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Exposures of the Hudson Valley Fold-Thrust Belt, west of Catskill, New York

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LOCATION

Outcrops visible along New York 23 and along Catskill Creek, about 1.2 mi (2 km) northwest of the town of Catskill, New York (about 33 mi [55 km] south of Albany), provide a nearly complete cross-sectional display of the Hudson Valley Fold-Thrust Belt (Marshak, 1983; 1986a). These exposures provide an excellent opportunity both to examine thin-skinned structural styles and to study facies relationships among shallow marine carbonate rocks. The roadcuts are accessible directly from the highway, and it is legal to park for short periods anywhere along the highway shoulder. Creek exposures are accessible from paths that run north and south from the southeast side of the New York 23 bridge over Catskill Creek, but it is necessary to obtain permission of landowners (see posted signs) to view these exposures.

The New York 23/Catskill Creek site can be reached from the New York State Thruway Exit 21 (Fig. 1). Leave the Thruway at Exit 21 and pass through the tollgate. At the end of the tollgate access road, turn left (southeast) onto New York 23B heading toward Jefferson Heights and Catskill. Continue on New York 23B for 0.2 mi (0.3 km) to the junction with New York 23. The outcrops along the west shoulder of New York 23B at this parking spot are composed of Kalkberg Formation and display several small thrust faults with adjacent "drag" folds. To reach outcrops N5 and N4 (labeled in Figs. 1, 2), park on the west shoulder of 23B just north of the entrance ramp that leads onto New York 23 heading northwest. Outcrop N5 is along the exit ramp from New York 23 northwest leading to 23B, and outcrop N4 is along the entrance ramp from 23B onto 23 northwest. To reach outcrops N3-N1 and S3-S1, drive onto New York 23 heading northwest toward Cairo. Outcrops N3 and S3 lie southeast of the Thruway, N2 and S2 lie between the Thruway and Catskill Creek, and N1 and S1 lie northwest of Catskill Creek.

Our discussion will consider only the New York 23 and Catskill Creek outcrops. Figure 2 (see also Babcock, 1966) illustrates that sufficient outcrops occur away from these cuts to permit mapping of the area. In addition, excellent exposures of the fold-thrust belt are available elsewhere along the Hudson Valley fold thrust belt (Fig. 3). Notable examples include (1) quarry exposures at Fuerra Bush (Marshak, 1986a), Becraft Mountain (Chapple and Spang, 1974), Mount Ida (Ratcliffe and others, 1975), Quarry Hill, West Camp (Leftwich, 1973; Zadins, 1983), and Kingston (McEachran, 1985; Tabor, 1985; Marshak, in preparation); (2) roadcuts along New York 23A (Marshak and Geiser, 1980), New York 199 and 32 in Kingston (Waines and Hoar, 1967), U.S. 9W in Kingston (Marshak, 1986b), and the New York State Thruway (written permission must be obtained from the Thruway Authority in Albany to view Thruway cuts); and (3) in Hasbrouck Park in the City of Kingston (Marshak, in preparation).

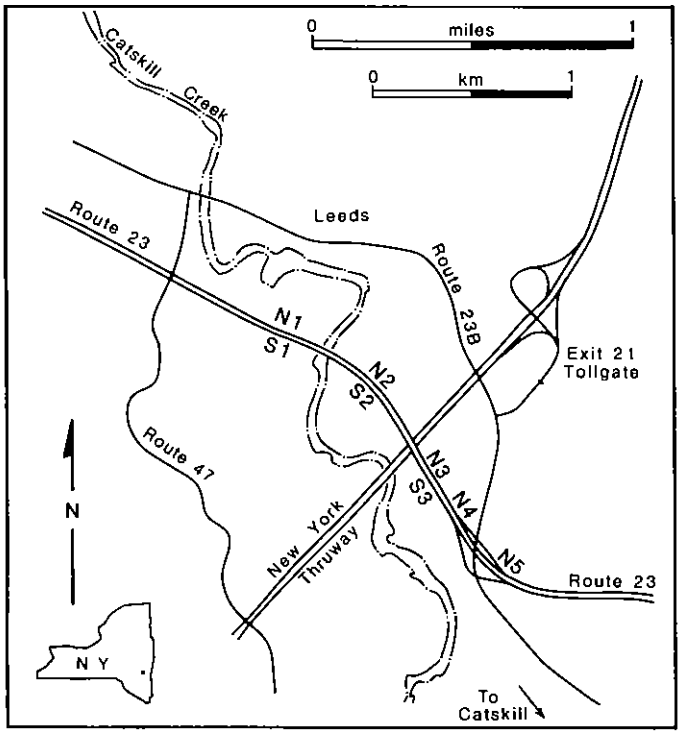

Figure 1. Sketch map of the Catskill area showing the location of the New York 23 and Catskill Creek outcrops discussed in the text.

SIGNIFICANCE

The Hudson Valley Fold-Thrust Belt (HVB) involves Upper Silurian through lower Middle Devonian strata, and lies along the west edge of the Hudson Valley between Kingston and Albany (Fig. 3). Structural features within the HVB are similar in style to those of most fold-thrust belts except that the dimensions of structures in the HVB are so small that most structures can be seen in their entirety in a single outcrop (Davis, 1882; 1883; Sanders, 1969). The HVB, in effect, provides scale models of range-scale structures that occur in large fold-thrust belts, such as the Canadian Rockies. In particular, the exposures near Catskill provide (1) numerous examples of thin-skinned structural geometries, (2) exposures of the Taconic angular unconformity (Rodgers, 1971), (3) examples of mesoscopic structures (e.g., tectonic cleavage and

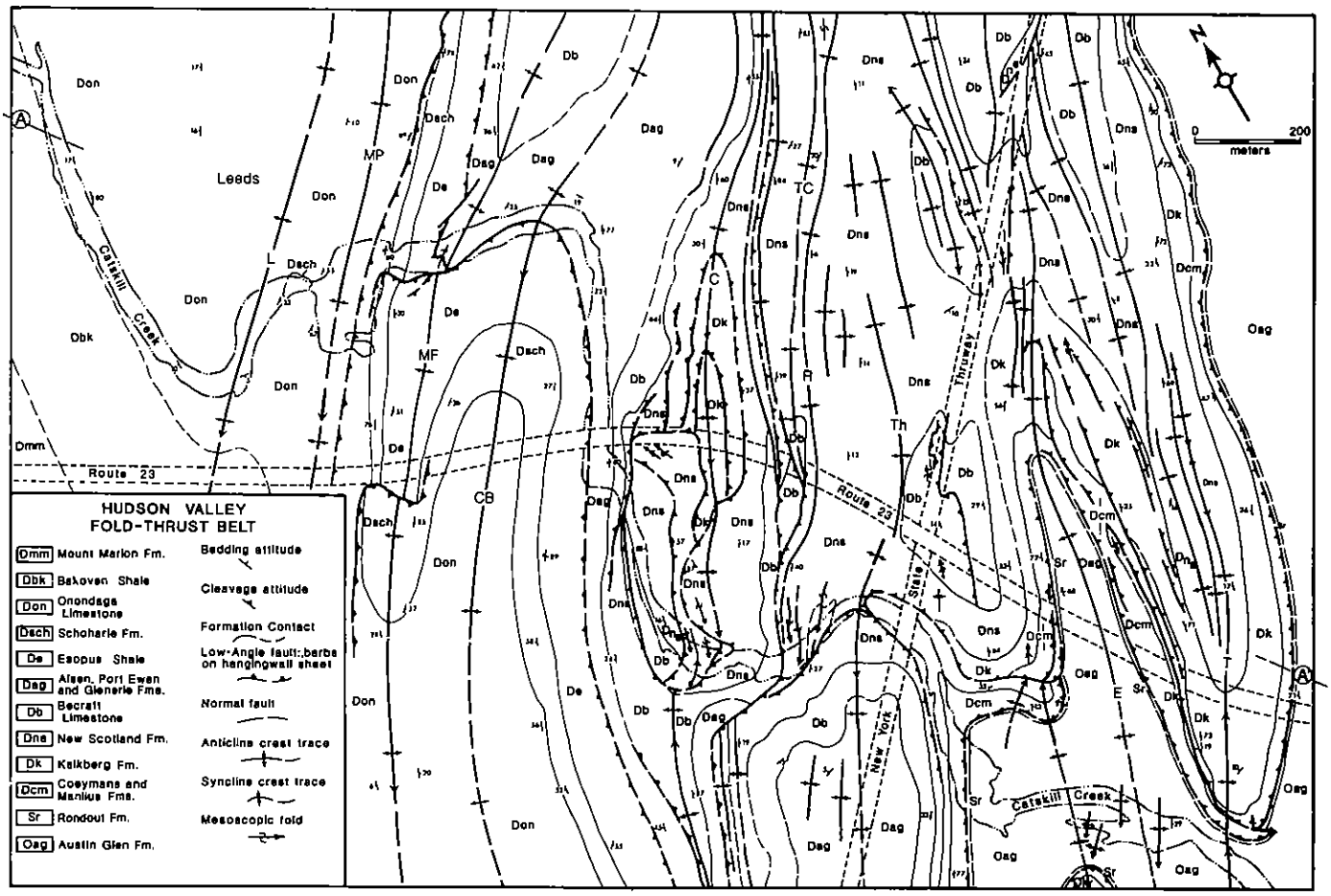

Figure 2. Geologic map of the HVB along New York 23 and Catskill Creek, northwest of Catskill, New York. T = Tollgate; E = Eastern; Th = Thruway; R = Rip van Winkle; TC = Town & Country; C = Central; CB = Creek Bend; MF = Mill Falls; MP = Mill Pond; L = Leeds.

slip fibers) that characteristically form in sedimentary rocks deformed under relatively low pressure and temperature conditions (Marshak and Engelder, 1985), (4) classic Lower Devonian North American faunas (see Chadwick, 1944; Goldring, 1943), and (5) examples of shallow-marine carbonate facies (Rickard, 1962; LaPorte, 1969). Studies of structures in the HVB also provide useful information concerning tectonics of the New England Appalachians (Marshak, 1986a).

SITE INFORMATION

The HVB involves units that lie above the Taconic unconformity (Fig. 4). Near Catskill, the subunconformity sequence is composed of the Austin Glen Formation, which consists of interbedded greywacke and shale. Locally, this shale contains well-developed pencil cleavage. The basal unit above the unconformity is the Rondout Formation, represented by 3 to 6 ft (1 to 2) m of sandy dolomitic limestone. (This unit thickens significantly to the south.) Above the Rondout Formation are the Helderberg and Tristates Groups, which include a range of units indicative of successive transgressions of a shallow sea (see Sanders, 1969). The only noncarbonate unit in this sequence is the Esopus Formation. Above the Tristates Group is the Onondaga Limestone, which is the youngest carbonate unit to be deposited prior to the deposition of the Catskill clastic wedge. Deformation features characteristic of the HVB are visible in the Bakoven Shale and Mount Marion Formation but cannot be found in younger units (Murphy and others, 1980). Below, we discuss structural features exposed along New York 23 and along Catskill Creek. Only brief descriptions are possible here; for further descriptions, see Marshak, 1986b.

Across the width of the HVB near Catskill, there are 10 major folds (named in Fig. 2) with amplitudes in the range of 164 to 394 ft (50 to 120 m). These folds generally trend north-south to N.15°E., and are gently plunging. Within these folds, there are many significant faults and, locally, zones of mesoscopic folding.

Outcrop N5 (Fig. 5) is the easternmost outcrop the HVB along New York 23. At the east end of this outcrop is an exposure of the Taconic unconformity, which here is a pronounced angular unconformity. The upper meter of the overlying Rondout Formation is intensely deformed and may be the location of a detachment fault, called the Rondout detachment, which acts as

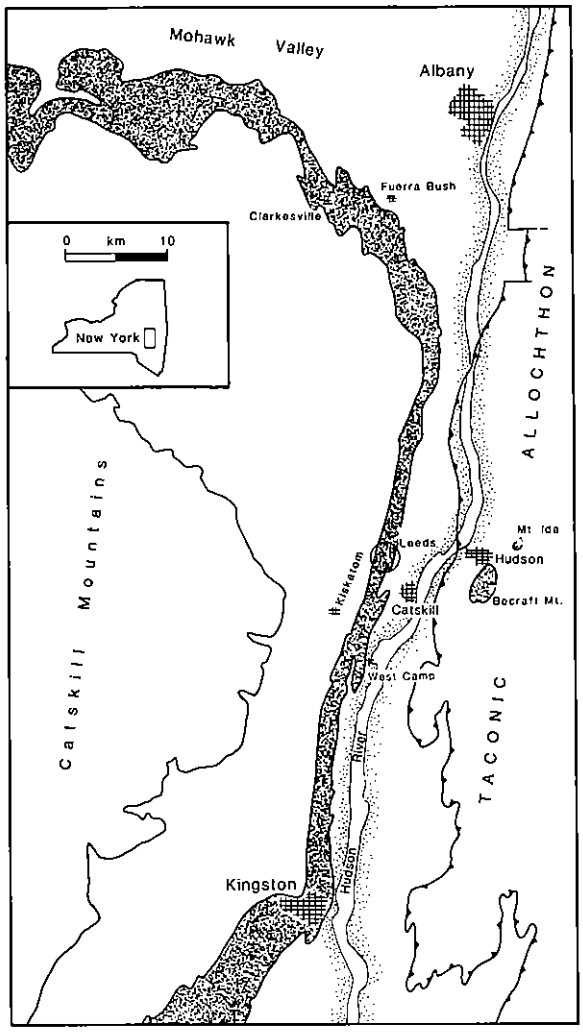

Figure 3. Location map of the HVB. The outcrop belt of Silurian through lower Middle Devonian strata is stippled.

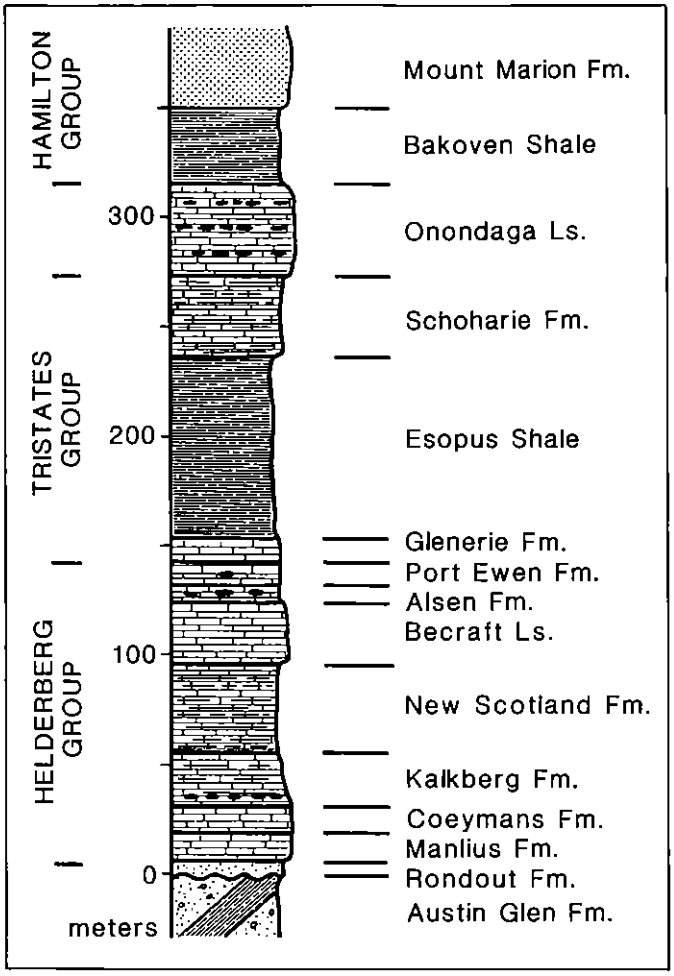

Figure 4. Stratigraphic column of units exposed in the HVB near Catskill.

the floor thrust with regard to faults exposed within Lower Devonian units (Marshak, 1986a, b). Over the Rondout Formation, in this outcrop, is a homoclinally dipping sequence of the lower Helderberg Group (Manlius-Kalkberg Formations). Note that here, as throughout the HVB, development of cleavage is lithologically controlled; cleavage occurs primarily in rocks containing greater than 10 percent clay.

Outcrop N4, on the western limb of the Tollgate Syncline (Fig. 2) provides another exposure of the lower Helderberg Group. In this outcrop, the section has been thickened as a result of movement on two well-exposed thrust faults. The lower fault has significant stratigraphic throw, for it brings the Manlius Formation over the Kalkberg Formation. These faults may be out-of-the-syncline faults (see Dahlstrom, 1970).

Outcrops N3 and S3 provide additional exposures of the Taconic Unconformity and of the Helderberg Group (through the Becraft Formation). Of particular note in these outcrops are the complex faults and folds in the Rondout and lower Manlius Formations; these structures are probably manifestations of movement on the Rondout detachment. Many bedding-plane slip surfaces, which developed during flexural-slip folding and are coated with sheets of calcite slip fibers, occur in outcrops N3 and S3. In the Kalkberg Formation, some of these slip surfaces are bounded by zones of nearly slaty cleavage. At the northwest end of outcrop N2, numerous mesoscopic folds, as well as two backthrusts, occur within the Becraft Limestone.

Outcrops N2 and S2 are the most spectacular of the New York 23 roadcuts. These exposures (which include rocks of the Manlius Formation through Becraft Limestone) display, from southeast to northwest, ramp faults with hanging wall anticlines (Rip van Winkle anticline), out-of-the-syncline forethrusts and backthrusts, folded ramps and flats (in the Central anticline), and zones of tectonic cleavage intensification (on the northwest limb of the Central anticline). Of particular note are the examples of fault bends (Suppe, 1983) at which bedding-parallel flats join cross-strata ramps. The Central anticline appears to be composed

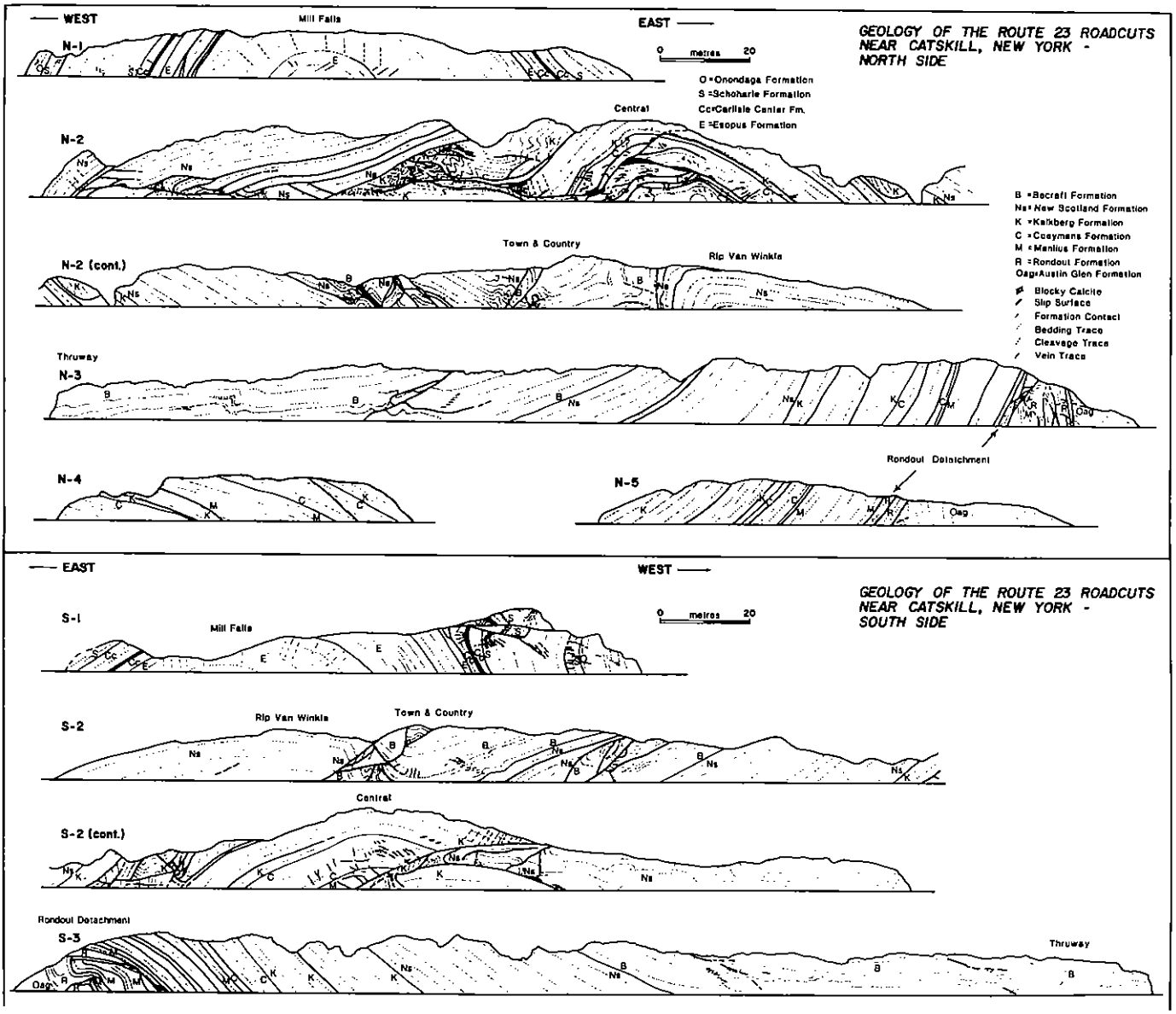

Figure 5. Structural features of the New York 23 roadcuts in the HVB. These cross-sections were constructed on a photomosaic base.

of a stack of fault-bounded horses (see Boyer and Elliott, 1984), one of which is internally deformed throughout by mesoscopic folds. Structures of outcrops N2 and S2 do not directly correlate across the highway, illustrating how rapidly structural geometry can change along strike in a fold-thrust belt. The contrast in structural geometry between outcrops on opposite sides of the road may reflect the occurrence of a lateral ramp in the interval that was excavated during construction of the highway.

Outcrops N1 and S1 expose the Esopus and Schoharie Formations, and the base of the Onondaga Limestone. These units are arched around the Mill Falls anticline. Nearly slaty cleavage occurs within the lower Esopus Formation. The upper few meters of the Esopus Formation are composed of beds of finely laminated mudstone and siltstone that have been crinkled into tiny folds. A subhorizontal fault is present at the top of outcrop S2.

Creek exposures provide both map-view and cross-section views of principal folds and faults in the HVB. North of the New York 23 bridge (locality C1), the Mills Falls anticline and the Creek Bend syncline are visible. South of the bridge (locality C2), the creek cuts through imbricate thrust sheets involving the Becraft and New Scotland Formations (Fig. 2).

The depth of exposure available at Catskill does not permit direct construction of a cross section down to the basal detachment of the belt. Figure 6 presents a reasonable cross-sectional model of the belt. In this model, the thrust system visible at the

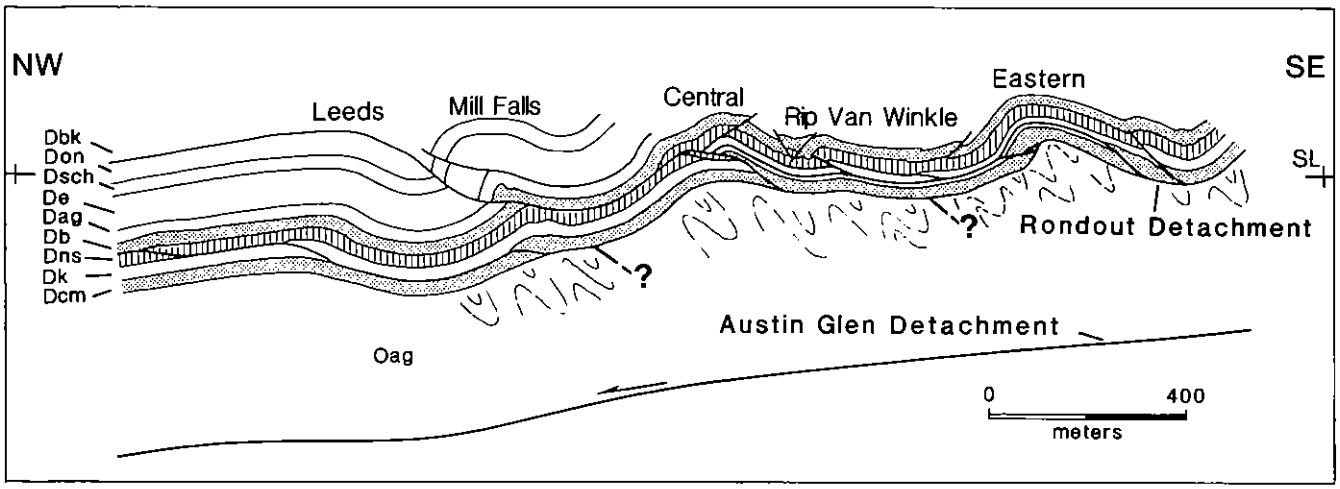

Figure 6. Interpretive cross section of the HVB at Catskill. Abbreviations refer to fold names identified in Figure 2. RD = Rondout detachment; AD = Austin Glen detachment.

field site lies entirely above the Rondout detachment. Some of the faults describe an upward-imbricate fan and others a duplex (see Boyer and Elliott, 1984). The Rondout detachment in this model is itself folded; this feature requires that there was shortening of the subunconformity Austin Glen flysch during the development of the HVB. A lower blind thrust, called the Austin Glen detachment (Marshak, 1986), may have developed at depth to accommodate this shortening. Deformation of the HVB dies out westward; west of Leeds, there appears to have been movement on blind thrusts, for the Bakoven Shale and the Mount Marion Formation contain tectonic cleavage. Present exposures of the HVB are probably only the western edge of what was once a much wider Acadian (?) fold-thrust belt that extended farther to the east, perhaps across the Taconic Mountains.

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