UNIVERSITY OF ILLINOIS

April 19 90

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Christopher Alan Hedlund

ENTITLED LATERAL VARIATION IN DISPLACEMENT AND GEOMETRY NEAR THE NORTHERN TERMINATION OF THE WHITEPORT THRUST, FOURTH LAKE, NEW YORK

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science

Instructor in Charge

APPROVED:

HEAD OF DEPARTMENT OF Geology

O-1364

LATERAL VARIATION IN DISPLACEMENT AND GEOMETRY NEAR THE NORTHERN TERMINATION OF THE WHITEPORT THRUST, FOURTH LAKE, NEW YORK

BY
CHRISTOPHER ALAN HEDLUND

THESIS

FOR THE
DEGREE OF BACHELOR OF SCIENCE
IN LIBERAL ARTS AND SCIENCES

COLLEGE OF LIBERAL ARTS AND SCIENCES
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS
1990

LATERAL VARIATION IN DISPLACEMENT AND GEOMETRY NEAR THE NORTHERN TERMINATION OF THE WHITEPORT FAULT, FOURTH LAKE, NEW YORK

Abstract

Exposed Silurian and Devonian strata in the southern segment of the Binnewater Lakes thrust system in the Kittatiny-Shawangunk segment of the post-Taconic Applachian fold-thrust belt near Fourth Lake, New York, contain westward-verging structures trending approximately N25^{o}E. Detailed mapping in the Fourth Lake area provides evidence for two distinct detachments in the area; one just above the Taconic unconformity in the Upper Silurian Binnewater Sandstone, and a second in the Ordovician Austin Glen Formation. The upper detachment correlates with the Rondout detachment in the Hudson Valley fold-thrust belt near Kingston, New York, but is lower in the stratigraphic section, presumably due to thickening of the Upper Silurian stratagraphic section to the southwest. This detachment is locally manifested by a thrust, here named the Whiteport fault, which shows abrupt changes in displacement and geometry along strike near its northern termination. The lower detachment in the Fourth Lake area is interpreted to be equivalent to the Austin Glen detachment recognized in the Hudson Valley fold-thrust belt.

Acknowledgements

The author thanks Dr. Stephen Marshak for suggesting, supervising, and funding this study and for assisting in mapping. Thanks also to M. Scott Wilkerson for assistance in mapping and reviewing the manuscript, and Dr. Ralph L. Langenheim, Jr. for reviewing the manuscript. The author also acknowledges the Williams Lake Hotel for permission to conduct field studies on their property and the Department of Geology at the University of Illinois at Urbana for its support of this project.

Table of Contents

List of Figures

Introduction

Exposed Silurian and Devonian strata southwest of Kingston, New York, near Fourth Lake (Fig. 1), contain fold-thrust structures which verge westward and trend approximately N25°E, forming a narrow, continuous belt from Kingston, New York, to the Delaware Water Gap. This belt of deformed Silurian and Devonian rocks is referred to as the Kittatiny-Shawangunk segment of the post-Taconic Appalachian fold-thrust belt (Marshak and Tabor, 1989). Near Fourth Lake, this belt is comprised of structures of the southern segment of the Binnewater Lakes thrust system (Tabor, 1985).

The structural geology north of Fourth Lake in the Binnewater Lakes thrust system has been previously studied by Tabor (1985) and Marshak and Tabor (1989), but the geology at the latitude of Fourth Lake has not been mapped in detail. Previous work to the north (McEachran, 1985; Tabor, 1985; Marshak, 1986; Marshak and Tabor, 1989) suggests that a significant detachment fault occurs at the base of the Silurian section in this region. Studies of the Silurian and Devonian stratigraphy of southeastern New York (Wanless, 1920; Rickard, 1962; Hoar and Bowen, 1967; Waines and Hoar, 1967; Epstein and Lyttle, 1987) show that the Silurian section (Fig. 2) thickens significantly to the southwest. Near Kingston, the Silurian consists of only a thin section of the Rondout Formation, whereas

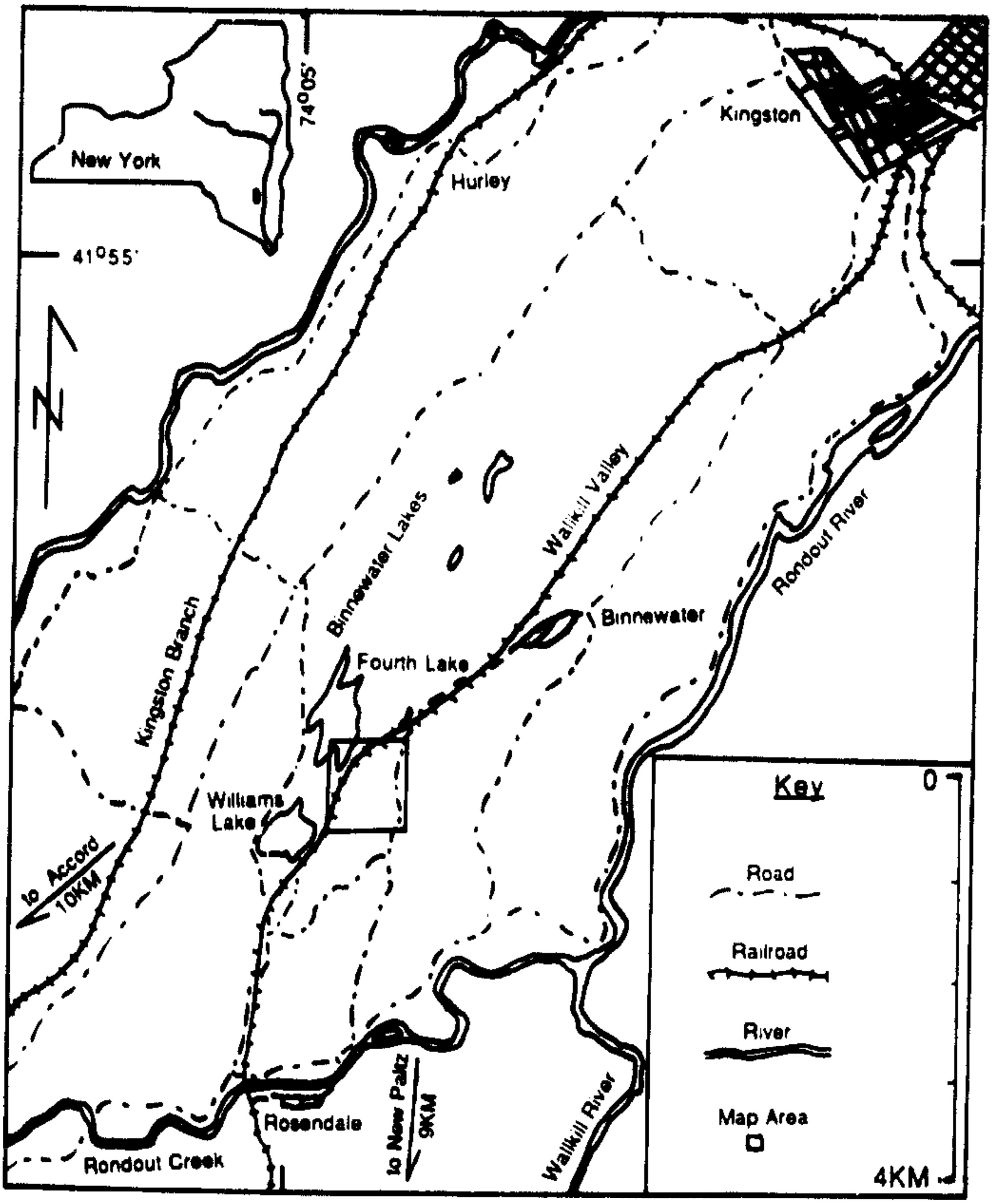

Figure 1. Location map (from USGS Rosendale Quadrangle) showing location of the geologic map (Fig. 4).

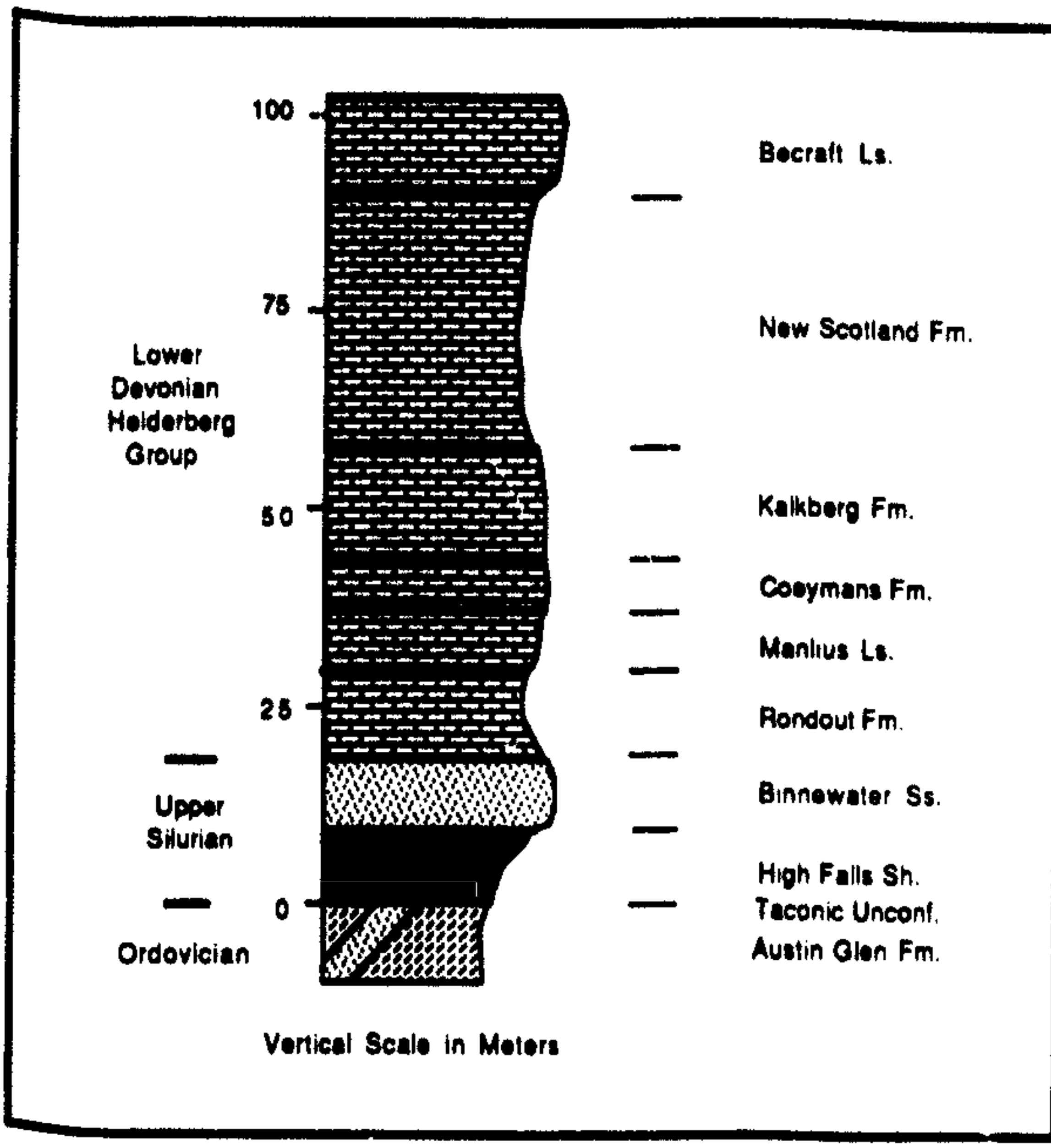

Figure 2. Stratigraphic column of units exposed at Fourth Lake in the Kittatiny-Shawangunk segment of the Appalachian fold-thrust belt.

south of Kingston, near Fourth Lake, it contains a thickened section of the Rondout Formation as well as the Binnewater Sandstone, High Falls Shale, and the northern edge of the Shawangunk Conglomerate (Fig. 3).

The purpose of this study is threefold; (1) to determine if a detachment exists in the Upper Silurian near Fourth Lake, (2) to determine the exact stratigraphic location of the detachment, and, (3) to describe the lateral variation in both displacement and geometry of the local manifestation of this detachment, here named the Whiteport fault, near its northern termination.

To address these questions, the area east of Fourth Lake and Williams Lake, on the property of Williams Lake Hotel, was mapped during March, 1990. Detailed mapping of stratigraphic contacts and orientations of bedding and cleavage were recorded on both topographic (1:9000) and areal photograph (1000 foot altitude) bases (Fig. 4). Sketches of important outcrops were also made. The abundant roof and pillar quarries in the area, which were mined for natural cement in the Rosendale and Whiteport Members of the Rondout Formation late in the nineteenth century, provide excellent three-dimensional exposure of the geology.

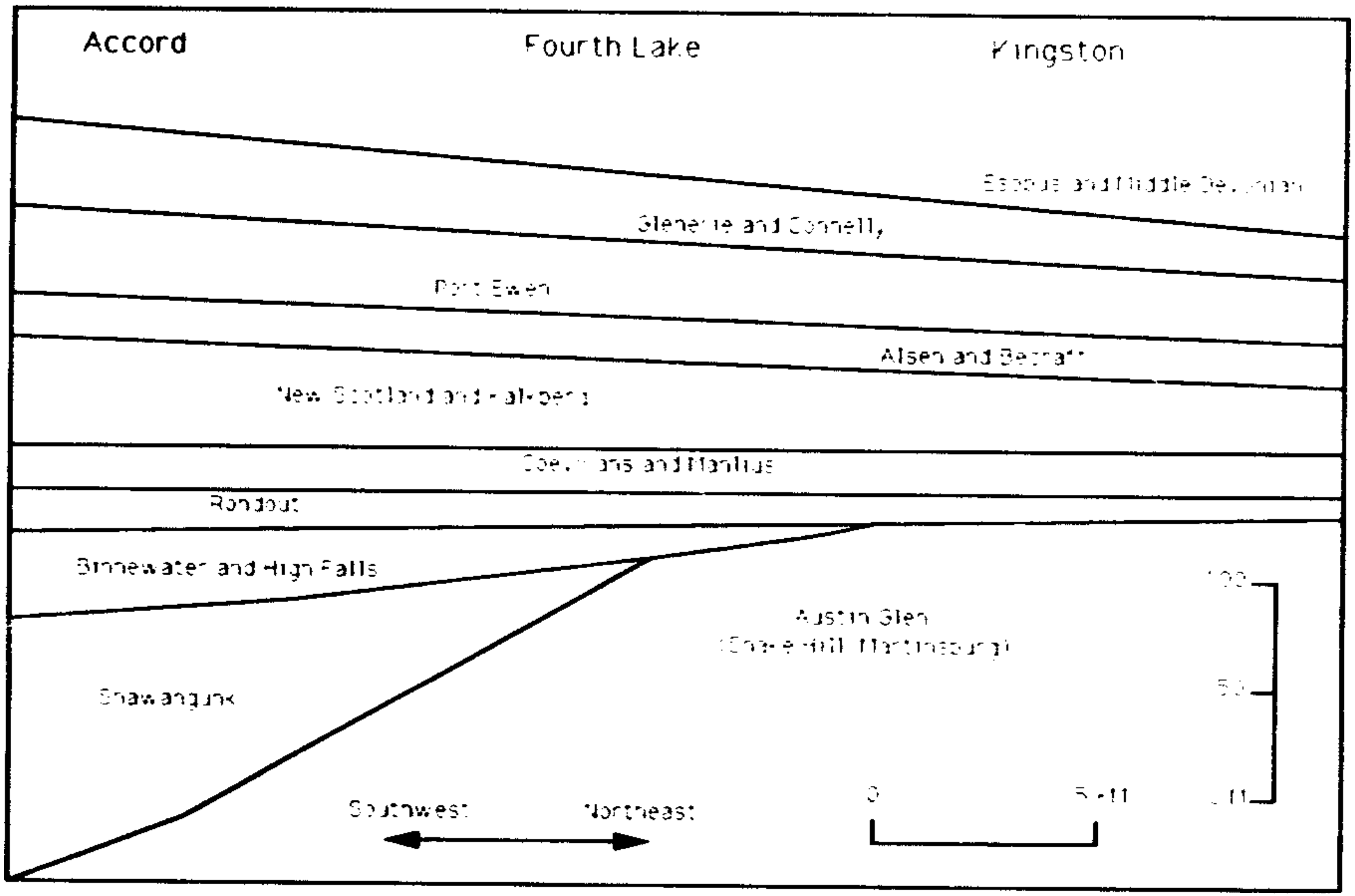

Figure 3 Diagram showing variations in thickness of stratigraphic units from Kingston to Accord, New York. Datum is top of Rondout (modified from Waines and Hoar, 19[illegible])

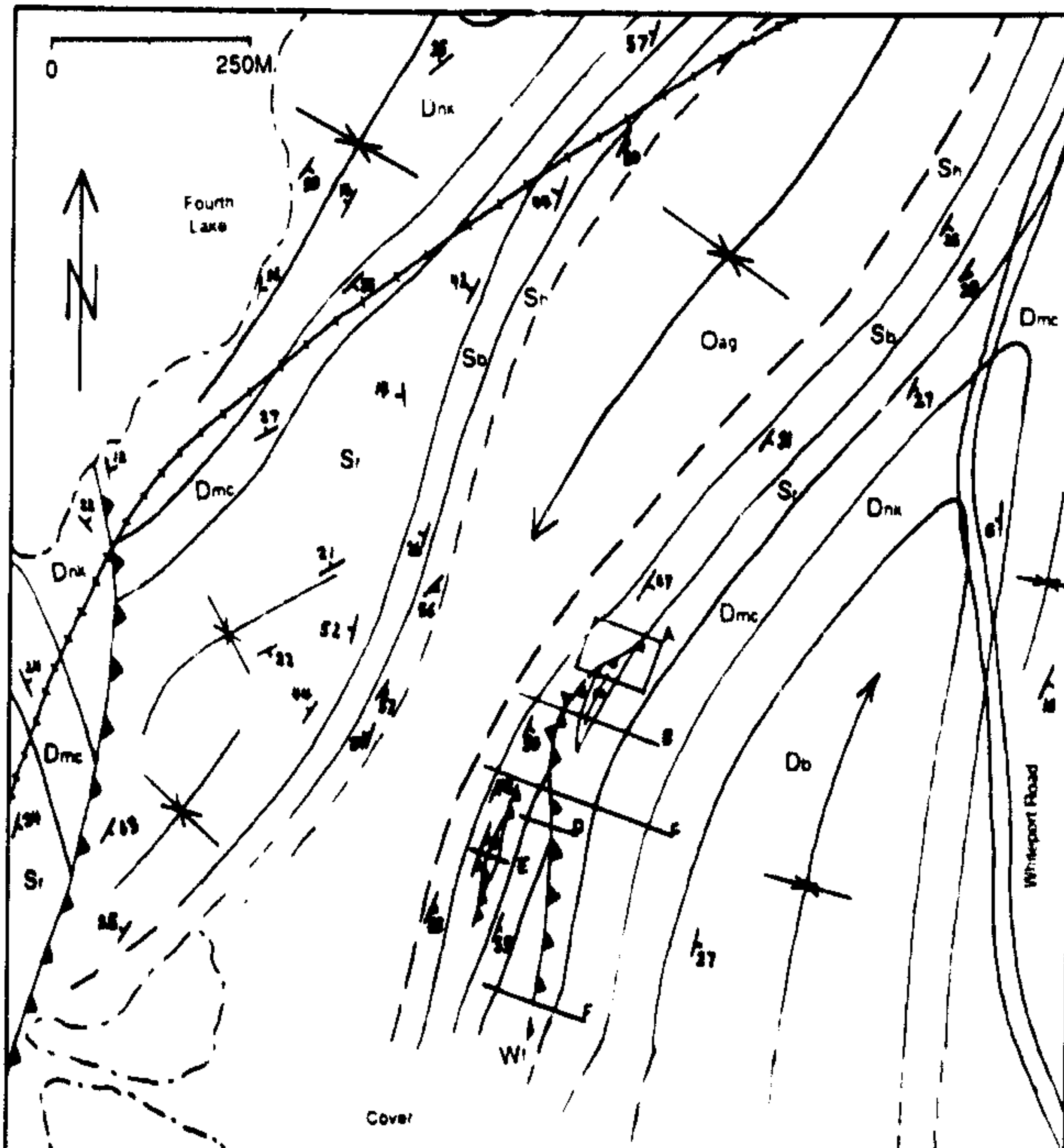

Figure 4. Geologic map of area to the southeast of Fourth Lake.

Db	Becraft Formation	⊥	Bedding Attitude
Dnk	New Scotland and Kalkberg Fms	▲	Cleavage Attitude
Dmc	Coeymans and Manlius Fms.		Formation Contact
Sr	Rondout Formation		Thrust Fault
Sb	Binnewater Sandstone		Syncline axial trace
Sh	High Falls Shale		Anitcline axial trace
Oag	Austin Glen Formation		Road
			Railroad
Wf	Whiteport fault		Lake, Pond

Regional Geologic Setting

Structures in the Fourth Lake area occur within the southern segment of the Binnewater Lakes thrust system in the Kittatiny-Shawangunk segment of the post-Taconic fold-thrust belt. The Kittatiny-Shawangunk segment is continuous from Kingston in the north to the Delaware Water Gap in the south (Fig. 5). Silurian and Devonian strata of the Kittatiny-Shawangunk segment are exposed west of the Helderberg Escarpment and are believed to have been deformed during the Lackawana (early) Phase (Geiser and Engelder, 1983; Marshak and Tabor, 1989) of the Alleghenian Orogeny in the Pennsylvanian. Structures north of Kingston trend approximately N10°E and are part of the Hudson Valley fold-thrust belt, which was deformed during the Acadian Orogeny (Marshak, 1986). In Kingston, an intersection orocline formed where structures of the Kittatiny-Shawangunk segment overprinted and reoriented structures of the Hudson Valley fold-thrust belt (Tabor, 1985; Marshak and Tabor, 1989). Southwest of the Delaware Water Gap, the Pennsylvania Salient fold-thrust belt represents the trend of the Main (late) Phase (Geiser and Engelder, 1983) of Alleghenian deformation, which occurred during the Permian.

The deformed Silurian and Devonian strata of the Kittatiny-Shawangunk segment lie unconformably over the Ordovician Austin Glen Formation, which was previously deformed

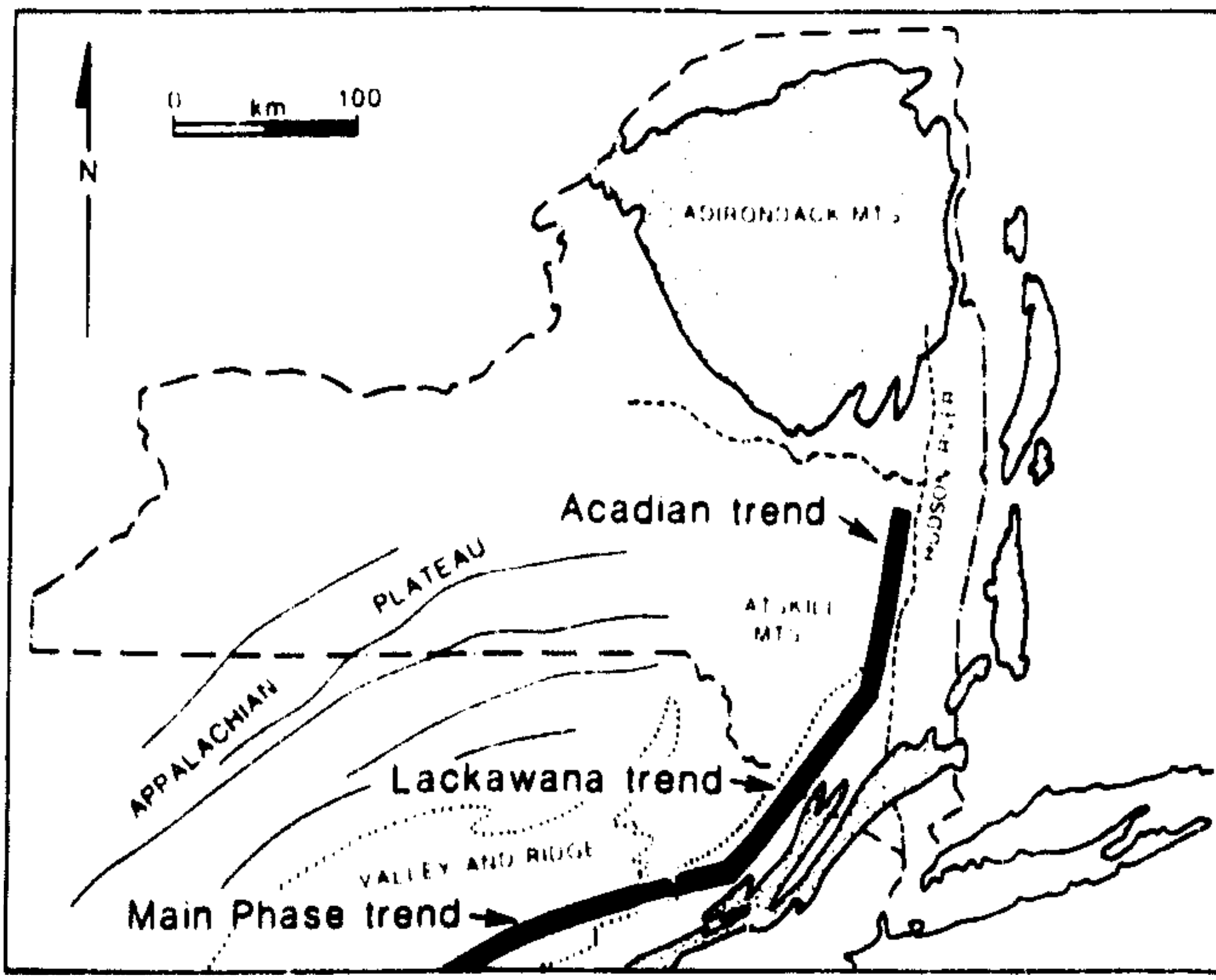

Figure 5. Schematic map indicating the trends of three possible noncoeval structural segments of the post-Taconic Appalachian fold-thrust belt in New York and Pennsylvania. The Kittatiny-Shawangunk segment is represented as the Lackawana trend. Heavy lines are trendlines; thin lines are fold traces on the Appalachian Plateau; dotted lines are the boundaries of the Valley and Ridge province (figure from Marshak and tabor, 1989).

during the Early Ordovician Taconic Orogeny (Fig. 6). The angular unconformity between the Austin Glen Formation and the Silurian strata is called the Taconic Unconformity and is itself deformed. East of the Kittatiny-Shawangunk segment, on both sides of the Hudson River, is a belt of Ordovician flysch which is overlain by the Taconic Allocthon further east. To the northwest, the Middle to Upper Devonian Catskill clastic wedge consists of undeformed gently westward dipping clastic sediments derived from uplifts of the Acadian Orogeny. Directly west of the Kittatiny-Shawangunk segment, a thicker section of Upper Silurian Shawangunk Conglomerate forms the Shawangunk mountains.

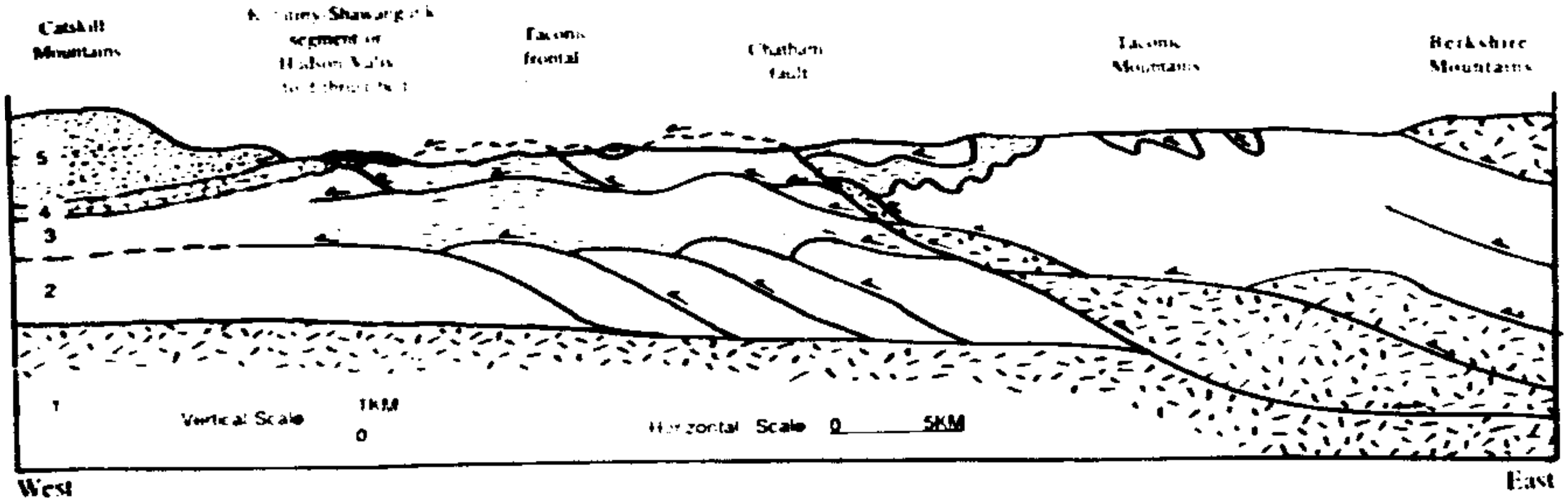

Figure 6. Schematic cross section showing regional structure from Catskill Mountains to Berkshire Mountains near Kingston New York. Units: 1) Grenville basement, 2) Cambro-Ordovician carbonates, 3) Ordovician flysch, 4) Siluro-Devonian carbonates, 5) Upper Devonian clastics. Scale is approximate (figure modified from Marshak, unpbl.).

Stratigraphy

Stratigraphic units exposed in the Fourth Lake area are summarized in figure 2. Although the Ordovician Austin Glen Formation (equivalent to Snake Hill and Martinsburg Formations) does not outcrop in the area, stratigraphic relations indicate exposure in the cores of anticlines. This unit consists of interbedded sandstone and shale comprising turbidite flysch deposited in the Taconic foreland.

The Upper Silurian and Lower Devonian strata that lie unconformably (Taconic Unconformity) over the Austin Glen Formation form a transgressive sequence of shallow water platform sediments deposited in a southwestward deepening basin (Hoar and Bowen, 1967). These units, particularly those in the Upper Silurian, thicken considerably to the southwest (Waines and Hoar,1967) (Fig. 3).

The basal Upper Silurian unit above the Taconic Unconformity, the Shawangunk Conglomerate, pinches out at the latitude of Fourth Lake, but is exposed less than one kilometer to the southwest. The Shawangunk consists of sand and pebbles of clean white quartz. The High Falls Shale consists of red, grey, and green shale, is approximately 9 meters thick at Fourth Lake, and displays axial-planar, close-spaced, disjunctive cleavage throughout the area. The Binnewater Sandstone includes white, grey, and pink banded quartz sandstone with ripple marks, cross beds, and thin, interbedded shale. The Binnewater Sandstone is approximately 9 meters thick. The Rondout Formation consists of three members in this area. The Wilbur Member of the Rondout Formation is exposed to the northeast, but pinches out by the latitude of Fourth Lake (Hoar and Bowen,1967). The Rosendale Member is a 5 meter thick buff dolomite that has been extensively mined in this area for use as natural cement. The Glasco Member is dark grey limestone containing *Halysites centularia* and is approximately 4 meters thick. The uppermost member of the Rondout Formation, the Whiteport Member, is a buff colored dolomitic limestone, about 3 meters thick, and has also been mined for natural cement.

The Lower Devonian Series includes the Helderberg Group, a transgressive sequence of shallow water marine carbonates (Rickard, 1962). The Manlius Limestone is a 7 meter thick buff limestone unit with thinly laminated beds, desiccation cracks, and locally abundant ostracods near its base. The Coeymans Formation consists of fine-grained grey limestone with locally abundant *Gypidula coeymanensis*, and is approximately 7 meters thick. The Kalkberg Formation consists of about 14 meters of grey to buff argillaceous limestone containing black chert layers near its base, irregular bedding, and locally abundant crinoid ossicles and *Leptina*. The New Scotland Formation is a 32 meter thick, brown to grey argillaceous limestone with abundant *Spirifer* and *Leptina*, and some chert. The Becraft Formation is a coarsely crystalline grey limestone unit with abundant crinoid ossicles, and is approximately 12 meters thick.

Other formations of the Lower Devonian Helderberg, Tristates, and Hamilton Groups are exposed in surrounding areas, but not in the Fourth Lake area.

Structural Observations: General Setting

A series of asymmetric, westward-verging, N25°E-trending anticline/syncline pairs exist in the Fourth Lake area. These first order folds have wavelengths ranging from 375 meters to 750 meters and amplitudes of as much as 50 meters. Because the anticlines are cored by Austin Glen Formation, these folds are believed to have resulted from shortening within the Austin Glen Formation caused by displacement above a detachment within this unit (Marshak, 1986). Bedding-parallel slip lineations on fold limbs indicate that flexural slip accommodated strain incurred during formation of these structures. Numerous thrust faults with minor displacement (no stratigraphic discontinuity) are exposed on the limbs of the anticlines. These faults are laterally discontinuous and most occur within the Rondout Formation (particularly the Glasco Member) or the Binnewater Sandstone. More continuous thrusts with greater displacement, such as the Whiteport fault, are also exposed in the area.

Structural Observations: The Whiteport Fault

The Whiteport fault is exposed on the eastern limb of one of the anticlinal folds, here named the Whiteport anticline. The eastern limb of the Whiteport anticline forms a prominent topographic ridge which has roof and pillar quarries along much of its length.

Figure 7 is a block diagram (see Fig. 3 for location) depicting the geology at the northern termination of the Whiteport fault. At the northeastern section of the figure, a normal stratigraphic succession exists, and the Whiteport fault parallels bedding at the top of the Binnewater Sandstone. Displacement decreases abruptly to zero to the northeast. To the southwest, fault displacement increases and the fault ramps laterally (Boyer and Elliot, 1982) downward to partially duplicate the Binnewater Sandstone. Slip lineations on the bedding surface between the Binnewater Sandstone and the Rosendale member indicate that some minor displacement has occurred on this bedding plane. This could be either due to flexural slip, accommodating folding, or a minor thrust, forming a duplex (Boyer and Elliot, 1982) with the Whiteport fault.

Further southwest, displacement on the Whiteport fault increases and a tight, anticlinal kink fold with a nearly vertical western limb forms in the hangingwall (Fig. 8). Here, footwall Binnewater Sandstone is placed over nearly vertical, westward-dipping Rosendale Member of the hangingwall by a

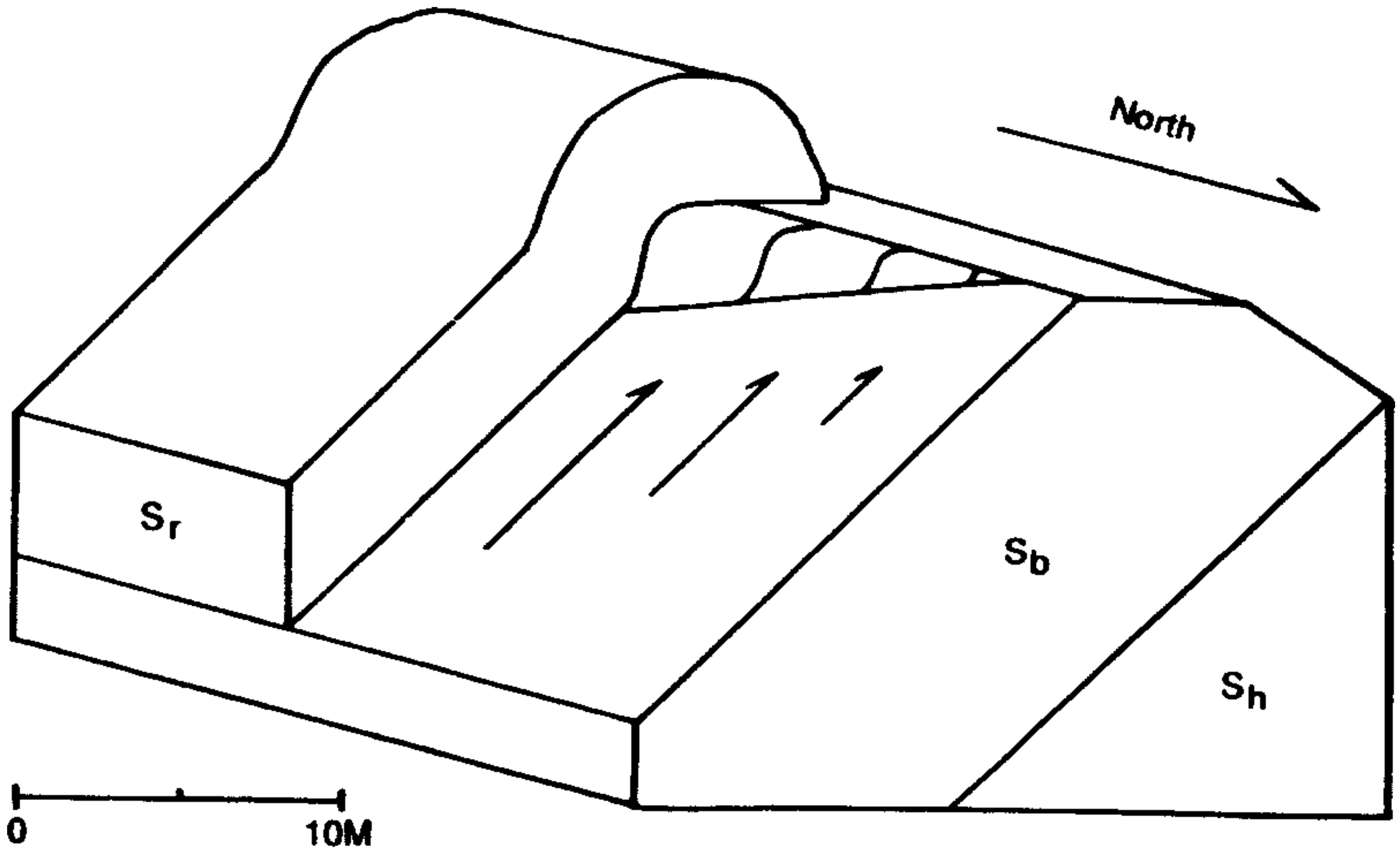

Figure 7. Block diagram A (see Fig. 4 for location) showing the northern termination of the Whiteport fault. Arrows indicate relative magnitude of displacement on the Whiteport fault (units as in Fig. 4).

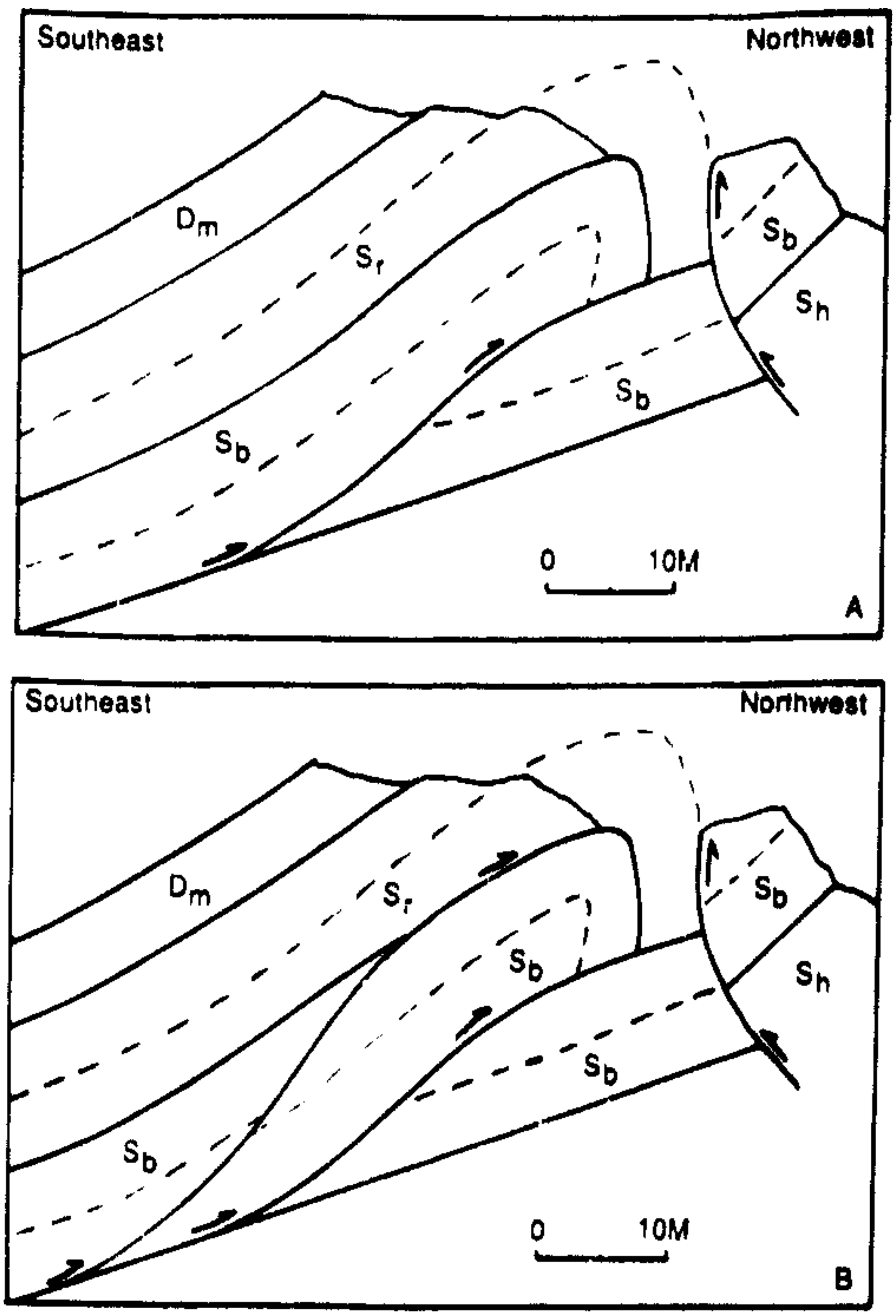

Figure 8. Cross section B showing two alternative interpretations of the Whiteport fault: A) slip linaetions near hinge of fault propagation fold are due to flexural slip, o:, B) slip lineations are caused by displacement on a minor imbricate thrust (units as in Fig.4).

high-angle backthrust. The Whiteport fault is not exposed at the surface because of truncation by the backthrust, but is inferred to exist by the presence of the fold and stratigraphic relations. Slip lineations between the hangingwall Binnewater Sandstone and the Rosendale Member are equivalent to those described above, and may represent either flexural slip lineations (Fig. 8 A) or a minor imbricate thrust (Fig. 8 B).

At the location of figure 9, the anticlinal fold is still present in the hangingwall, but the Whiteport fault has ramped laterally upward to place Binnewater Sandstone and Rosendale Formation over footwall Glasco Member in a ramp on flat geometry. The backthrust exposed to the northeast in the figure 8 section has died out by this location.

Further southwest, the Whiteport fault is exposed in the northern end of a collapsed quarry (Fig. 10). Here, hangingwall Rosendale Member is placed over footwall Glasco Member in a ramp on flat geometry, and the anticlinal fold in the hangingwall has died out. A stratigraphically lower imbricate thrust, here called the Rosendale fault, has partially duplicated the Binnewater Sandstone in the footwall of the Whiteport fault.

In the center of the collapsed quarry, the Whiteport fault continues to ramp up laterally to the southwest, placing Glasco Member over Lower Coeymans Formation in a flat on flat geometry. Displacement on the Rosendale fault has also increased to place

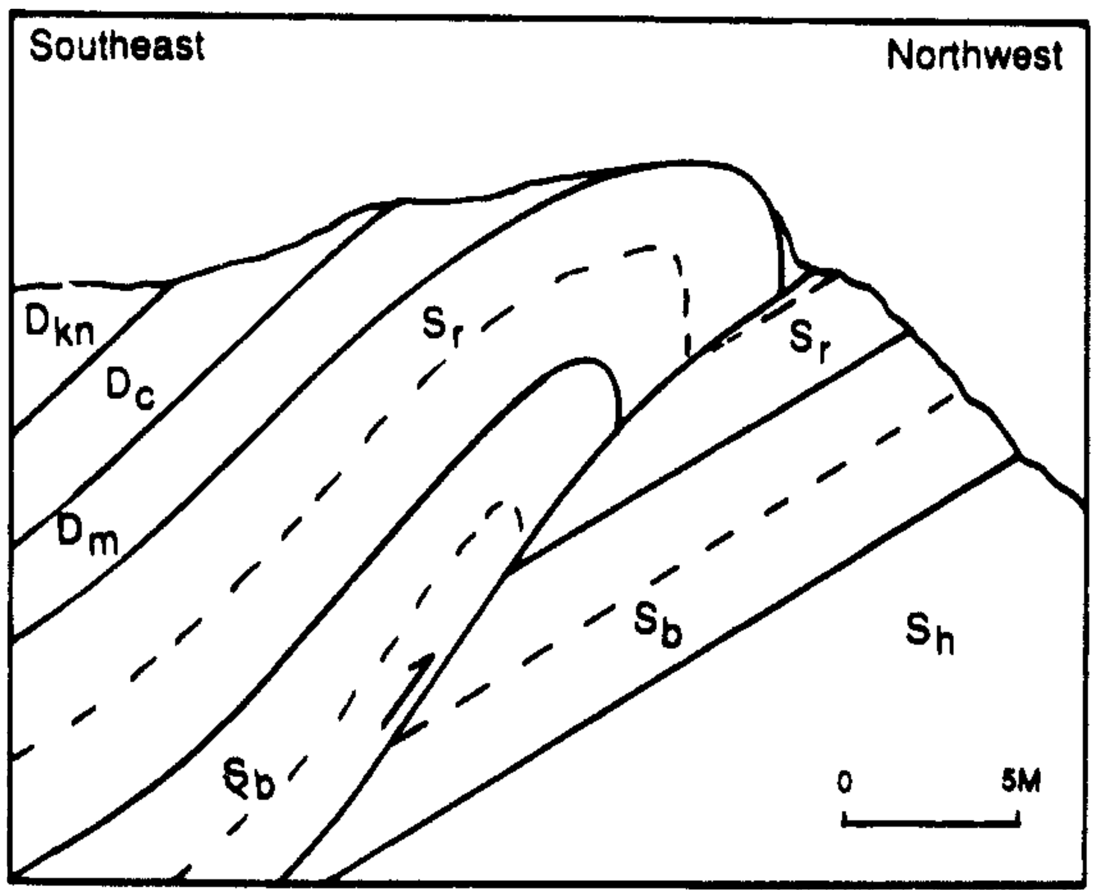

Figure 9. Cross section C depicting the southernmost exposure of the anticlinal fault propagation fold in the hangingwall of the Whiteport fault (units as in Fig. 4).

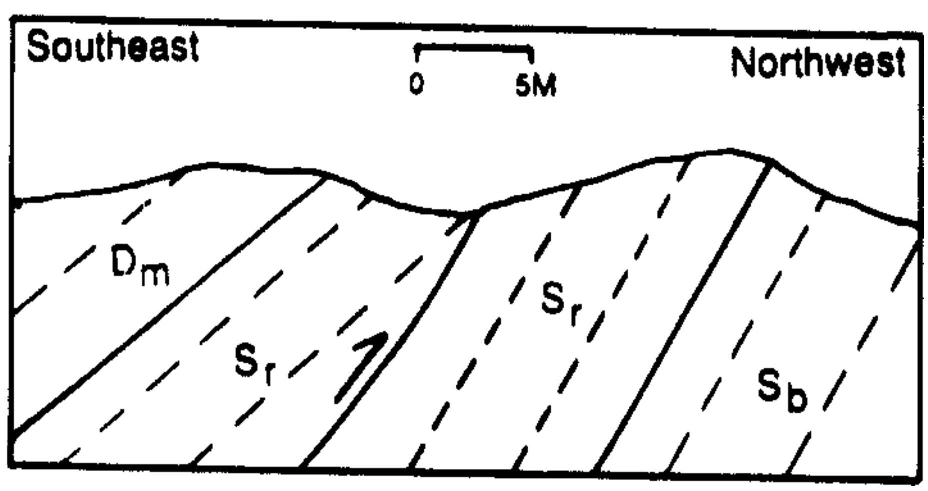

Figure 10. Cross section D showing a segment of the Whiteport fault where Whiteport Member is thrust over Rosendale Member in a ramp on flat geometry (units as in Fig. 4).

hangingwall Binnewater Sandstone over footwall Rosendale Member in a complex geometry (Fig. 11).

At the southernmost exposure of the Whiteport fault, Whiteport Member is placed over Upper Coeymans in a ramp on flat geometry (Fig. 12). Displacement on the Rosendale fault has decreased here so that there is no stratigraphic offset.

Because of poor exposure to the southwest, it was impossible to trace the Whiteport fault along strike. Available outcrops, however, suggest the possibility of another major thrust to the south of and below the Whiteport and Rosendale faults, as eastward-dipping Rondout Formation occurs below eastward-dipping Binnewater Sandstone.

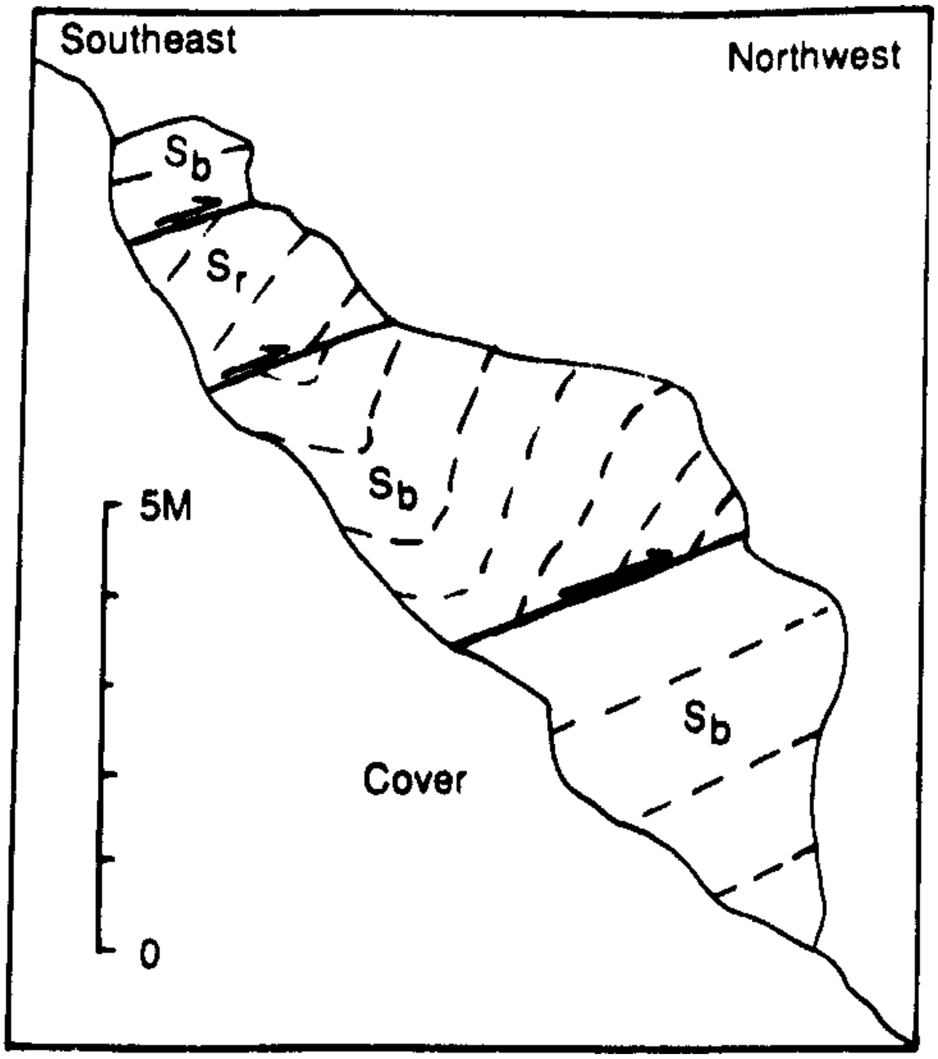

Figure 11. Cross section E depicting an exposure of the Rosendale fault (top) and associated imbricate thrusts (below). Synfrom folds in the Binnewater Sandstone are interpreted to be detachment folds (units as in Fig. 4).

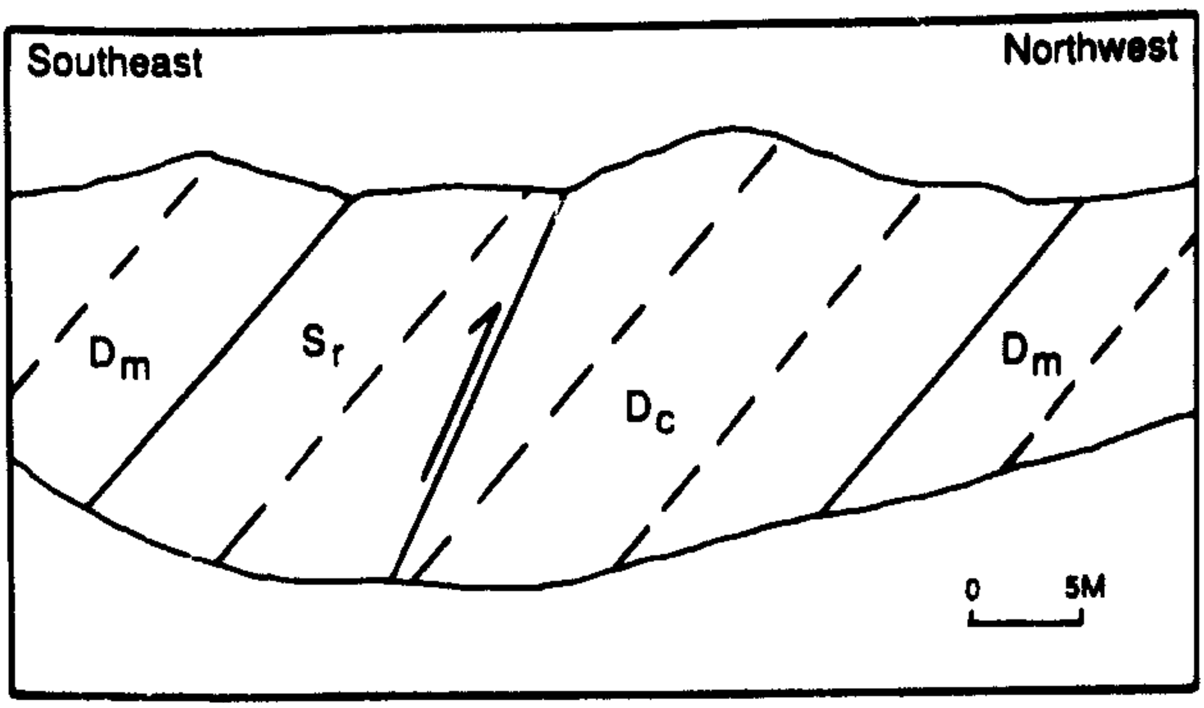

Figure 12. Cross section F showing the Whiteport fault placing Rondout Formation (Whiteport Member) over Coeymans Formation in a ramp on ramp geometry (units as in Fig. 4).

Interpretation

The numerous thrust faults within the Upper Silurian section in the area of Fourth Lake, New York, suggest that a significant regional detachment exists at this stratigraphic level in the Kittatiny-Shawangunk segment. The Whiteport fault is the local manifestation of this detachment, and probably correlates (structurally, but not temporally) to the Rondout detachment described by Marshak (1986) in the Hudson Valley fold-thrust belt. The Whiteport fault, however, detaches in the Binnewater Sandstone and the Rondout detachment occurs in the Rondout Formation. A second, lower detachment is inferred from the presence of larger scale folds. Because the larger scale anticlinal folds are cored by Austin Glen Formation, the second detachment is thought to occur at depth within this unit (Fig. 13). This interpretation is equivalent to the recognition of the Austin Glen detachment in the Hudson Valley fold-thrust belt by Marshak (1986). Area-balancing of cross sections suggests that the Austin Glen detachment is approximately 400 meters below the Taconic unconformity in the Hudson Valley fold-thrust belt near Catskill (Marshak, 1986). Assuming a normal, break-forward thrusting sequence, displacement on the Austin Glen detachment probably post-dates displacement on the Whiteport fault, although no conclusive evidence for the relative timing of the faults was found.

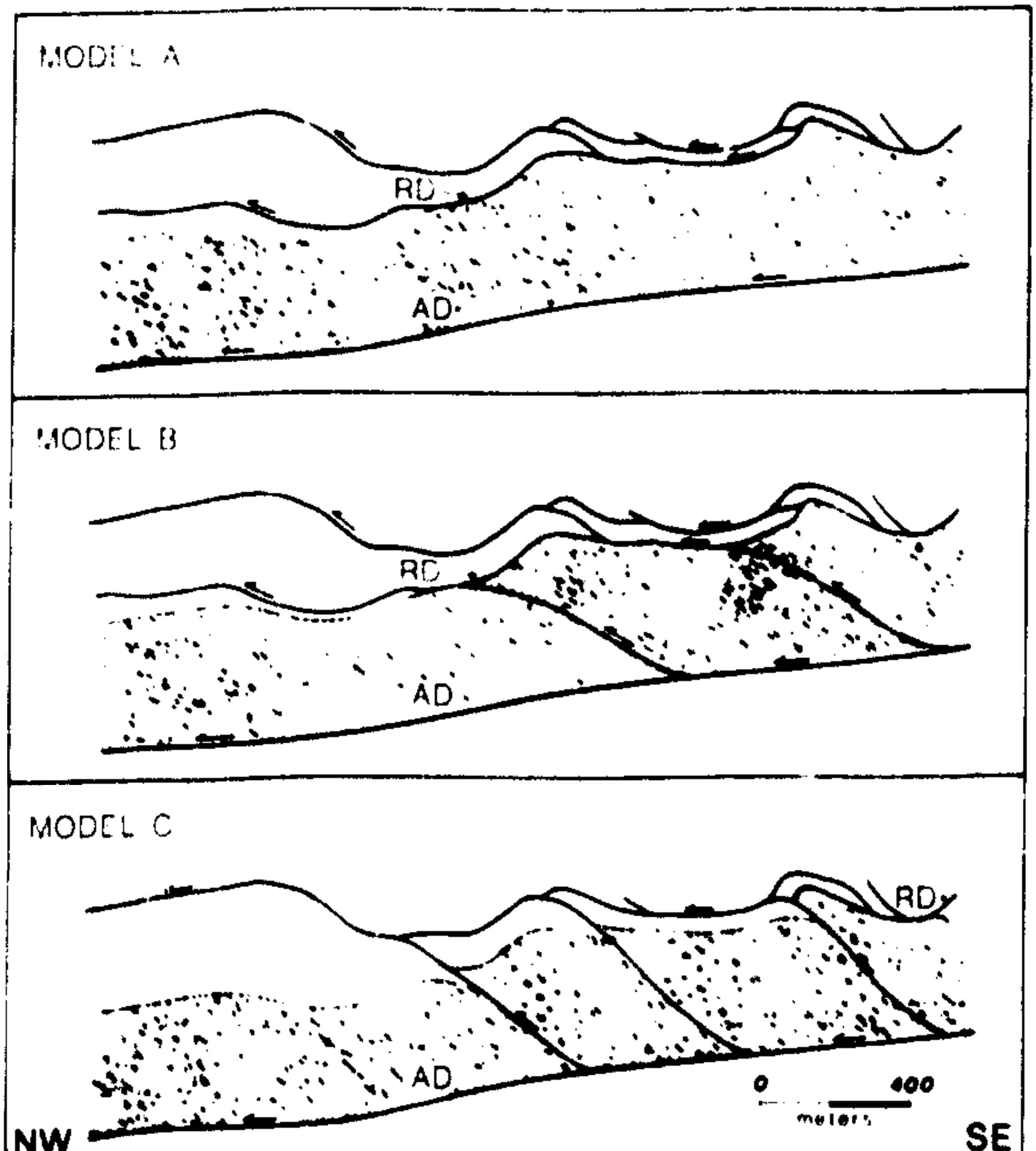

Figure 13. Alternative models showing three possible relationships between the Rondout (eqivalent to Whiteport fault) and Austin Glen detachments near Catskill, New York A similar relationship is interpreted to exist between the Whitoport fault and the Austin Glen detachment near Fourth Lake. RD: Ror.dout detachment, AD Austin Glen detachment (figure from Marshak, 1986).

Because the northern termination of the Whiteport fault is exposed, and because stratigraphic separation increases along strike to the southwest, displacement must increase to the southwest. Because the Whiteport fault cuts upsection to the southwest in both the hangingwall and the footwall, it is interpreted as a lateral fault ramp. The Rosendale fault most likely joins the Whiteport fault along a branch line (Boyer and Elliot, 1982) located in the subsurface to the southeast (Fig. 14). The complex thrust geometry shown in figure 11 can be explained by the formation of small-scale detachment folds within the Binnewater Sandstone and Rosendale Member. A viable explanation for the tight anticlinal fold in the hangingwall of the Whiteport fault is that this is the hangingwall anticline of a fault propagation fold (Suppe and Medwedeff, 1984), in which the fault has subsequently propagated through the fold. In this case the fold presumably continued along strike to the southwest, but is not exposed because increased displacement on the Whiteport fault to the southwest places the fold in the eroded core of the Whiteport anticline. Because of the available exposure, it is impossible to establish if the slip lineations shown in figures 7 and 8 are due to flexural slip or displacement on a minor thrust. In the former case they could have accommodated formation of either the hangingwall ramp anticline or the Whiteport anticline, while in the latter case they might represent a minor thrust, which most likely joins the Whiteport fault. Neither interpretation changes the overall

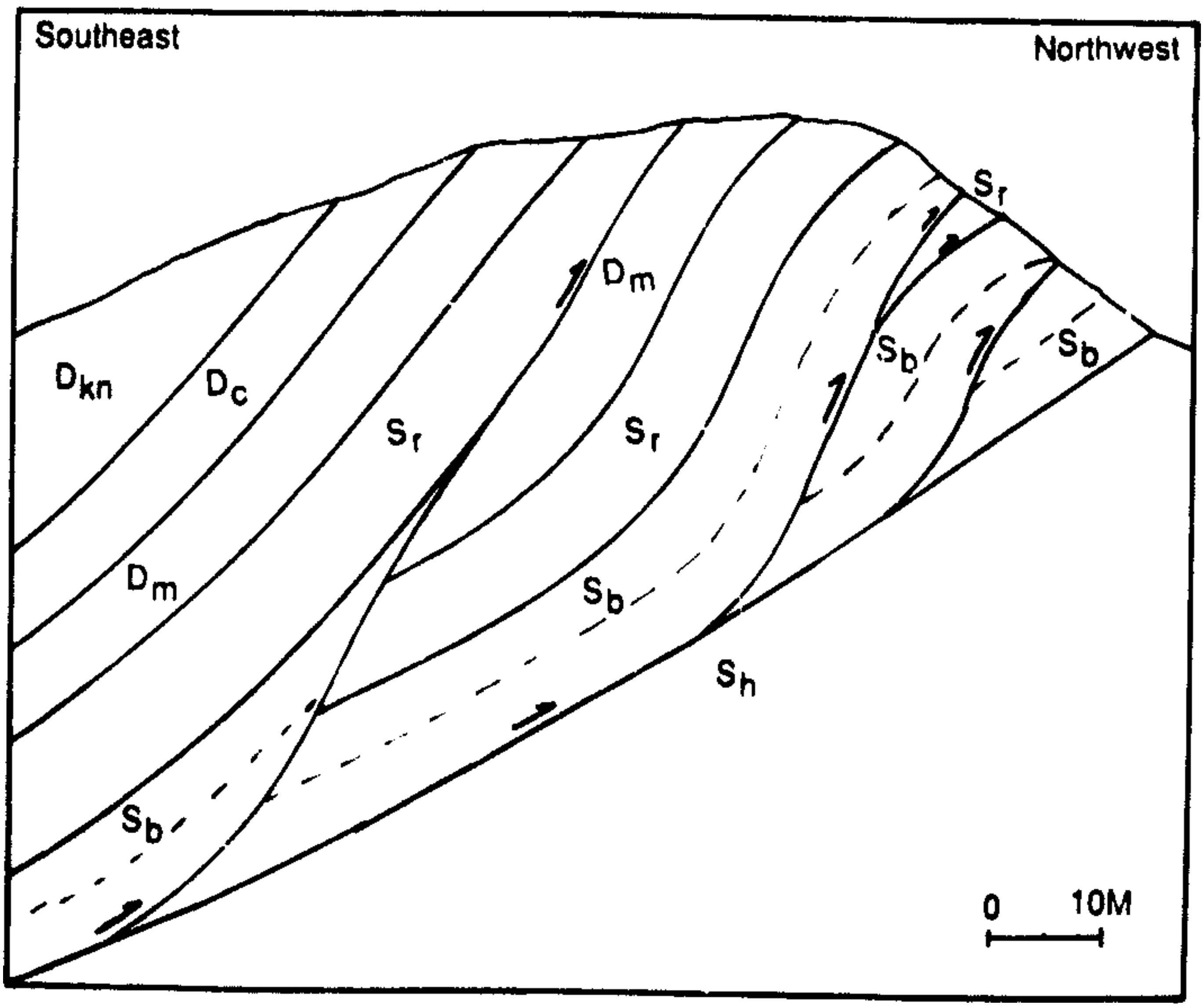

Figure 14. Interpretive cross section showing linking of the Whiteport and Rosendale faults along a branchline. Location of section is between sections D and E (units as in Fig. 4).

thrust geometry (compare Fig. 8 A and B). The relationship of the backthrust (Fig. 8) to the Whiteport fault is unclear. This backthrust most likely originates within the Austin Glen Formation on a pre-existing plane of weakness (fault surface) and possibly accommodated the formation of the Whiteport anticline, thus post-dating deformation associated with displacement on the Whiteport fault.

Conclusions

The recognition of two separate detachments in the Fourth Lake area, one in the Upper Silurian and one in the Ordovician Austin Glen Formation, agrees with previous studies in the region that found evidence for two distinct detachments (McEachran, 1985; Tabor, 1985; Marshak, 1986; Marshak and Tabor, 1989). The Whiteport fault described in this paper is equivalent to Marshak's Rondout detachment (1986) in the Hudson Valley fold-thrust belt, with the exception that the Whiteport fault detaches at a lower stratigraphic horizon (base of the Binnewater Sandstone) than the Rondout detachment (Rondout Formation). Thus, a regional detachment, locally called the Whiteport fault (in the Kittatiny-Shawangunk segment of the Appalachian fold-thrust belt) or the Rondout detachment (in the Hudson Valley fold-thrust belt), is interpreted to be localized above the Taconic unconformity. Continued study is necessary further to the south, where the Upper Silurian section continues to thicken, to completely understand the effect of lateral variations in stratigraphic thickness on detachment geometry.

Detailed mapping has shown that displacement along the Whiteport fault and the geometry of the Whiteport fault and associated structures changes rapidly along strike. The Whiteport fault changes from a bedding parallel thrust with minor displacement and no stratigraphic offset in the northeast to one with approximately 18 meters of stratigraphic offset in the southwest along strike over a distance of about 250 meters. This corresponds to a minimum displacement of 35 to 40 meters on the Whiteport Fault. As a result of the change in displacement, geometry also changes along strike, as shown by the development of the anticlinal fault propagation fold and lateral ramping of thrusts.

References Cited

Boyer, S.E., and Elliot, D., 1982, Thrust Systems: American Association of Petroleum Geologists Bulletin, v. 66, p. 1196-1230.

Epstein, J.B., and Lyttle, P.T., 1987, Structure and stratigraphy above, below, and within the Taconic unconformity, southeastern New York, *in* Waines, R.H., ed., New York State Geological Association 59th annual meeting field trip guidebook, New Paltz, New York, P. C1-C78.

Geiser, P., and Engelder, T., 1983, The distribution of layer-parallel shortening fabrics in the Appalachian foreland of New York and Pennsylvania: Evidence for two noncoaxial phases of the Alleghenian orogeny: Geological Society of America Memoir 158, P.161-175.

Hoar, F.G., and Bowen, Z.P., 1967, Brachiopoda and stratigraphy of the Rondout Formation in the Rosendale Quadrangle, southeastern New York: Journal of Paleontology , v. 41, p. 1-36.

Marshak, S., 1986, Structure and tectonics of the Hudson Valley fold-thrust belt, New York: Geological Society of America Bulletin, v. 97, p. 354-368.

Marshak, S., and Tabor, J.R., 1989, Structure of the Kingston orocline in the Appalachian fold-thrust belt, New York: Geological Society of America Bulletin, v. 101, p. 683-701.

McEachran, D.B., 1985, Structural geometry and evolution of the basal detachment in the Hudson Valley fold-thrust belt north of Kingston, New York [M.S. thesis]: Urbana, Illinois, University of Illinois, 97 p.

Rickard, L.V., 1962, Late Cayugan (Upper Silurian) and Helderbergian (Lower Devonian) stratigraphy in New York: New York State Museum and Science Service Bulletin 386, 157 p.

Suppe, J., and Medwedeff, D.A., 1984, Fault propogation folding: Geological Society of America Abstracts with Proceedings, v. 16, p. 670.

Tabor, J.R., 1985, Nature and sequence of deformation in the southwestern limb of the Kingston orocline [M.S. thesis]: Urbana, Illinois, University of Illinois, 87 p.

Waines, R.H., and Hoar, F.G., 1967, Upper Silurian-Lower Devonian stratigraphic sequence, western mid-Hudson Valley region, Kingston to Accord, Ulster County, New York, *in* Waines, R.H., ed., New York State Geological Association Guidebook, 39th meeting, New Paltz, New York, p. D1-D28.

Wanless, H.R., 1920, Final report on the Geology of the Rosendale Cement District [M.S. thesis]: Princeton, New Jersey, Princeton University, 280 p.