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Stratigraphy of the Cambrian platform in northwestern Vermont

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LOCATION

The Cambrian to Lower Ordovician stratigraphic sequence in northwestern Vermont outcrops in a north-south trending belt bordered on the east by the Green Mountain anticlinorium and on the west by deformed Middle Ordovician shales. Significant facies changes, both parallel and perpendicular to depositional strike, can be observed between Burlington and U.S. 2, 8 mi (13 km) to the north (Fig. 1). Stops 1 to 5 in the Lower Cambrian Dunham Dolomite, Middle Cambrian Monkton Quartzite, and Winooski Dolomite are located on a 3 mi (5 km) west-to-east series of outcrops along U.S. 2 near Milton, starting in an abandoned quarry on the north side of the road, 5 mi (8 km) east of the Sand Bar State Park. The section continues 0.9 mi (1.5 km) farther east along U.S. 2 at a large roadcut on the north side of U.S. 2 (Stop 2), and again another 0.8 mi (1.3 km) farther along Route 2 at a roadcut on the south side of the road (Stop 3). The final two stops along U.S. 2 are another 0.8 mi (1.3 km) (Stop 4) and 0.8 mi (1.3 km) (Stop 5, Chimney Corners). Total mileage along U.S. 2 is 3.3 mi (5.3 km). Stop 6 is located along the Winooski River in downtown Winooski, Vermont, where the supra-to-intertidal and shallow subtidal facies of the Monkton, Winooski, and Danby Formations are exposed. All outcrops are accessible by car; access does not require permission.

SIGNIFICANCE

Cambro-Ordovician siliciclastic and carbonate sediments in western Vermont were deposited on a tectonically stable shelf following late Precambrian rifting of the Iapetus Ocean (Rodgers, 1968). The alternating siliciclastic and carbonate units record sedimentation in supra-to shallow subtidal platform environments, which pass laterally into platform margin and basinal deposits. The basal Cheshire Quartzite, not included in this site, represents a shallow siliciclastic "blanket" over the Eocambrian rift topography (Myrow, 1983). Subsequent Cambrian units record the vertical upbuilding of the carbonate platform characteristic of the early Paleozoic continental margin in the Appalachians.

SITE INFORMATION

Background. The Lower Cambrian Dunham Dolomite lies in gradational contact with the Cheshire Quartzite (Fig. 2) and represents the initial carbonate deposition on the newly formed shelf (Gregory, 1982). The Dunham Dolomite is important because it records the initial carbonate facies development and the establishment of the platform geometry that are continued in subsequent units in northwestern Vermont. Upward building of the carbonate platform during Dunham time resulted

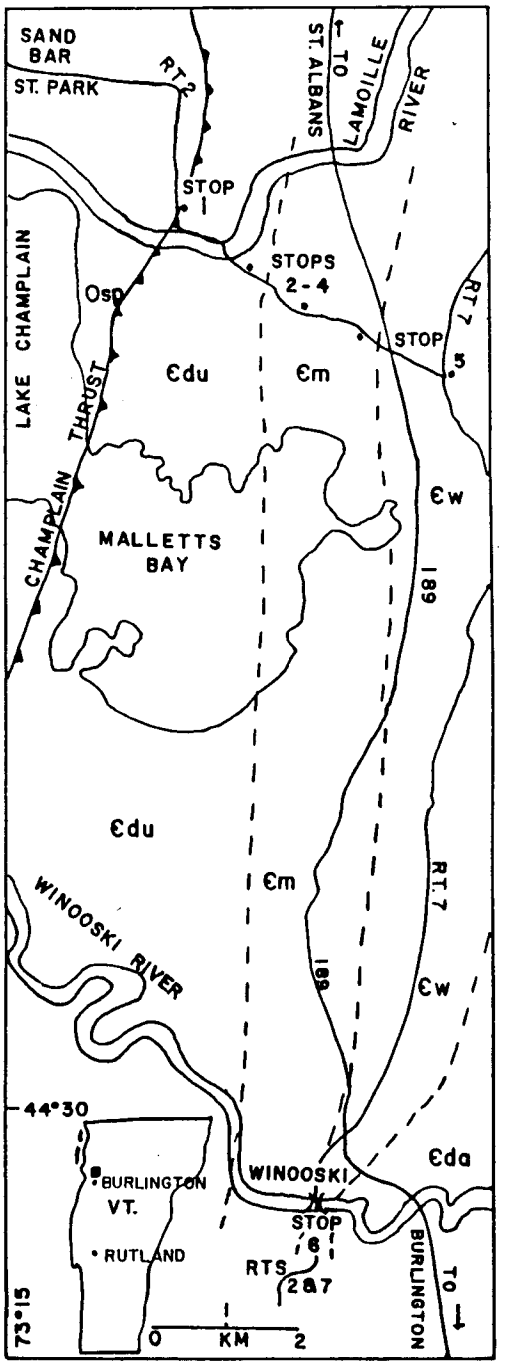

Figure 1. Locality map for stops in northwestern Vermont. Stops 1-5 occur along U.S. 2 between Sand Bar State Park and the intersection of U.S. 2 and 7 (Chimney Corners). Stop 6 occurs along the banks of the Winooski River in downtown Winooski, starting at the first ledges downstream of the bridge and extending upstream past the mill to the last ledges. Lithic designators: Cdu-Dunham Dolomite, Cm-Monkton Quartzite, Cw-Winooski Dolomite, Cda-Danby Quartzite, Osp-Stony Point Shale.

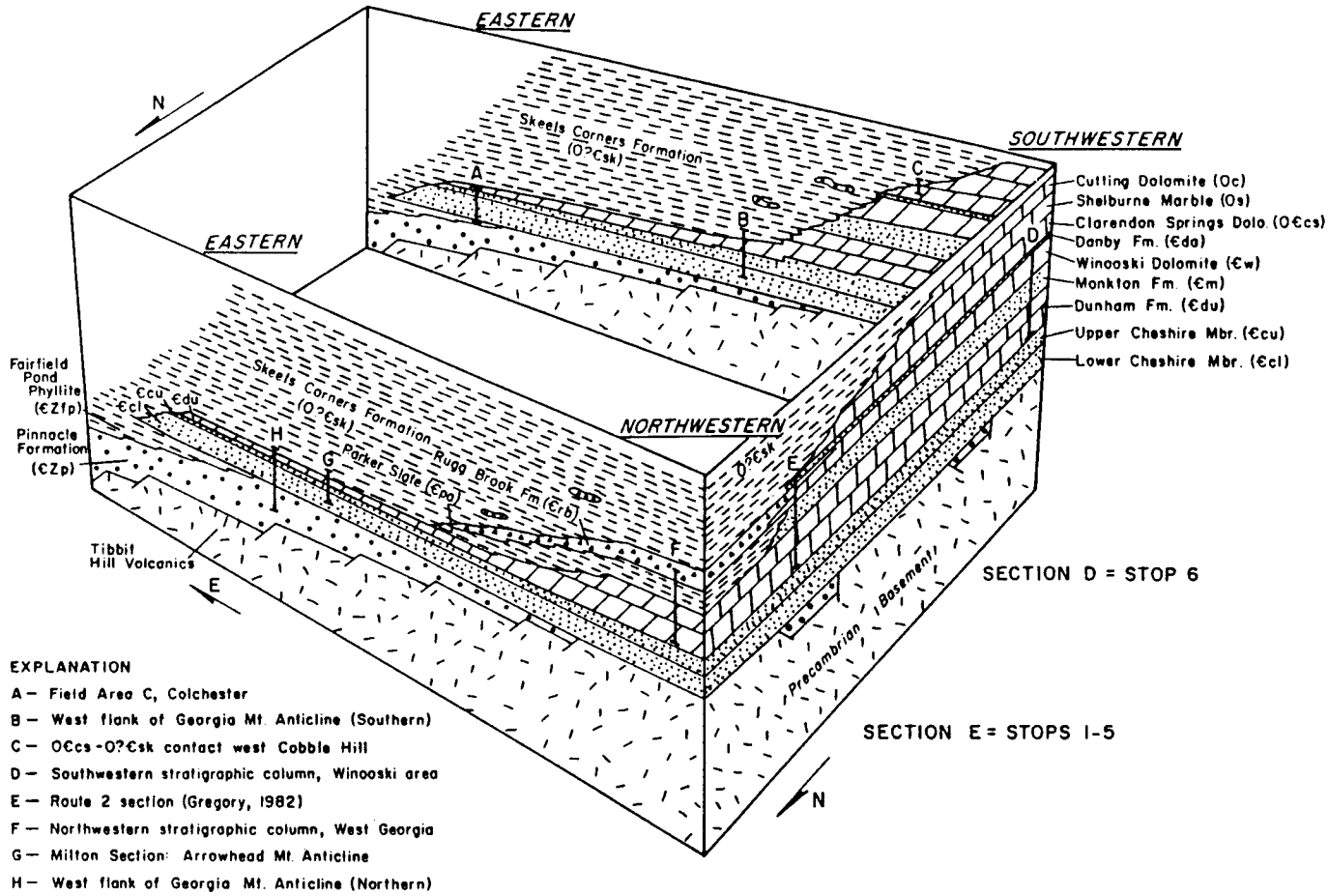

Figure 2. Block diagram from Dorsey, and others (1983) illustrating the platform stratigraphy and the eastward to northward facies changes associated with the platform margin transition. Sections represented by Stops 1-5 and 6 are sections E and D, respectively.

in the development of a platform-to-platform margin transition which was characterized by the abrupt pinch-out of shallow water facies into basinal shales and proximal talus slope breccias. This platform-to-basin transition remained localized in roughly the same paleogeographic position throughout the remainder of the Cambrian and Early Ordovician, probably as a result of movement on underlying rift-related faults. The Cambro-Ordovician platform was characterized by vertical upbuilding and little-to-no progradation into the adjacent basin.

The nature and distribution of lithofacies in the Monkton Quartzite (lower Middle Cambrian) can be compared to the underlying Dunham Dolomite; these also serve as models for interpreting the youngest siliciclastic unit, the Danby Quartzite. As seen in the Dunham Dolomite, the Monkton also records deposition in tidal, shallow subtidal, and platform margin environments. The distribution of lithofacies on the platform is also similar, recording both east-to-west and north-to-south facies changes into the adjacent shale basin. The lithofacies and environments of deposition of the Monkton Quartzite were studied and summarized by Rahmanian (1981). Rahmanian recognized seven lithofacies: three comprise mixed siliciclastic and carbonate sediments associated with shallowing-up cycles, three are pure siliciclastic deposits, and one is a pure carbonate (oolitic dolomite) facies. The 1,000-ft (300-m)-thick Monkton is composed of cyclic shallowing-up cycles characterized by repetitive packages of: (1) basal subtidal siliciclastic sand shoals and channels (Stop 4) overlain by, (2) interbedded siliciclastic sand and silt and carbonate intertidal flat sediments (Stop 6), capped by (3) carbonate muds of the high intertidal and supratidal flat (Stop 6). These shallowing-up cycles are interpreted to represent prograding tidal flat deposits, structurally similar to those in the underlying Dunham Dolomite (Mehrtens, 1986).

The Winooski Dolomite (Middle Cambrian) is a structureless dolomite with disseminated quartz sand and cryptalgalaminites common throughout. Little detailed sedimentology has been done on the Winooski, but based on its stratigraphic relationship with over- and underlying units as well as lithofacies analysis, it is interpreted to represent shallow subtidal (Stop 6) to platform margin (Stop 5) environments.

The Upper Cambrian Danby Quartzite is a mixed siliciclas-

tic and carbonate unit (Butler, 1986) that represents deposition in intertidal to shallow subtidal as well as platform margin settings. Butler (1986) has interpreted much of the Danby as recording shallow subtidal, storm-influenced sedimentation.

The Cambro-Ordovician sequence seen in Vermont records alternating carbonate and siliciclastic sedimentation not seen elsewhere in the Appalachian-Caledonide Orogen. The environments of deposition represented by each formation are similar, regardless of composition, and contacts between units are gradational. These three characteristics: regionally localized cyclic carbonate or siliciclastic sedimentation, similarity of platform paleogeography, and consistently gradational contacts, suggests that the cyclicity is not a result of large-scale regressive events (Rowley, 1979), but rather local variations in siliciclastic sand supply and distribution.

Stop 1. Stop 1, an abandoned quarry, lies immediately above the Champlain Thrust, as the floor of the quarry is Middle Ordovician Stony Point Shale overlain by Lower Cambrian Dunham Dolomite. The Dunham Dolomite is approximately 1,300 ft (400 m) thick and is exposed along U.S. 2, near Milton (Stops 1-3), where rocks characteristic of the peritidal, subtidal/open shelf, and platform margin can be seen. Stop 1 exhibits fresh exposures of the peritidal facies, characterized by the rhythmic interbedding of white dolomite and red dolomitic siltstone in a "sedimentary boudinage" bedding style. Intraformational conglomerate, imbricated clasts, and burrows are locally common. It is strongly recommended that visitors to this stop avoid climbing on the quarry walls but confine themselves to large blocks lying around the quarry floor.

Stop 2. The overlying subtidal/open shelf facies of the Dunham Dolomite is characterized by shallowing-up cycles up to 30 ft (10 m) thick that have at their base massive beds of bioturbated and mottled dolomite with disseminated quartz and feldspar sand throughout. This lithology is capped by packages of the rhythmically interbedded dolomite and dolomitic siltstone of the peritidal facies. These shallowing-up cycles are interpreted to represent tongues of tidal flat sediments that prograded into the adjacent subtidal shelf. Shallowing-up cycles make up the bulk of the 1,000-ft (300-m)-thick subtidal facies, and these pass upsection into structureless, subtidal, burrowed muds before passing into the platform margin facies.

Stop 3. Stop 3 exhibits massive beds of polymictic breccia interpreted as proximal debris flows interbedded with graded dolomitic sandstone beds interpreted as turbidites. Clasts within the breccia are poorly sorted and angular. Beds are poorly developed and structureless. At other localities the Dunham platform margin lithofacies can be seen to pass laterally into basinal shales of the Parker Slate.

Stop 4. Stop 4, along U.S. 2, exhibits the subtidal and platform margin facies of the Monkton Quartzite. At this stop, subtidal/tidal channel, crossbedded sands pass up section into thickly bedded, crossbedded platform margin sand bodies. A smaller outcrop immediately to the east of Stop 4 exposes horizons of the platform margin polymictic breccia in a matrix of coarse-grained quartz sand. Note the variable clast composition and the angularity and poor sorting of the clasts. Compare the sedimentary structures and bed thickness at this exposure to the inter- and supratidal Monkton seen at Stop 6.

Stop 5. The Winooski Dolomite exposed at Stop 5 (Chimney Corners) consists of structureless dolomite which is environmentally nondiagnostic, but it is capped by horizons of polymictic breccia in a sand-rich dolomite matrix which has been interpreted as a platform margin breccia. The breccia can be compared to those seen in the underlying Monkton and Dunham Formations.

Stop 6. Stop 6, downstream of the bridge (southeast bank) over the Winooski River in Winooski, exhibits shallow-water facies of the Monkton, Winooski, and Danby Formations. The base of the section is in the Monkton Quartzite, where inter- and supratidal facies are exposed in shallowing-up cycles. Bedforms diagnostic of supra-, inter- and shallow subtidal environments are exposed on broad bedding planes. Several different ripple morphologies can be identified, along with mudcracks and vertical and horizontal burrows. Structureless beds of buff dolomite are interpreted as supratidal deposits.

The Winooski Dolomite is also exposed on the north side of the Winooski River (Stop 6) from below the bridge to 300 ft (100 m) upstream. The basal contact with the Monkton is underwater here, but in a quarry a few miles away it can be seen to be gradational over a 30-ft (10-m) interval. The upper contact of the Winooski with the Danby Quartzite (Stop 6, upstream on ledges above the mill) is also gradational, characterized by increasing sand content until the first quartzite bed of the Danby is reached. The Winooski here consists of structureless dolomite, which, with the exception of horizons of cryptalgalaminites, is environmentally nondiagnostic. The Winooski is interpreted as shallow subtidal in origin, based on the abundance of stromatolites(?) and its stratigraphic position relative to the underlying inter- and supratidal Monkton facies.

The Danby Quartzite (Stop 6) is exposed in a series of ledges upstream of the bridge over the Winooski River in Winooski. The outcrop at Stop 6 exhibits beds with a diverse assemblage of ripple morphologies, laterally discontinuous bedding, hummocky cross-stratification, stromatolites, and oncolites. The platform margin facies of the Danby is not exposed along Route 2, but occurs in the woods nearby. It is also characterized by polymictic breccia clasts in a crossbedded sand matrix, similar to those described for the Monkton Quartzite.

SUMMARY

The distribution of facies on the Cambrian platform records deposition on a flat-topped, low-gradient platform bordered on the east and north by a deep basin in which shale was deposited (Fig. 2). Regardless of siliciclastic or carbonate composition, all platform deposits appear to record similar facies: supratidal to shallow subtidal in the platform interior and platform margins characterized by carbonate or siliciclastic shoal deposits and talus

slope breccias. Significant lateral migration of facies between units is not seen, suggesting that sedimentation on the platform was continuous and able to keep pace with subsidence.

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