

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 GEISER¹

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We thank Geiser for the opportunity to further clarify important relationships in western New England and eastern New York that bear directly on our tectonic synthesis of the Taconic Orogeny. Geiser's main concern is the possible importance of post-Taconic deformation to the "final" assemblage of the Taconic terrane into its present form. Along this line, Geiser points to several aspects of the regional geology that he feels are critical to establishing the credibility of our synthesis. These specifically include: (1) the constraints on timing and sequence of thrust faulting within and adjacent to the Allochthon; and (2) constraints on timing of the major regional cleavage forming events within eastern New York. We consider each of these in turn.

FAULT SYSTEMS

Geiser states that there are *two* distinct fault systems in the lower and central Hud-

son Valley. The first is said to be pre-metamorphic and of Taconic age, and the second is post-metamorphic, high angle, and presumably of post-Taconic age. He further states that only faults of the later system are decorated with tectonic slivers of Cambro-Ordovician shelf-derived carbonate and, rarely, Grenville basement. We take strong exception to this assertion. Detailed mapping by members of this department (Jacobi 1977; Rowley 1980, 1982; Bosworth 1980; Vollmer 1981) has dominantly focused on the northern and central Taconics and the immediately adjacent parautochthonous and autochthonous flysch terrane, north of South Bethlehem, New York to near Fair Haven, Vermont. Based on this mapping and previously published work of Zen, Bird, and Ratcliffe, among others, we conclude that a minimum of five fault systems are present within the Allochthon, and at least two or three in the parautochthonous flysch to the west (Bosworth in press; Bosworth and Vollmer 1981). At least two of the systems within the Allochthon are cut by the frontal thrust that forms the present western edge of the Taconic Allochthon (Rowley and Kidd in press), and which carries slivers of Cambro-Ordovician shelf carbonate rocks. On the

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basis of structural relations, the major thrusts within the parautochthonous flysch are probably equivalent to the frontal thrust (see Bosworth in press). In addition, it is now clearly documented that the frontal thrust and equivalent thrusts within the flysch are sub-horizontal, post-cleavage, and therefore presumably post-metamorphic thrusts of syn- to post-Caradocian and pre-Devonian, i.e., Taconic age. The constraints for this timing are best provided by exposures at Bald Mountain and Spruyt Creek.

The Bald Mountain terrane consists of tectonic slivers of parautochthonous shelf-derived lithologies within a dark shale matrix bounded both above and below by subhorizontal, post-cleavage thrusts (Bosworth 1980; Bosworth and Vollmer 1981). Olistostromal deposits containing shelf-derived carbonate blocks are exposed below the lower thrust. These carbonate olistoliths are interpreted to be derived from the tectonic slivers of the Bald Mountain terrane, and therefore date the time of motion on this post-metamorphic thrust. The age of these olistostromes is syn- to post-Caradocian based on the presence of *Cryptolithus tessellatus* in the carbonate blocks at Bald Mountain (Platt 1960). From regional relations and fossils in their matrices (Berry 1962), these Taconic melanges are late medial to late Caradocian in age (*D. multidentis* to *C. spiniferus* zones of Riva 1974).

The time of major thrusting within the parautochthonous to autochthonous flysch ("Normanskill") of the Hudson Valley is constrained to pre-Manlius time (pre-early Devonian), by an outcrop in Spruyt Creek described by Vollmer (1981) and Bosworth and Vollmer (1981). At this locality, near South Bethlehem, New York early Devonian Manlius Formation unconformably overlies a zone of phacoidally cleaved melange associated with post-slaty cleavage thrusts within the parautochthonous medial Ordovician flysch terrane (Bosworth and Vollmer 1981; Bosworth in press). Deformation associated with this thrusting and associated melange fabric does not affect the unconformably overlying Manlius, and is therefore pre-early Devonian, and presumably of Taconic age.

Geiser also questions the age of the "regional" slaty cleavage observed in "Normanskill" rocks of the Hudson Valley. He

suggests that the cleavage may be correlative with the slaty cleavage observed in the Martinsburg Formation of Pennsylvania. Epstein and Epstein (1969) suggested that the Martinsburg slaty cleavage is Alleghanian, and Geiser suggests that this age may apply as well to the cleavages in the Normanskill flysch of the Hudson Valley. The age of the regional slaty cleavage in the Martinsburg is not well constrained, but contrary to Geiser's interpretation, Beutner (pers. comm.) among others believes that this cleavage is Taconic, not Alleghanian in age.

In fact, the best documentation of the age of this cleavage is available within and adjacent to the Taconic Allochthon. Several lines of evidence show this, including: (1) The presence of clasts of pre-depositionally foliated slate in the basal latest Silurian-earliest Devonian beds at Mount Ida (Ratcliffe et al. 1975), in the late medial to late Ordovician Quassaic sandstones at Illinois Mountain (Waines 1980), and in medial Ordovician Austin Glen greywackes ("Normanskill") of the Hudson Valley (Rowley and Kidd 1981; Vollmer 1981). (2) The presence of a polyphase deformation history, including folding (generally considered F_2) and associated slaty cleavage (S_2) development in Taconic rocks unconformably below only poorly cleaved and considerably less deformed early Devonian Manlius Formation at Mount Ida and Becraft Mountain (Ratcliffe et al. 1975; Rodgers 1971). (3) A few isotopic dates from metamorphic muscovite developed along the cleavage in both Vermont ($420 \pm$ —revised to $434 \pm ?$) (Harper 1968) and eastern New York (442 ± 16 m.y.) (Ratcliffe and Hatch 1979). To the south, the Cortlandt Complex, dated as 430 to 440 m.y. (late Ordovician to early Silurian) by a variety of isotopic systems (see reviews by Ratcliffe et al. in press; Bender 1981) cross-cuts the slaty cleavage foliation in the surrounding highly deformed, metamorphosed, and foliated country rock, providing a further constraint on the age of this foliation (Ratcliffe 1968).

In addition to the mesoscopic and microscopic similarity of the slaty cleavage of the Hudson Valley to the regional Taconic-age slaty cleavage of the Allochthon there are numerous exposures of the angular unconformity between Siluro-Devonian sediments

of the Heldeberg Group overlying folded, cleaved, and thrust-faulted flysch with no evidence of correlative deformation affecting rocks above the unconformity (Vollmer 1981; Bosworth and Vollmer 1981). Bosworth and Vollmer (op. cit.) describe the deformation in the Hudson Valley from the area just south of Albany to near Schuylerville, New York. Their observations indicate that the deformation within this flysch is quite dissimilar to that observed in the Devonian rocks of the Heldeberg Group. The major deformation in the flysch is tectonically most compatible with deformation related to the medial Ordovician emplacement of the Taconic Allochthon.

Ratcliffe et al. (1975) were able to characterize the nature of the post-Taconic deformation in the Hudson Valley region by studying the structures both above and below the unconformity exposed at Mount Ida. They found that the *post-Taconic* deforma-

tion involved some bedding-parallel slip and open folding with an associated spaced solution cleavage in the Manlius and a weak, spaced *crenulation* cleavage in the underlying Taconic units, not the regional slaty cleavage. These spaced foliations have traditionally been assigned an Acadian age; however they may be Alleghanian as Geiser suggests. From these observations and other relationships described in our paper we do not think that the post-Taconic deformation has significantly affected the pre-existing structural relationships associated with the Taconic Allochthon, and therefore cannot consider this later deformation as "the" major deformation in the Hudson Valley. Compared with the large-scale overthrusting and bulk shortening of the Taconic Orogeny in this area, the post-Taconic deformation is of decidedly secondary importance, not "a major deformation" as stated by Geiser.

REFERENCES CITED

- BENDER, J., 1980, Petrogenesis of the Cortlandt Complex: Unpub. Ph.D. dissertation, State University of New York, Stony Brook, 306 p.
- BERRY, W. B. N., 1962, Stratigraphy, zonation, and age of the Schaghticoke, Deepkill, and Normanskill Shales, eastern New York: Geol. Soc. America 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, and experimental and theoretical studies of solution transfer in deforming heterogeneous systems: Unpub. Ph.D. dissertation, State University of New York, Albany.
- , 1982, Evolution and structural significance of master shear zones in parautochthonous flysch of eastern New York: Vermont Geol., in press.
- , and VOLLMER, F. W., 1981, Structures of the medial Ordovician flysch of eastern New York: deformation of synorogenic deposits in an overthrust environment: Jour. Geology, v. 89, p. 551-568.
- EPSTEIN, J. B., and EPSTEIN, A. G., 1969, Geology of the Valley and Ridge Province between Delaware Water Gap and Lehigh Gap, Pennsylvania: Geol. Soc. America 82d Ann. Mtg. Guidebook, p. 132-205.
- HARPER, C. T., 1968, Isotopic ages from the Appalachians and their tectonic significance: Can. Jour. Earth Sci., v. 5, p. 50-59.
- JACOBI, L. D., 1977, Stratigraphy, depositional environment, and structure of the Taconic Allochthon, Central Washington County, New York: Unpub. M.S. thesis, State University New York, Albany, 191 p. (Note: Delano and Jacobi are the same person).
- PLATT, L. B., 1960, Structure and stratigraphy of the Cossayuna area, New York: Unpub. Ph.D. dissertation, Yale University, New Haven, 126 p.
- RATCLIFFE, N. M., 1968, Contact relations of the Cortlandt complex at Stony Point, New York, and their regional implications: Geol. Soc. America Bull., v. 79, p. 777-786.
- ; ARMSTRONG, R. L.; MOSE, D. G.; SENESCHAL, R.; WILLIAMS, N.; and BAIAMONTE, M. J., 1982, Emplacement history and tectonic significance of the Cortlandt Complex, related plutons, and dike swarms in the Taconide Zone of Southeastern New York based on K-Ar and Rb-Sr investigations: Am. Jour. Sci., in press.
- ; BIRD, J. M.; and BAHRAMI, B., 1975, Structural and stratigraphic chronology of the Taconide and Acadian polydeformational belt of the central Taconics of New York State and Massachusetts: in RATCLIFFE, N. M., ed., Guidebook for 67th Annual Meeting NEIGC, p. 55-86.
- , and HATCH, N. L., JR., 1979, A traverse across the Taconide Zone in the area of the Berkshire Massif, western Massachusetts, in SKEHAN, J. W., and OSBERG, P. H., eds., The Caledonides in the U.S.A., Geological Excursions in the Northeast Appalachians: Weston, Mass., Weston Observatory, p. 175-224.

- RIVA, J., 1974, A revision of some Ordovician graptolites of eastern North America: *Paleontology*, v. 17, p. 1-40.
- RODGERS, J., 1971, The Taconic Orogeny: *Geol. Soc. America Bull.*, v. 82, p. 1141-1178.
- ROWLEY, D. B., 1980, Complex structure and stratigraphy of the lower slices of the Taconic Allochthon near Granville, New York: Unpub. M.S. thesis, State University of New York, Albany, 258 p.
- , 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.
- , and ——— 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 reply to Rodgers: *Jour. Geology*, v. 90, p. 223-226.
- VOLLMER, F. W., 1981, Structural studies of the Ordovician Flysch and Melange in Albany County, New York: Unpub. M.S. thesis, State University of New York, Albany, 151 p.
- WAINES, R. H., 1980, Stratigraphy and significance of a 10,000 ft. arenite sequence in a late medial-medial late Ordovician outlier in southeastern Ulster County, New York: *Geol. Soc. America Abs. with Prog.*, v. 12, p. 543.