentially correlative with the slaty cleavage of the allochthon. However it is likely that cleavage and folding occur diachronously during deformation, and therefore the cleavage in the allochthon may have developed earlier than that in the parautochthonous flysch to the west. We think they are structurally equivalent, and therefore that if a correlation is to be made it should be with the slaty cleavage of the allochthon. However, our observations show (Bosworth, 1980; Bosworth and Vollmer, 1981) that the cleavage within the parautochthonous flysch is differently oriented than is observed in the adjacent allochthon (fig. 1). It is clear from this that the frontal thrust of the allochthon is a post-cleavage structure and that cleavage does not "pass" from allochthon into "autochthon" (statement 3).

Steuer and Platt are ambiguous about the relationship of the Pawlet to the P_1 folds (cf. p. 135 versus 136-137). We have previously argued (Rowley and Kidd, 1981) that the conformable relationship between the Pawlet and underlying Mount Merino indicates that the Pawlet was deposited on an undeformed and untransported substrate, which allows us to infer that the allochthon was initially stacked from east to west (top to bottom). In addition our recognition of a pre-P_1 generation of folds, in which the Pawlet is intimately involved, leads us to conclude that the Pawlet was deposited prior to and therefore must have been completely involved in P_1 folding.

Thrust Faults

Steuer and Platt discuss thrust faults only briefly in their paper, and appreciate the difficulty of ascertaining the detailed relationships associated with many of these thrusts in the field. We agree with Steuer and Platt that many thrust faults within the allochthon post-date P_1, as demonstrated by the cross-cutting relationship of the faults and P_1 axial planes (See Rowley et al., 1979, Middle Granville Thrust, etc.,). Our mapping, however, suggests that there are many different generations of thrusts within the allochthon, including significant pre-P_1 thrusts, for example exposed in a roadcut along Route 4 just across the New York-Vermont border in Vermont (Rowley, Ph.D. in progress). As well, more than one generation of post-P_1 thrusts are also discernable. We are sympathetic to Steuer and Platt's suggestion that at least some of the post-P_1 thrusts are related to P_2 deformation as has also been suggested by Rowley et al. (1979). In addition, based on the relationships depicted by Steuer and Platt on their section (plate 1) it appears that the basal thrust of the allochthon bears a somewhat different relationship to the deformation within the allochthon than that described by them. Based on their section, we suggest that 1) P_1 deformation completely pre-dates the basal thrust, as it cross-cuts both limbs of P_1 folds; and 2) the basal thrust post-dates P_2 since it does not conform to the form surfaces of the chevron type P_2 folds on the east side of the allochthon.

Constraints on Deformation Timing

Steuer and Platt state that pebble to boulder size blocks of Taconic lithologies occur within the "autochthonous" "Canajoharie" shale, with at least some displaying possible pre-depositional deformational features. We have also noted such pre-depositional deformation features both in allochthonous Pawlet and parautochthonous Austin Glen greywackes (Rowley and Kidd, 1981; Bosworth and Vollmer, 1981) and believe these occurrences unequivocably demonstrate that at least some deformation and metamorphism in the source area predate Pawlet and Austin Glen ("Canajoharie") deposition.

We wish to point out that Steuer and Platt make the assumption that the "autochthonous" shales were "unlithified and unable to receive cleavage at the time of P_1 and allochthon emplacement" (p. 137), and that the time required for lithification constitutes an important "limiting factor for elapsed time between allochthon emplacement and P_2 deformation...." (p. 137). The data needed to support this assumption is not discussed. We point out that in modern trench environments young trench-fill turbidite sequences involved in accretionary prism deformation display rapid compaction and lithification and concomitant development of tectonic foliations (Moore and Karig, 1976). Thus we think that this assumption is unjustified without supporting observational evidence, and therefore does not constrain the timing of deformation.

In the final paragraph of their paper Steuer and Platt describe what they conceive of as the sequence of events necessitated by their observations. Our observations, many of which have been described elsewhere, suggest a somewhat different sequence briefly outlined below.

1) Pre-P_1 folding and thrusting of consolidated continental rise (Taconic Sequence) sediments, post-dating deposition of the Pawlet Formation.

2) P_1 folding, slaty cleavage development, and contemporaneous deposition of parautochthonous and autochthonous (?) flysch on the shelf.

3) Imbrication of allochthon, accompanied locally by folding and crenulation cleavage development in the west, intensity of deformation (P_2 folding; Cl_2- cleavage development) increasing markedly to the east.

4) Development of the present "frontal" thrust (see discussion in Rowley and Kidd, in press, a.) of allochthon on the west, associates with attachment of slivers of shelf carbonate onto the thrust, and syn-thrusting erosion of these carbonates to produce the Forbes Hill conglomerate (Zen, 1967). This constrains this deformation to medial to late Caradocian based on the fossils found within these rocks (Berry, 1962; Zen, 1967; Fisher, 1977) and therefore demonstrably Taconic and not younger in age (Rowley and Kidd, in press, b.).

As a final note we wish to emphasize that we appreciate the difficulty involved in constructing the type of cross-section that Steuer and Platt have prepared. As Steuer and Platt have noted, different workers have reached different conclusions in the Taconics, even in adjacent areas. As a result it is important that these differences be aired in free and constructive discussion, as we have attempted to do here.

REFERENCES

BERRY, W.B.N., 1962, Stratigraphy, zonation and age of the Schaghticoke, Deepkill and Normanskill Shales, eastern New York: Geol. Soc. Amer. Bull., v. 73, p. 695-718.

BOSWORTH, W., 1980, Structural geology of the Fort Miller, Schuylerville and portions of the Schaghticoke 7½' Quadrangles, Eastern New York, and its implications in Taconic geology: Ph.D. Thesis, Part I, SUNY at Albany, 237 p.

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: Jour. of Geol., v. 89, p. 551-568.

FISHER, D.W., 1977. Correlation of the Hadrynian, Cambrian, and Ordovician rocks in New York State: New York State Museum and Science Service Map and Chart Series no. 25, 75 p.

JACOBI, L.D., 1977, Stratigraphy, depositional environment and structure of the Taconic Allochthon, Central Washington County, New York: M.S. Thesis, SUNY at Albany, 191 p. (Note: Delano and Jacobi are the same person.)

METZ, R., 1967, Stratigraphy and structure of the Cambridge Quadrangle, New York: Ph.D. Thesis, Rensselaer Polytechnic Inst., 118 p.

________, 1980, Stratigraphy and structure of the Cambridge Quadrangle, New York: Northeastern Geol., v. 2, p. 44-53.

MOORE, J.C., and KARIG, D.E., 1976. Sedimentology, structural geology, and tectonics of the Shikoku subduction zone, southwestern Japan: Geol. Soc. Amer. Bull., v. 87, p. 1259-1268.

PLATT, L.B., 1960, Structure and stratigraphy of the Cossayuna area, New York: Ph.D. Thesis, Yale University, 126 p.

ROWLEY, D.B., 1980, Complex structure and stratigraphy of the lower slices of the Taconic Allochthon near Granville, New York: M.S. Thesis, SUNY at Albany, 258 p.

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, p. 186-242, in Friedman, G.M., (ed.), New York State Geol. Assoc., and N.E.I.G.C. Güidebook, 457 p.

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: Jour. of Geol., v. 89, p. 199-218.

________, in press a., Stratigraphic relationships and detrital composition of the Medial Ordovician flysch of western New England: implications for the tectonic evolution of the Taconic Orogeny: A reply to John Rodgers, Jour. of Geol., March 1982.

________, in press b., Stratigraphic relationships and detrital composition of the Medial Ordovician flysch of western New England: implications for the tectonic evolution of the Taconic Orogeny: A reply to Peter Geiser, Jour. of Geol., March, 1982.

STEUER, M.R. and PLATT, L.B., 1981, A structure section in eastern New York showing variation in style of deformation across the Taconic Allochthon, Northeastern Geol., v. 3, 134-137.

THEOKRITOFF, G., 1964, Taconic stratigraphy in northern Washington County, New York: Geol. Soc. Amer. Bull., v. 75, p. 171-190.

ZEN, E., 1961, Stratigraphy and structure at the north end of the Taconic Range in west-central Vermont: Geol. Soc. Amer. Bull., v. 72, p. 293-338.

________, 1964, Stratigraphy and structure of a portion of the Castleton Quadrangle: U.S. Geol. Surv. Bull., no. 1174, 94 p.

________, 1967, Time and space relationships of the Taconic Allochthon and Autochthon: Geol. Soc. Amer. Spec. Paper 97, 107 p.

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A STRUCTURE SECTION IN EASTERN NEW YORK SHOWING VARIATION IN STYLE OF DEFORMATION ACROSS THE TACONIC ALLOCHTHON: REPLY[1]

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We thank the discussants for their interest in our cross section (Steuer and Platt, 1981). Their comments help to clarify how different people can look at the same and slightly different features and reach substantially different conclusions.

The first part of their discussion covers some details of the stratigraphic sequence. We used established formation names in the allochthonous rocks partly to keep stratigraphic discusssion as brief and simple as possible. Whether or not there are lenses of black rocks within the Bull Formation, we didn't see them so we didn't map them. The Truthville Slate Formation and Browns Pond Formation of Rowley, Kidd and Delano (1979, p. 194-195) are about at the level of resolvability on our cross section. Given the nature of the Bull Formation, such lenses would not be suprising. In truth, Dale (1904, p. 29) indicated the existence of such, and other mappers have commented on the discontinuous nature of the rock types.

Another stratigraphic point made by discussants is of interest but not very well substantiated. Whereas they believe that no unconformity exists between the cherty Mount Merino and the overlying Pawlet, we find several references in the literature to this discontinuity (e.g. Berry, 1959, p. 62; Zen and Bird, 1963, p. 50). The discussants note a locality where bedding in the cherty rocks is parallel to bedding in the overlying graywacke. The reader with our cross section in hand will findno discernible discordance of bedding or change of thickness of the cherty unit below the Pawlet. They are folded together. This is not suprising, for there is little time between deposition of one and deposition of the other within one graptolite zone. Berry (1962, p. 713) noted conformable relations in southern counties along the Hudson. But of significance for our position that the Pawlet has an unconformity at its base is the observation that it rests on three different units in the Taconic sequence in parts of Washington county (Berry, 1962, p. 713) and the report that pieces of chert are in it (Offield, 1967, p. 51). Rowley and others (1979, p. 201) note possible chert fragments in the Pawlet.

A particular point about stratigraphic terminology needs more analysis and evaluation. There appears to be a real difficulty in establishing the age of an outcrop of graywacke, the allochthony of that outcrop, the formation name to be attached, and genetic interpretations. It seems to us that discussants have not separated these four points with care in all cases. Their first paragraph under the heading Constraints on Deformation Timing asserts, "at least some deformation and metamorphism <u>in the source area</u> pre-date Pawlet and Austin Glen ("Canajoharie") deposition." We reproduce their underlining, etc. There seems nothing right about this. The Canajoharie is certainly not equivalent to the Austin Glen or Pawlet in age, rock type, or allochthony (Fisher, 1977; Rickard and Fisher, 1973). No doubt some deformation in the original home of the Taconic allochthonous sequence, including the Pawlet, occurred before or during deposition of some of the autochthonous shale and graywacke, but that does not carry the implication that the transported rocks in our cross section were deformed and metamorphosed prior to said movement, for they are older than the autochthonous shale and graywacke we called Canajoharie.

In our view this is more than just what name is attached to what body of rock. While we would agree with several readers including the original reviewers that using Snake Hill might have been better than Canajoharie for the autochthonous shale and graywacke beds, we disagree with discussants that Austin Glen or Pawlet beds were deposited upon or interfinger with autochthonous units. Rowley and Kidd (1981, Fig. 2 and p. 203) imply this relationship and seem to suggest that D. W. Fisher agrees. We get a contrary message from his publications (Fisher, 1977; Rickard and Fisher, 1973, Fig. 1). Insofar as these units are involved, the timing argument of discussants are not well supported by the stratigraphy, possibly in part because adequate discriminatory criteria are difficult to establish at the outcrop and in part because they have misconstrued stratigraphic relations.

In summary of the stratigraphic points, others have noted the existence of lenses of black sedimentary rock within the Bull Formation, and discussants assertion that the Pawlet is conformable with the rocks below is at variance with substantial literature. We purposely compressed the stratigraphic descriptions to emphasize the folded folds shown in our cross section. In compressing, we apparently oversimplified in the opinion of the discussants.

The comments on the structure of our cross section are interesting but do not persuade us to change our interpretation. The complexities emphasized by discussants suggest there is yet much to clear up in the Taconics. A few points of geometry might be reviewed to show how their interpretation differs from ours.

Discussants say they have found a fold set older than our P_1 in adjacent regions, recognized by downward-facing beds in our P_1 set. Zen (1964) and Rodgers (1982) had previously noted recumbent folds that were folded by what seem to be our P_1 folds at the north end of the klippe. Of course, an entire sequence of Lower Cambrian through Middle Ordovician Taconic shaly rocks may lie upside

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down beneath the surface near our cross section. Obviously we believe that P_1 folded upright beds at the level we can see, based on such criteria as stratigraphic sequence, opposing dips, cleavage/bedding relations, and sparse primary top indicators. Unfortunately, primary top indicators are not always abundant where one might wish to find them. A new method for recognizing regionally inverted rocks has been developed by Poulsen and others (1980), who noted that even though the younging direction reverses across a fold, cleaved beds will show the same younging direction along the cleavage of both limbs. We were unsuccessful in applying this method in the eastern part of the area where younger folds deform P_1 and its cleavage.

We are not much impressed with the statements at the end of the paragraph titled Thrust faults "that 1) P_1 deformation completely pre-dates the basal thrust, as it cross-cuts both limbs of P_1 folds; and 2) the basal thrust post-dates P_2 since it does not conform to the form surfaces of the chevron type P_2 folds on the east side of the allochthon." The first point is not forced by any rules of which we are aware; Allmendinger (1981) proposed essentially the opposite development--thrusting produced folds that were cut by progressive thrusting. The second point specifically denies the possibility of disharmonic folds in differing units, or so it seems to us.

We find some confusion in the discussion about cleavages on and off the allochthon. The eighth paragraph under Folds says that our P_2 does not exist along the western side of the allochthon and that cleavage west of the allochthon must be more or less correlative with our P_1. In our view this is possible but not preferred. But if, as above, discussants want P_1 to have occurred somewhere else and before thrusting, any relation between cleavage in P_1 folds on the allochthon and cleavage in the shales tens of kilometers away on the continental shelf seems tenuous. The rocks would be different tectonic regimes until thrusting juxtaposed them.

The geologic ages of cleavages in the rocks near our cross section are not yet established to everyone's satisfaction. We are impressed by the data of Beutner and others (1977) extracted from the Martinsburg Shale, even though their locale is far from Cossayuna, N. Y., showing that the cleavage was imprinted on consolidated rock. However, the topic cannot be closed so simply. A regional metamorphism along the east side of the allochthon and farther east post-dates thrusting and possibly some slaty cleavage (e.g. Potter, 1972, p. 49). Rodgers (1977, p. 1150-1152) noted both Acadian and Taconic deformation and metamorphism in Vermont. As he observed, separation of these is not everywhere unambiguous. Indeed, Robinson and Fyson (1976) reported a remarkable ambiguity. Folds in pre-Middle Ordoviian schists are in one place parallel to and similar in form to folds in Devonian rocks but elsewhere the schist is unconformably overlain by Silurian strata.

Discussants and we agree on several points, not least of which is that the complex geometry in eastern New York State and adjacent regions requires a complex geologic history varying from place to place. We caution that, in projecting relations from one area to another, even along strike, one might easily oversimplify or overgeneralize. For example, Hiscott (1978) described a Lower Ordovician flysch in Quebec; to fit his Tourelle Formation into the apparently quiet Early Ordovician depositional history of the Taconic allochthonous rocks or the autochthonous carbonates near our cross section is not easy. Here again, we and discussants agree that some aspects of the deformation are likely progressive and diachronous. There are other points of agreement. We hope to have clarified at least a few of the points of disagreement above.

We thank John Riva and David Rowley for Conversations that led to focusing the issues in the discussion and reply.

REFERENCES

ALLMENDINGER, R.W., 1981, Structural geometry of Meade thrust plate in northern Blackfoot Mounains, southeastern Idaho: Am. Assoc. Petroleum Geologists Bull., v. 65, p. 509-525.

BERRY, W.B.N., 1959, Trip G Part 3 Graptolite faunas of the northern part of the Taconic area: in Zen, E-an, ed., Guidebook for 51st New England Intercollegiate Geological Conference, p. 61-70.

BERRY, W.B.N., 1962, Stratigraphy, zonation, and age of Schaghticoke, Deepkill, and Normanskill shales, New York: Geol. Soc. America Bull., v. 73, p. 695-718.

BEUTNER, E.C., JANCIN, M.D., and SIMON, R.W., 1977, Dewatering origin of cleavage in light of deformed calcite veins and clastic dikes in Martinsburg slate, Delaware Water Gap, N. J.: Geology, v. 5, p. 118-122.

DALE, T.N., 1904, Geology of the Hudson Valley between the Hoosic and the Kinderhook: U. S. Geol. Survey Bull. 242, 63 p.

FISHER, D.W., 1977, Correlation of Hadrynian, Cambrian and Ordovician rocks in New York State: New York State Museum Map and Chart Series, No. 25, 75 p.

HISCOTT, R.N., 1978, Provenance of Ordovician deep-water sandstones, Tourelle Formation, Quebec, and implications for initiation of the Taconic orogeny: Canadian Jour. Earth Science, v. 15, p. 1579-1597.

OFFIELD, T.W., 1967, Bedrock geology of the Goshen-Greenwood Lake area, N. Y.: New York State Museum Map and Chart Series, No. 9, 77p.

POTTER, D.B., 1972, Stratigraphy and structure of the Hoosick Falls area, New York-Vermont, east-central Taconics: New York State Museum Map and Chart Series, No. 19, 71 p.

POULSEN, K.H., BORRADAILE, G.J., and KEHLEN-

BECK, M.M., 1980, An inverted Archaean succession at Rainy Lake, Ontario: Canadian Jour. Earth Science, v. 17, p. 1358-1369.

RICKARD, L.V., and FISHER, D.W., 1973, Middle Ordovician Normanskill Formation, eastern New York, age, stratigraphic and structural position: Am. Jour. Science, v. 273, p. 580-590.

ROBINSON, S.D., and FYSON, W.K., 1976, Fold structures, southern Stoke Mountain area, Eastern Townships, Quebec: Taconic or Acadian?: canadian Jour. Earth Science, v. 13, p. 66-74.

RODGERS, JOHN, 1971, The Taconic orogeny: Geol. Soc. America Bull., v. 82, p. 1141-1177.

RODGERS, JOHN, 1982, Stratigraphic relationships and detrital composition of the medial Ordovician flysch of western New England: implications for the tectonic evolution of the Taconic orogeny: a discussion: Jour. Geology, v. 90, p. 219-226.

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: Jour. Geology, v. 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., Guidebook for New York State Geological Assoc. and New England Intercollegiate Geological Conference, p. 186-242.

STEUER, M.R., and PLATT, L.B., 1981, A structure section in eastern New York showing variation in style of deformation across the Taconic allochthon: Northeastern Geology, v. 3, p. 134-137.

ZEN, E-AN, 1964, Stratigraphy and structure of a portion of the Castleton quadrangle, Vermont: Vermont Geol. survey Bull. 25, 70 p.

ZEN, E-AN, and BIRD, J.M., 1963, Road log: in Bird, J.M., ed., Guidebook for Field Trip Three, Geol. Soc. America, p. 39-57.

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