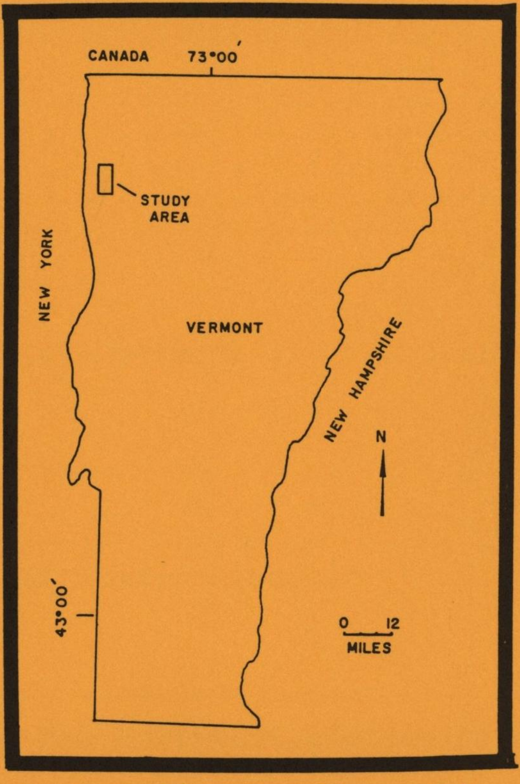
Stratigraphy and Bedrock Geology of Parts of the Colchester and Georgia Plains Quadrangles, Northwestern Vermont

Charlotte J. Mehrtens and Mary A. Borre



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STRATIGRAPHY AND BEDROCK GEOLOGY OF PARTS OF THE COLCHESTER AND GEORGIA PLAINS QUADRANGLES, NORTHWESTERN VERMONT

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Abstract

This study of the bedrock geology of a portion of the Colchester and Georgia Plains 7.5 minute quadrangles, Vermont, has resulted in a new geologic map (1:24,000) for the region. Significant differences of this map from the existing State Geologic Map (Doll, et al., 1961) include: (1) termination of the Winooski Dolomite outcrop belt at Chimney Corners; (2) extention of the Monkton Quartzite northward to the Milton Dam on the Lamoille River, where it interfingers with the Rugg Brook Dolomite; and (3) differentiation of facies within the Rugg Brook Dolomite. A more detailed map (1:12,000) shows the structure of the outcrop belt of the Rockledge Formation in the northeastern part of the study area. This study also describes the facies of the Cambrian units within the study area and their interpretation as platform, platform margin or basinal deposits. The southern margin of the St. Albans Reentrant is defined by platform margin facies in the Dunham, Monkton and Winooski Formations.

INTRODUCTION

The study area is in the northern part of the Colchester quadrangle and the southern part of the adjacent Georgia Plains quadrangle. It is underlain by Cambrian rocks which record the evolution of the Cambro-Ordovician platform in the northern Appalachians. These rocks are part of an extensive belt of similar facies extending from Newfoundland to Alabama along what Rodgers (1968) recognized as the margin of the Cambro-Ordovician platform in eastern North America. These facies consist of carbonate and siliciclastic deposits characteristic of a shallow-water platform, bordered to the east by a basin which accumulated muds and debris shed off the adjacent platform.

This study extends the revised stratigraphy developed by Mehrtens and Dorsey (1987) for the St. Albans area south into the Georgia and Milton region. This stratigraphy is in agreement with interpretations of depositional environments of the Cambro-Ordovician platform developed by Mehrtens (1985).

The Champlain thrust forms the western boundary of the study area. The Cambrian stratigraphic sequence described in this study lies on the upper plate of the Champlain thrust which has emplaced Cambro-Ordovician rocks on Middle Ordovician shales. The dominant structural feature of the study area is the St. Albans synclinorium, a broad, open syncline plunging gently to the south. Immediately to the east of the study area is the deformed eastern limb of the St. Albans synclinorium, which includes the Hinesburg thrust, mapped by Dorsey, et al. (1983). Emplacement of the Hinesburg thrust is thought to control the structural evolution of the Skeels Corners Slate in the eastern part of this study area.

PREVIOUS WORK

The geology of the region around the Georgia and Milton areas has been studied extensively for more than 100 years, mostly for paleontological interests. The most important of these earlier works were those of Walcott (1886, 1891), who studied the trilobite faunas of the Lower Cambrian units. Schuchert's contributions (1933 and 1937) are especially noteworthy, as they summarize the results of geologic studies up to that time. Shaw (1958) extensively studied the structure and stratigraphy of the St. Albans region to the north, and developed a regional stratigraphic sequence which has been adapted by most workers. His work, based on his doctoral dissertation and several years of Harvard field camp studies, interpreted the Cambrian sequence as a north-south trending outcrop belt of easterwardly-dipping, laterally continuous strata. Easily recognizable breccia horizons (Rugg Brook, Mill River, Rockledge Formations) separated discrete shale units (Parker, St. Albans, Skeels Corners, Morses Line). Mehrtens and Dorsey (1987) remapped the St. Albans region, and demonstrated that rock units within the region record complex sedimentology at the Cambrian platform margin and basin transition and that breccia horizons represent a series of debris flow deposits from the platform into the basin. Breccia horizons are not time-stratigraphic horizons, and different shale units do not occur between breccias. The whole sequence, instead, consists of undifferentiated Parker and Skeels Corners Slate and numerous pods of breccias.

Other studies of the field area include Stone and Dennis (1964), who remapped the Milton quadrangle which includes the southernmost part of this study area. The western part of Stone and Dennis' map is included in the work by Dorsey, et al. (1983), which revised the structure along the Hinesburg thrust.

STRATIGRAPHY

Rocks in the Milton region can be divided into two groups: the Western Shelf and Eastern Basinal Sequences (terminology after Dorsey, et al., 1983). The Western Shelf Sequence includes carbonate and siliciclastic rocks of shallow water platform origin which occur in a north-south trending outcrop belt in the western part of the study area. The Western Shelf Sequence is bordered on the east by the rocks of the Eastern Basinal Sequence. These rocks consist of shale (slate), sandstone, breccia and conglomerate horizons. Important facies changes occur between the Western and Eastern Basinal Sequences in the study area.

Stratigraphic relationships of the rocks within the Georgia and Milton areas have been the subject of many previous studies, most notably Schuchert (1933 and 1937), Palmer (1970) and Shaw (1958). These authors have concentrated on the trilobite zonation of the basinal shales. The ages of contacts between units on the platform are all approximate, and are only based on intertonguing relationships with the more well zoned shales. Mehrtens and Dorsey (1987) and this study have suggested that major revisions of the regional stratigraphy are warrented, and, based on physical stratigraphic relationships, the current zonations may need to be revised. A correlation chart for the Cambro-Ordovician sequence in northwestern Vermont is presented in Figure 1. It is based on a synthesis of biostratigraphic data of Palmer (1970, who revised Shaw, 1958), Palmer and James (1980) and Landing (1983), and also on physical stratigraphic relationships developed by Mehrtens and Dorsey (1987) and this study.

Because of the imprecision in biostratigraphic dates of the shelf sequence, it is not possible to tell from fossil data if unconformities exist. Sedimentologic evidence, such as gradational contacts, suggests that sedimentation was continuous (Mehrtens, 1985). Shelf units have been dated by interfingering with basinal deposits, and this study and Mehrtens and Dorsey (1987) shows that these shales and breccias are not time-stratigraphic units. The ages of each of the units will be discussed in the stratigraphy section, but a few points are worth noting. A major unconformity within the basinal sequence is illustrated by the shaded area in Figure 1 within the Parker Slate. This represents the hiatus termed the Hawke Bay Event of Palmer and James (1980), a period of non-deposition recognized within the basinal deposits in the northern Appalachians. Palmer and James suggested that the Hawke Bay Event equivalent on the adjacent shelves were regressive

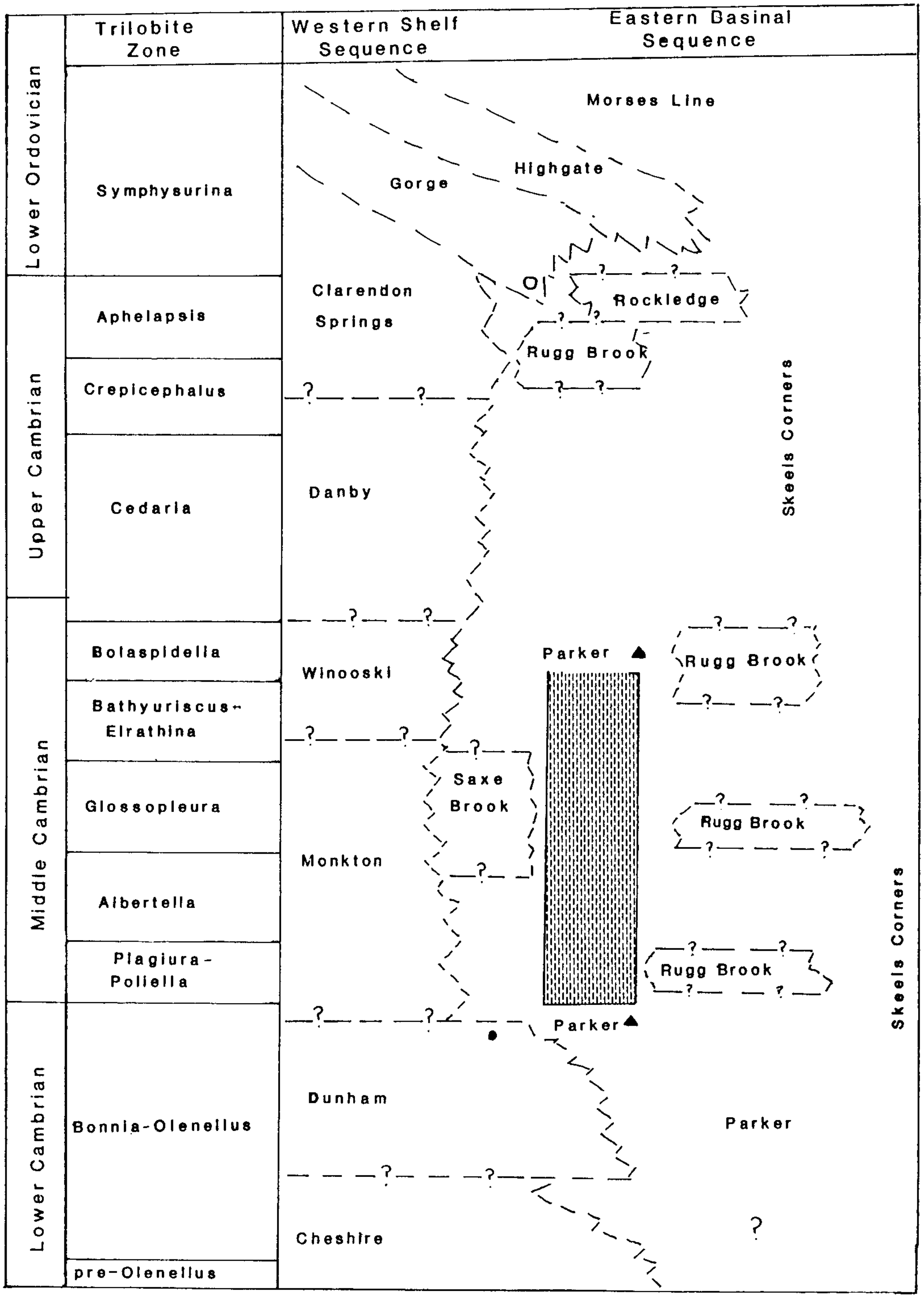
Trilobite Zone
Western Shelf Sequence
Eastern Basinal Sequence
Lower Ordovician
Upper Cambrian
Middle Cambrian
Lower Cambrian
Symphysurina
Aphelapsis
Crepicephalus
Cedaria
Bolaspidella
Bathyuriscus-Elrathina
Glossopleura
Albertella
Plagiura-Poliella
Bonnia-Olenellus
pre-Olenellus
Morses Line
Highgate
Gorge
Clarendon Springs
Rockledge
Rugg Brook
Danby
Skeels Corners
Parker
Winooski
Saxe Brook
Monkton
Dunham
Cheshire

Figure 1

Figure 1. (previous page) Correlation chart for the Cambro-Ordovician strata of northwestern Vermont. Chart is based on biostratigraphic data by Palmer (1970), and Palmer and James, (1980, triangles), Landing (1983, open circles), and physical stratigraphic relationships mapped by Dorsey, et al., 1983; Mehrtens and Dorsey, 1987 and this report. Note that ages between all units on the shelf are approximate because they have been based on intertonguing relationships with basinal units. The Hawke Bay Event is illustrated by the wide bar of shaded lines within the Parker Slate. Numerous pods of Rugg Brook breccias are shown extending from post-Dunham to pre-Rockledge Formation time. The Skeels Corners Slate has been dated as Bolaspidella zone in age but mapping relationships suggest it has a much broader age range. In the St. Albans region, the Gorge and Highgate Formations are seen onlapping the platform in Lower Ordovician time, marking the final drowning of the platform, which continued into deposition of the Lower Ordovician Morses Line Slate (see Mehrtens and Dorsey, 1987 for details).

sandstone units, which in Vermont would be the Monkton Quartzite.

Previous workers, on the basis of map patterns and dolomite lithologies, interpreted the Rugg Brook Formation to be the lateral equivalent of the Winooski Dolomite. Mapping in the St. Albans area by Mehrtens and Dorsey (1987) and this report show that the Rugg Brook is not a time-stratigraphic unit and that the Rugg Brook lithologies occur in pods at several stratigraphic intervals throughout the basinal sequence. The oldest Rugg Brook deposits in the study area lie stratigraphically below the Monkton Quartzite. In the St. Albans area, Mehrtens and Dorsey (1987) found that the Rugg Brook Formation extended from above the Dunham Dolomite up to, and interfingered with, the Rockledge Formation. The correlation chart (Figure 1) illustrates several undated pods of Rugg Brook Formation within the Parker and Skeels Corners Slates extending from post-Dunham to Rockledge time.

Physical stratigraphic relationships were also important in redefining the age range of the Skeels Corners Slate. Palmer (1970), reinterpreting the earlier work of Shaw (1958), dated the Skeels Corners as Bolaspidella zone (Middle Cambrian) in age. Dorsey, et al. (1983), however, found the Skeels Corners immediately overlying the Dunham Dolomite (Lower Cambrian) in the Milton area (immediately to the east of the present study area), and, to the north, the Skeels Corners overlies the Clarendon Springs Dolomite (Uppermost Cambrian-Lower Ordovician).

The specific ages of each rock unit within the study area are discussed in the text.

DEPOSITIONAL ENVIRONMENTS

Rock units within the study area can be broadly grouped as representing deposits formed in one of three settings: (1) shallow water shelf or platform; (2) platform margin; and (3) basin. A shelf is defined as a type of platform where a narrow, steep slope has developed on the margin of a flat-topped, shallow water platform (Ahr, 1973). Rocks formed in this environment exhibit cryptalgalaminites, wave-generated bedforms, tidal features and bioturbation (Mehrtens, 1985). The "shelf margin" or "platform margin" is characterized by deposits which exhibit graded bedding, clast and matrix supported breccias and conglomerates and parallel laminations, all of which are features common to turbidity current and debris flow deposits. The basinal deposits consist of shales and slates, often exhibiting parallel and cross laminations, interpreted as distal turbidites. Rocks of the platform margin and basin represent a continuum of debris flow and high and low density turbidity current deposits which reflects the increasing importance of water turbulence as a transporting mechanism. As a result, platform margin and basinal deposits show gradations in characteristics of many features, such as clast size, matrix grain size and bedforms, as well as overall textures and fabrics of flows. Lowe (1982) contains an excellent review of the classification and hydraulics of sediment gravity flows.

WESTERN SHELF SEQUENCE

Dunham Dolomite (Ꞓdu)

The Dunham Dolomite is a pink to buff-weathering dolomite which outcrops in a north-south trending belt in the western part of the study area. The base of the unit is truncated by the Champlain thrust which emplaces the Dunham over Middle Ordovician black shales (Plate 1, Figure 1). It is the only rock unit in the Western Shelf Sequence which extends continuously from south of the study area northward to, and across, the Canadian border. The lithofacies of the Dunham Dolomite and their environmental interpretations were presented by Gregory (1982) and summarized in

Mehrtens (1985) and are not repeated here. All four lithofacies which comprise the Dunham (peritidal, channel, open shelf and shelf margin) can be seen in the study area, especially along Route 2 (Plate 1, Figure 1 A-B). Most important, however, is the location of the shelf margin facies (Plate 1, Figure 1, locality 3D) because it represents the edge of the Dunham shelf adjacent to the Parker Shale basin. Here, polymictic clasts of sandstone, dolomite, and arenaceous dolomite can be seen floating in an arenaceous dolomite matrix. Clasts are angular and extremely poorly sorted, and these horizons are interpreted to represent debris flows. Thick beds of graded dolomitic sandstone are interpreted as turbidites. Gregory (1982) contains additional information on composition and shape of clasts for the shelf margin exposure along Route 2. To the north a second outcrop of the Dunham Dolomite platform margin can be seen (Plate 1, Figure 1, locality 15E). Here the platform margin breccias of the Dunham float in a shaley matrix and pass upward over a few hundred meters into slump-folded Parker Slate containing dolomite clasts.

Because the base of the Dunham Dolomite in the study area is everywhere truncated by the Champlain thrust, it is not possible to determine its true thickness. Gregory (1982), however, measured a section along Route 2 which was approximately 400 meters thick.

The age of the Dunham Dolomite is difficult to determine due to the paucity of fossils. Mehrtens and Gregory (1984), however, recovered specimens of <u>Salterella</u> <u>conulata</u> from the open shelf facies which indicate that the Dunham is, at least in part, Olenellus zone (Lower Cambrian) in age.

Monkton Quartzite (Ꞓm)

The Monkton Quartzite is a buff to red quartz arenite and dolomite which locally exhibits horizons of breccia. The Monkton overlies the Dunham Dolomite and is, in turn, overlain by the Winooski Dolomite. The facies which comprise the Monkton have been described by Rahmanian (1981). He recognized that the Monkton was a mixed siliciclastic-carbonate unit composed of numerous cycles of supra- to subtidal deposits. Facies described by Rahmanian include: supratidal and intertidal flats, tidal channel, subtidal sand bars and sand shoals, oolitic dolomites and platform margin carbonate breccias. In the Burlington region (south of the study area) the Monkton consists mostly of the supra-, inter-, and shallow subtidal facies which are interpreted to represent prograding tongues of tidal flat sediments. Proceeding northward toward Milton, subtidal sand shoals and sand bars become more common and finally along Route 2 (Plate 1, Figure 1, locality F2) the platform margin oolite shoals and breccias are exposed. A second important outcrop of the platform margin breccias occurs along the banks of the Lamoille River (Plate 1, Figure 1, locality G7). This exposure contains cross-bedded quartz arenites interpreted as turbidites (Bouma division Tc), quartz arenites containing floating sandstone clasts, and dolomite matrix sandstone clast breccias, all interpreted as deposits from high density turbidity currents and debris flows. These two occurences of breccias define the margin of the Monkton platform. It is important to note that the platform margin facies of the Dunham Dolomite and the Monkton Quartzite occur in geographically the same region, which indicates that the platform margin was localized and remained stationary from Dunham through Monkton time.

The most northerly exposure of the Monkton Quartzite in the study area occurs at the dam on the Lamoille River below Milton (Plate 1, Figure 1, locality G8). The Monkton passes northward into the dolomite matrix, sandstone and dolomite clast conglomerate of the Rugg Brook Formation. The distribution of the Monkton Quartzite in the study area is different from that presented by Stone and Dennis (1964) and the Vermont State Geologic Map (Doll, et al., 1961). These earlier workers either did not recognize, or failed to understand, the significance of the platform margin breccia facies and the platform to basin transition. This study indicates that the Monkton Quartzite interfingers with the Rugg Brook Formation in the Milton region (Plate 1, Figure 1, locality E7 and F7), and therefore these units must be, at least in part, coeval.

The Monkton Quartzite has been dated by Palmer (1970) and Palmer and James (1980) as lowest Middle Cambrian in age or "uppermost Early Cambrian" (Palmer and James, 1980) on the basis of trilobites found in associated shale deposits (Parker Slate).

Winooski Dolomite (Ꞓw)

The Winooski Dolomite is a grey to white dolomite containing horizons of arenaceous dolomite. In the Burlington area (south of the study area) the contact of the Winooski Dolomite with the overlying Danby Quartzite is gradational since the uppermost horizons of the Winooski contain progressively greater amounts of quartz sand. The contact of the Winooski Dolomite with the underlying Monkton Quartzite is also gradational in the Burlington area. The basal beds of the Winooski are quartz silt and sand-rich, and siliciclastic material becomes less abundant away from the contact. The facies of the Winooski have not been studied in great detail, but based on the few relict sedimentary structures (ripple marks, cryptalgalaminites, oolites) which remain in the thoroughly recrystallized dolomite, the Winooski appears to record the same general shallow water environments as the over- and underlying units.

Within the study area, the only facies of the Winooski Dolomite which have been recognized are the breccias of the platform margin environment (Plate 1, Figure 1, locality G2). The breccias are polymictic in composition (sandstone, dolomite and arenaceous dolomite) and are found supported by an arenaceous dolomite matrix. As with the underlying Dunham Dolomite and Monkton Quartzite, the breccias mark the position of the platform-to-basin transition. It is also significant to note that, as with the underlying units, the platform margin breccias all occur in the same geographic position on the shelf, indicating that the margin was stationary in position from Dunham through Winooski time.

The outcrop belt of Winooski Dolomite recognized in this study differs from that mapped by Doll, et al. (1961) and Stone and Dennis (1964). In these reports, the Winooski is shown extending northward through the study area and, when the Monkton pinches out, the Winooski lies in contact with the Dunham Dolomite and is overlain by the Rugg Brook Dolomite. This study reinterprets the belt of dolomite north of Chimney Corners (Plate 1, Figure 1, localities F7-12) as a facies of the Rugg Brook Dolomite (Crbd). This interpretation is based on several criteria. First, this dolomite is lithologically similar to the dolomites of the Rugg Brook Formation found in the St. Albans area (Mehrtens and Dorsey, 1987). Secondly, the map pattern shown on Plate 1, Figure 1 and the recognition of the breccia deposits in the Winooski Dolomite near Chimney Corners (Plate 1, Figure 1, locality C2) as platform margin breccias indicates that the Winooski is pinching out. Lastly, this study recognizes an outcrop of dolomite matrix, dolomite clast breccia on Interstate 89 north of Chimney Corners (outside of this study area) as Rugg Brook Dolomite, Crbsc), a basinward continuation of the Winooski platform margin deposits at Chimney Corners found immediately to the south.

The Winooski Dolomite has been dated as Middle Cambrian in age (Stone and Dennis, 1964), based on a facies association with the Parker Slate.

Danby Quartzite (Ꞓda) and Clarendon Springs Formation (Ꞓ-Ocs)

These formations outcrop immediately to the east, and outside of, the study area. Work on the lithofacies and depositional environments of the Danby by Butler (1986) has shown that the Danby pinches out in the Mutton Hill area and that the uppermost Danby is characterized by massive cross-bedded quartz arenite, dolomitic sandstone and arenaceous dolomites which are interpreted to represent shelf margin sand bodies. Shale horizons are also present between sandstone beds, which Butler (1986) interpreted as indicative of the proximity of the shelf margin.

The Clarendon Springs Formation also outcrops to the east of the study area where it overlies the Danby Quartzite. No facies analysis has been made on the Clarendon Springs, but Mehrtens and Dorsey (1987) described the Clarendon Springs in the St. Albans region as consisting of buff white, structureless, recrystallized dolomite containing chert pods. Reconnaissance work by Mehrtens has resulted in the recognition of polymictic breccia horizons in the Clarendon Springs immediately to the north of Mutton Hill (south and east of the study area). These breccia horizons may represent the platform margin facies of the Clarendon Springs.

EASTERN BASINAL SEQUENCE

The Eastern Basinal Sequence outcrops in a north-south trending belt in the study area and includes the Parker, Skeels Corners, Rugg Brook and Rockledge Formations. These units were all contained within the Woods Corners Group of Shaw (1958) in his study of the stratigraphy of the St. Albans region. Mehrtens and Dorsey (1987) revised the stratigraphic relationships of these units and showed that they represent a complex sequence of platform margin and basinal deposits.

Parker Slate (Єp)

The Parker Slate is the oldest, lowermost basinal shale deposit in the study area, and it overlies and lies eastward of the Dunham Dolomite. The Parker Slate was described by Shaw (1958) as a gray to black micaceous slate containing horizons of limestone, dolomite, quartzite and limestone "bioherms". In the study area, several excellent exposures of Parker Slate occur, including several (Plate 1, Figure 1, localities, G18, F15, for example) which show horizons of thin-bedded (2-5 centimeter thick), uncleaved, calcareous siltstone.

The contact of the Parker with the overlying Skeels Corners Slate is completely gradational and occurs over a relatively narrow stratigraphic interval in the study area. In the St. Albans region, however, Mehrtens and Dorsey (1987) demonstrated that only the endmembers of the Parker and Skeels Corners lithologies could be differentiated. Most shale within the area was mapped as undifferentiated Parker-Skeels Corners (Є-Op-sk). The Skeels Corners Slate is typically darker, more thinly-bedded, cleaves more readily than the Parker Slate and also contains yellow dolomitic laminae.

Palmer (1970) and Palmer and James (1980) reviewed the trilobite zonation presented earlier by Shaw (1958) and determined that the lower Parker Slate is late Lower Cambrian in age while the upper Parker is late Middle Cambrian (Figure 1) and thus a significant hiatus exists between the lower and upper portions of the unit.

Parker Conglomerate (€pc)

The Parker Conglomerate was a new unit recognized by Mehrtens and Dorsey (1987) in the St. Albans and Highgate regions of Vermont. It is characterized by horizons of micaceous and arenaceous slate with clasts of dolomite and arenaceous dolomite. The clasts weather buff orange in color and are well-rounded, but unsorted in size. Clast sizes range from a few centimeters to a meter in diameter. The unit immediately overlies the Dunham Dolomite (Plate 1, Figure 1, localities F14, F15). Based on the lithologies of the clasts and its stratigraphic position, the unit is interpreted to represent shelf margin detritus derived off the Dunham carbonate platform to the west and emplaced in a matrix of turbiditic shales.

Rugg Brook Formation (€rbd, €rbq, €rbs, €rbsc)

The Rugg Brook Formation was the name applied to dolomite horizons that lay stratigraphically betwen the Parker and St. Albans Slates in the St. Albans region (Shaw, 1958). The unit was interpreted by Shaw to be the northern equivalent of the Winooski Dolomite. In their study of the St. Albans and Highgate regions, Mehrtens and Dorsey (1987) recognized that the Rugg Brook consisted of five facies in association with the slates of the Parker and

Skeels Corners Formations. These facies include: (1) recrystallized dolomite (Єrbd), which may include horizons of dolomite clasts; (2) white, coarse-grained dolomitic quartzite (Єrbq); (3) sandy matrix, dolomite clast conglomerate (Єrbs); (4) shaley-silty matrix, dolomite clast conglomerate (Єrbsh); and (5) sandstone clast conglomerate in a dolomite matrix (Єrbsc). Four of these facies were recognized in their study area; only the shaley-silty matrix, dolomite clast conglomerate (Єrbsh) was absent.

The Rugg Brook Formation immediately overlies the Dunham Dolomite and is overlain by the Monkton Quartzite in the southern part of the study area (Plate 1, Figure 1, locality E7). In the northern part of the study area, the Rugg Brook is overlain by undifferentiated Parker and Skeels Corners Slates. The four facies of the Rugg Brook do not appear to have a distribution pattern reflecting mode of emplacement. Instead, all facies appear to be randomly interbedded with one another and with the basinal shales of the Parker and Skeels Corners Slates.

Shaw (1958) found no fauna in the Rugg Brook in the St. Albans region but assigned it to the Middle Cambrian on the basis of its stratigraphic position between the Parker and St. Albans Slates (the latter is a rock unit reassigned to undifferentiated Parker and Skeels Corners Slates by Mehrtens and Dorsey, 1987). Mehrtens and Dorsey (1987) expanded the definition of the Rugg Brook Formation to include all dolomites, arenaceous dolomites, dolomitic breccias and quartzites below the Rockledge Formation. The Rugg

Brook Formation therefore represents a mappable group of rocks and is not a time-stratigraphic unit. The base of the Rugg Brook Formation in this study area is probably latest Lower Cambrian or earliest Middle Cambrian in age (Figure 1) based on its stratigraphic position between the Dunham Dolomite and Monkton Quartzite in the southern part of the study area. The top of the Rugg Brook Formation, as defined by Mehrtens and Dorsey (1987), is the base of the overlying Rockledge Formation. This implys that horizons of the Rugg Brook are early Upper Cambrian (Dresbachian, Shaw, 1958) in age.

Rockledge Formation (Єrlm, Єrls, Єrlsh)

The Rockledge Formation is an easily recognizable unit within the study area because it forms a large pod of limestone clast breccias in the northeast part of the field area. Mehrtens and Dorsey (1987) described the Rockledge in the St. Albans area as being composed of three facies: (1) massive, structureless micrite beds (Єrlm); (2) sandy matrix, limestone clast breccias and conglomerates (Єrls); and (3) shaley-matrix, limestone clast breccias and conglomerates (Єrlsh). All three lithologies are recognized within this study area. Mehrtens and Hillman (1988) studied in detail the sedimentology of the Rockledge Formation and recognized many subfacies within the two breccia types. Often associated with the sandy-matrix limestone clast breccias are horizons of coarse-grained quartz arenites. These are found underlying the breccia horizons, and are usually 30-50 centimeter thick.

The clast composition of the Rockledge breccias is confined to three types: (1) recrystallized micrite; (2) sandy micrite; and (3) quartz arenite. Ripped-up horizons of underlying Skeels Corners Slate, however, can also be found. Clast size ranges from 1.5 centimeter to approximately 1 meter in diameter, with the average clast size 5.1 centimeter (n=111). The average clast size in the Rockledge Formation in the St. Albans region is 6 centimeter, and ranges from 0.05 centimeter to 2 meters (n=382). The source area for the Rockledge Formation is interpreted to be the carbonate platform to the north, in the St. Albans region, because there the Rockledge Formation is found in a linear belt outcropping immediately adjacent to the carbonate platform. In this study area, the Rockledge Formation occurs in a pod within the Skeels Corners Slate and is not immediately associated with the rim of the platform to the south. Also, the larger, structureless micrite facies (Crlm), which may represent huge slumped blocks, are much larger and more common in the St. Albans area than in this study area.

The Rockledge Formation was assigned a Dresbachian age by Shaw (1952), and a refined age of early Dresbachian by Palmer (1970). In the St. Albans region the Rockledge immediately underlies the Gorge Formation, which Landing (1983) determined spanned the Cambro-Ordovician boundary.

The value of the Rockledge as a stratigraphic marker horizon is limited as both this study and Mehrtens and Dorsey (1987) noted that the Rockledge and Rugg Brook Formations are interbedded. Therefore, although it is a readily recognizable unit, the Rockledge may just represent a diagenetic horizon with little value as a time-stratigraphic unit. For example, a very diagnostic lithology occurs in the field area (Plate 2, Figure 1, locality B6). It is a sandy dolomitic breccia of variable clast composition (quartzite, limestone and dolomite) and abundance, and is massively bedded. Clasts are often difficult to recognize but they differentially weather and produce a knobby surface. This breccia type is included within the Rockledge (type 2: sandy-matrix, limestone clast breccia). It represents a lithologic type intermediate in composition between the fully dolomitized Rugg Brook breccias and the limestones of the Rockledge and thus demonstrates that the Rockledge and Rugg Brook Formations may differ not by age or mode of emplacement, but by degree of dolomitization.

Skeels Corners Formation (O-Єsk)

The Skeels Corners Slate is the slate unit that immediately under- and overlies the Rockledge Formation. The Skeels Corners Slate is in gradational contact with the underlying Parker Slate but can be differentiated from the Parker because the Skeels Corners is darker (black to grey), more calcareous, and exhibits laminae of limonitic quartz silt and dolomite which give the unit the appearance of orange pinstripes.

Dorsey, et al. (1983) redefined the stratigraphy of the Skeels Corners Slate in the Milton region, recognizing that it overlies both the Dunham Dolomite (Lower Cambrian) and Clarendon Springs (Upper Cambrian-Lower Ordovician) Dolomites. This was a much broader age assignment than that of Shaw (1958) or Palmer (1970). Within the study area the Skeels Corners gradationally overlies the Parker Slate, which has been dated as early to late Middle Cambrian in age. This suggests that the base of the Skeels Corners is late Middle Cambrian in age. Since the Skeels Corners over- and underlies the Rockledge Formation (Dresbachian), it may be Upper Cambrian in age near the top of the unit in this study area.

Stony Point Shale (Osp)

Interbedded black shale and argillaceous limestones of the Stony Point Shale outcrop along the shore of Lake Champlain. The Champlain thrust has emplaced the Dunham Dolomite on top of these Middle Ordovician shales. The Stony Point has not been examined in detail for this study but Hawley (1957) and Teetsel (1984) contain biostratigraphic and sedimentologic information on this unit.

ENVIRONMENTAL INTERPRETATION

Shaw (1958) recognized the major facies changes in Cambrian units between Burlington and Milton and thought that this represented the abrupt pinchout of shallow water facies in the south against a structural arch in the north termed the Milton High. Subsequent work by Mehrtens on the sedimentology of the

Cambrian units (Mehrtens, 1985) documented that the abrupt facies change in the Milton region is due to a localized platform to basin transition in this region, a concept first proposed by Rodgers (1968). The Dunham, Monkton, Winooski and Danby Formations pass eastward and northward into shale and breccia horizons in a basin that Mehrtens and Dorsey (1987) termed the St. Albans Reentrant. The fact that the platform margin lithofacies from each of these units is in the same geographic position (Plate 1, Figure 1, localities D3, E2, F2, G2) indicates that the platform was characterized by vertical aggradation of platform sediments throughout the Cambrian. The platform margin was possibly localized in this area because of inherited topographic relief from older, Eocambrian rifting. It was suggested by Mehrtens and Dorsey (1987) that down-dropping of a block, or series of blocks, formed the basin within the St. Albans Reentrant, and that movement was initiated in late Dunham time. This time of initial movement is constrained by the widespread occurence of Dunham Dolomite shelf sediments across what later becomes the St. Albans Reentrant. Occurences of Dunham Dolomite breccia deposits signifies the creation of vertical relief by the end of Dunham deposition.

Interpretation of the lithofacies within the St. Albans Reentrant are important in developing an understanding of the sea level history of the adjacent platform. For example, this study documents that the Rugg Brook Formation intertongues with the Dunham Dolomite and Monkton Quartzite, suggesting that a major period of basinal sedimentation occurred in late, or post-Dunham, syn-Monkton time. The abundance of dolomitized carbonate sediment (Єrbd), punctuated with horizons of carbonate and sandstone breccias (Єrbsc) and quartzite horizons (Єrbq) suggests that a significant amount of carbonate mud washed off the adjacent platform, however, the abundance of siliciclastic detritus requires the presence of a sand source on the platform, which also suggests that the Monkton Quartzite is coeval with deposition of the Rugg Brook Formation.

Many workers believe that sedimentation in basins adjacent to carbonate platforms occurs during sea level highstands when carbonate productivity is high (Droxler and Schlager, 1985). The Rugg Brook Formation would therefore record basinal sedimentation when the platform was flooded during a sea level highstand. This interpretation would support the ideas of Mehrtens (1985) who suggested that eustatic sea level falls were not a factor in controlling the alternation between carbonate and siliciclastic sediment accumulation on the platform.

The apparently continuous sedimentation on the platform suggested earlier by Mehrtens was based on the conformable contacts between units on the platform. Although the breccia horizons in the St. Albans Reentrant are stratigraphically distributed from the Dunham Dolomite (Lower Cambrian) through the Rockledge Formation (Upper Cambrian), sedimentation of breccia horizons may not have been continuous. Sediment supply constraints discussed above strongly suggest that major breccia deposition occured at least in part synchronous with deposition of the Monkton Quartzite on the platform. Palmer and James (1980) documented a hiatus in deposition within the Parker Slate extending from late Lower Cambrian to late Middle Cambrian in duration. Thus, accumulation of both breccias and terrigenous muds within the St. Albans Reentrant may have been episodic. Assuming that the Monkton Quartzite does represent the major source for sediment in the Rugg Brook, and that the source for the Rockledge Formation is the Clarendon Springs Dolomite (Mehrtens and Hillman, 1988), breccia deposition may be confined to these two times. The slow accumulation of hemipelagic muds in this starved basin deposited the Parker and Skeels Corners Slates.

STRUCTURE

Rocks in the field area lie on the upper plate of the Champlain thrust, which has emplaced Cambrian strata on Ordovician shales. These rocks have subsequently been folded and form the west limb of the St. Albans synclinorium. The north-south trending belt of carbonate and siliciclastic deposits in the western half of the study area dips gently and uniformly to the east. With the eastward passage into younger shales and breccia deposits in the eastern part of the study area, deformation in the shales becomes more pronounced. This deformation is manifested by the development of multiple cleavage generations and several map-scale folds within the Skeels Corners Slate (Plate 2, Figures 1 and 2). The more competent Rockledge Formation resists deformation. Examination of the cross section (Plate 2, Figure 2) shows that the Rockledge

Formation is gently folded across the study area. Although the cross section does not illustrate this detail, the surrounding, less competent Skeels Corners Slate exhibits numerous smaller-scale folds. On the geologic maps (Plate 1, Figure 1; Plate 2, Figure 1) orientations of dominant cleavage which defines the larger-scale geologic structures are shown. A second cleavage occurs locally and defines some of the smaller-scale folds seen in individual outcrops. Several other cleavage directions occur but are only related to very local small-scale deformation in the incompetent shales.

Examples of outcrop-scale small faults are found within the study area (Plate 2, Figure 1, locality B7). These are thought to be the result of shearing out of a limb on a small, tight fold.

Folds seen in the eastern part of this study area are different from those described by Mehrtens and Dorsey (1987) in the St. Albans region where the rocks were dipping uniformly to the east. Folding of the Skeels Corners within this study area is thought to be the result of proximity to the Hinesburg thrust, which is located immediately to the east and outside of this study area.

REGIONAL SYNTHESIS AND SUMMARY

Significant findings of this study include: (1) redescription of the distribution of the Winooski Dolomite and Rugg Brook Formation in the northern part of the Colchester quadrangle; (2) recognition of the platform to basin transition for the southern rim of the St. Albans Reentrant; (3) identification of facies within the Rugg Brook Formation which are similar to those described by Mehrtens and Dorsey (1987) for the St. Albans region; and (4) information on the sea level history for the St. Albans Reentrant and adjacent carbonate platform, which suggests that the platform did not experience a significant sea level fall coincident with deposition of the Rugg Brook Formation.

These findings support the observations by Mehrtens (1985) and Mehrtens and Dorsey (1987) on the geometry and sea level history of the Cambrian platform. The platform was broad, flat-topped and passed abruptly into a deeper-water shale basin. The shelf to basin transition is noteworthy by the absence of significant talus deposits, which suggests that it was a bypass margin and that debris flows and high density turbidity currents flowed directly into the shale basin. The platform margin facies are localized in the same geographic area, which indicates that the platform underwent vertical aggradation throughout the Cambrian. The St. Albans Reentrant probably formed in late Dunham time as the Dunham Dolomite is the youngest unit to extend across what becomes the shale basin. The stratigraphies of the platform deposits in the St. Albans and Milton regions are very different, therefore the St. Albans Reentrant was successful in controlling the distribution of post-Dunham facies. This study, and that of Mehrtens and Dorsey (1987) suggest that the biostratigraphic data for the shale and breccia horizons in the St. Albans area may need to be re-evaluated in light of this detailed mapping.

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Plate 1

Figure 1

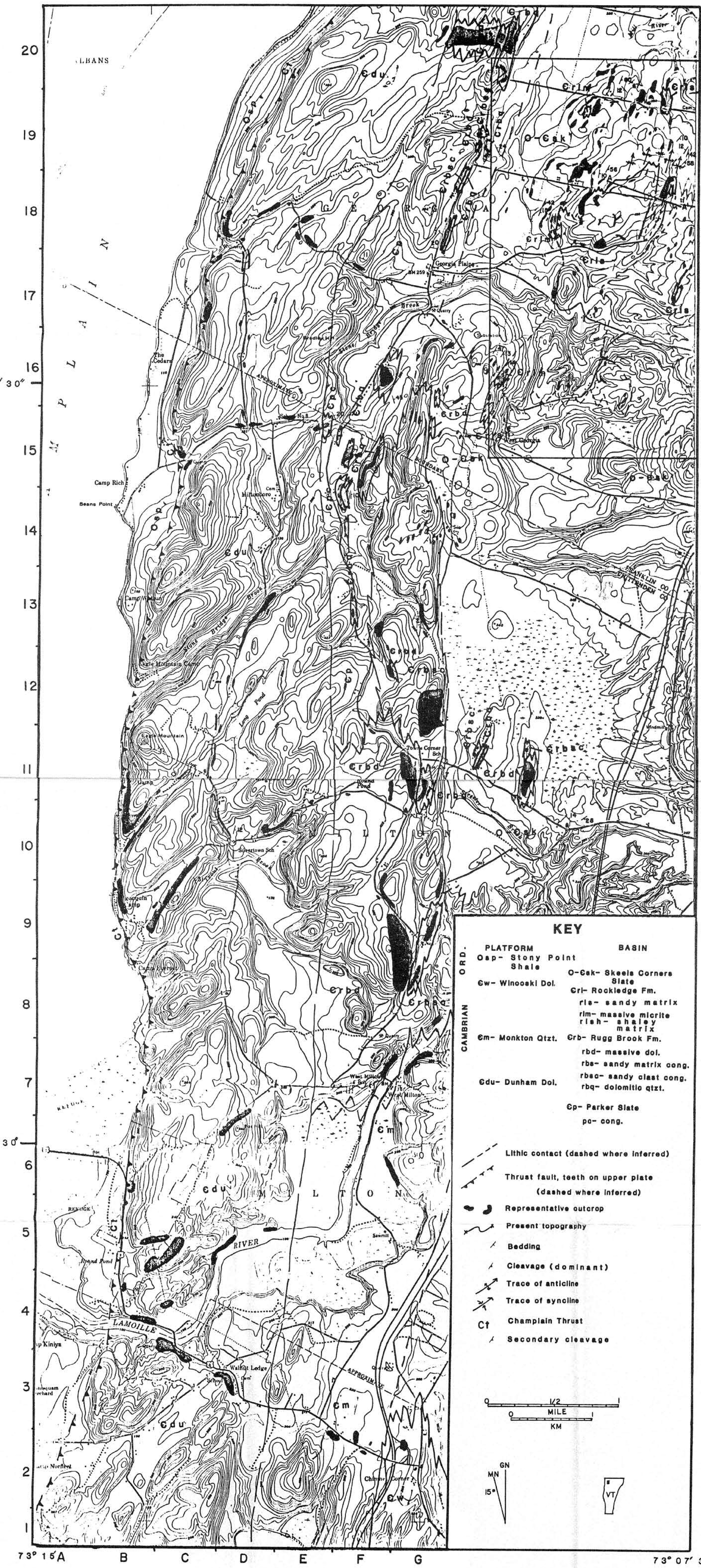

Figure 2

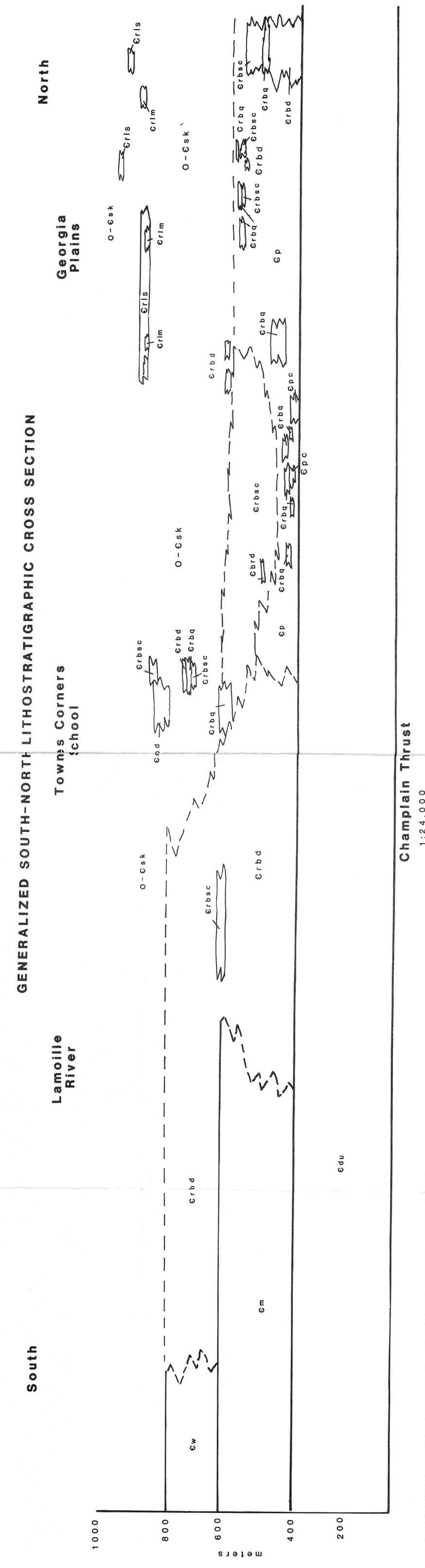

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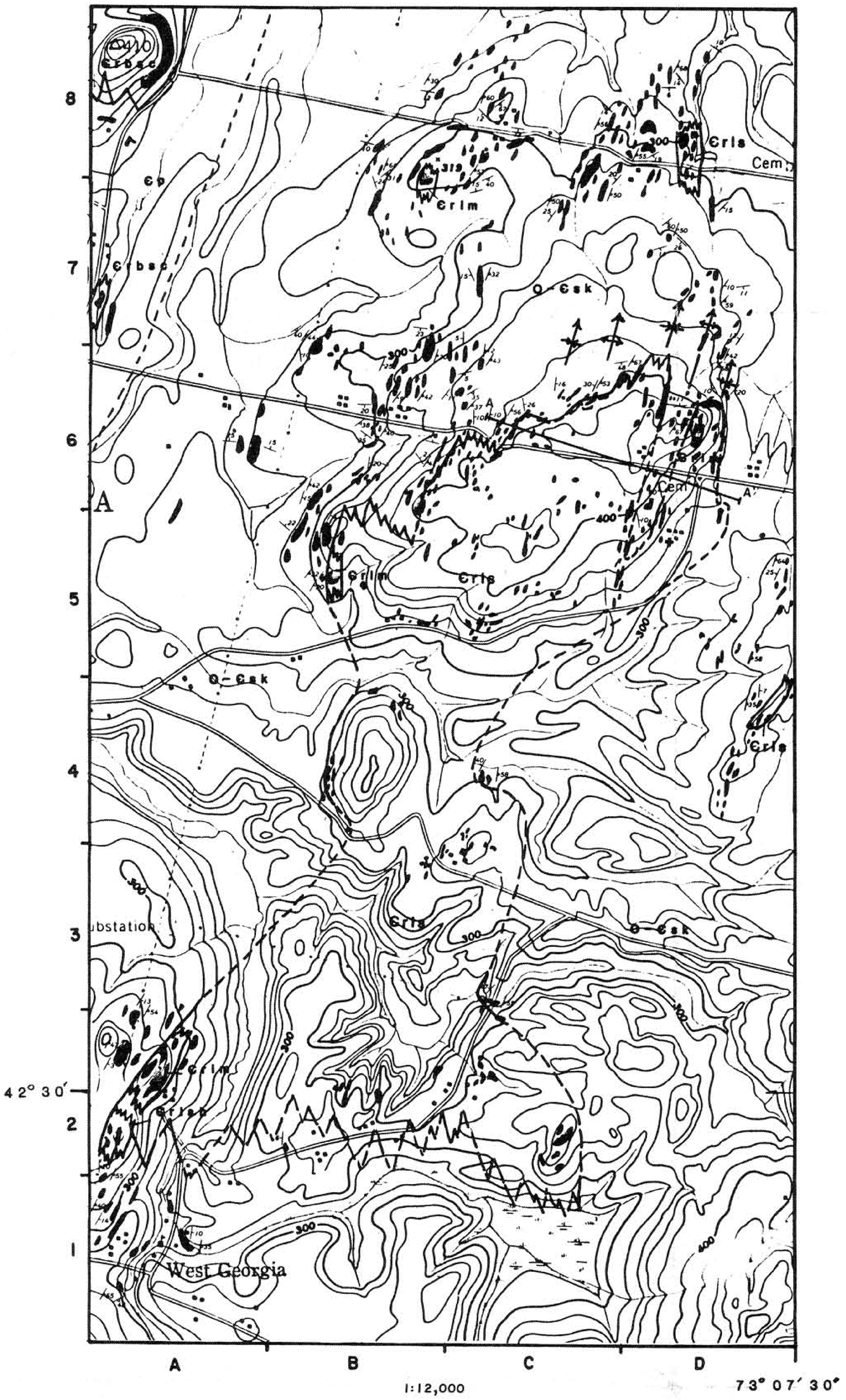
Plate 2

Figure 1



KEY

ORD. — O-Єsk- Skeels Corners Slate

CAMBRIAN —
Єrl- Rockledge Fm.
rlm- massive micrite
rls- sandy matrix
rlsh- shaley matrix

Єrb- Rugg Brook Fm.
rbsc- sandy clast cong.

Єp- Parker Slate

Lithic contact (dashed where inferred)

Representative outcrop

Present topography

Bedding

Cleavage (dominant)

Trace of anticline

Trace of syncline

Secondary cleavage

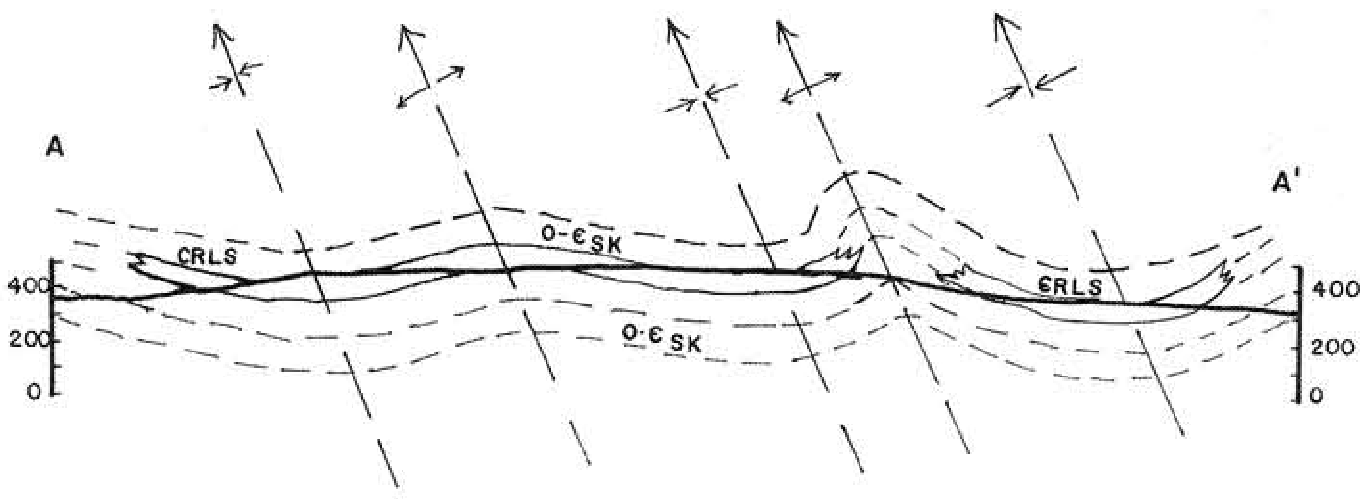
0 1/4 1/2 MILE

0 .5 KM

MN GN 15°

VT

Figure 2



Vertical and Horizontal Scale 2X

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