COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
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GEOLOGY OF THE CRIMORA QUADRANGLE, VIRGINIA

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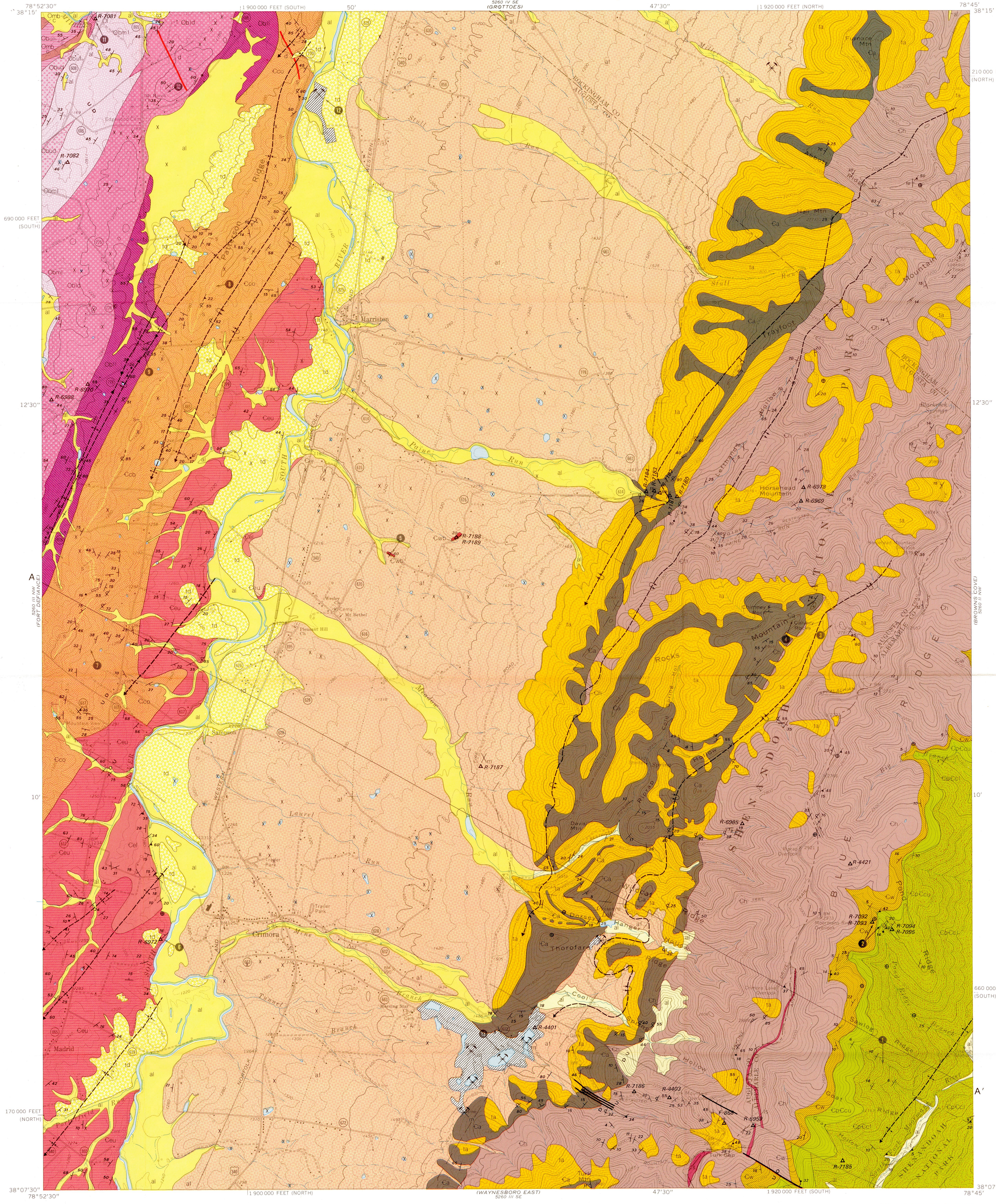
EXPLANATION

		UNIT CHARACTERISTICS	GEOLOGIC AND ECONOMIC FACTORS AFFECTING LAND MODIFICATION
QUATERNARY	al	Alluvium: *Flood-plain deposits of stratified, unconsolidated clay, silt, and sand with quartzite gravel at base. Chert gravel at base along streams west of South River. Thickness: 0-20 feet (0-6 m).*	Level land adjacent to streams, which may be readily tilled or excavated, is subject to periodic flooding that limits its use to farm or recreational activities. Excavations are subject to sliding and sloughing. In areas where alluvial and gravel deposits overlie cavernous limestone or dolomite, rapid ground-water withdrawals may induce surface subsidence or collapse. Marl deposits have been used locally as a source of agricultural lime.
	al	Alluvium: *Upland stream deposits of unconsolidated sand and gravel with cobbles and boulders of quartzite, sandstone, and metabasalt. Thickness: 0-15 feet (0-5 m).*	Wet, boulder-strewn land with very thin soil along mountain streams is subject to periodic flooding. This land is most suitable as woodland.
	ta	Talus: *Slope deposits of angular quartzite boulders and cobbles. Thickness: 0-10 feet (0-3 m).*	Steep, boulder-covered slopes are unsuited for construction or any form of development because of creep, slide or rockfall hazard.
	td	Terrace deposits: *Dissected remnants of unconsolidated, stratified alluvial deposits of clay, silt and sand with quartzite gravel at base. Chert gravel at base near streams west of South River. Thickness: 0-20 feet (0-6 m).*	Level benches or flats near streams are generally above flood levels. Artificial cuts and excavations are subject to sloughing and creep, and land is subject to subsidence or collapse where terrace deposits overlie cavernous limestone or dolomite.
	af	Alluvial fans: *Unconsolidated, locally dissected, poorly stratified, overlapping stream deposits of clay, silt, and sand with interbedded quartzite cobbles and boulders. Thickness: 0-200+ feet (0-61 m).*	Gently sloping, rocky land is characterized by water-filled depressions, braided, sinking, or incised streams, and cobbly, sandy, droughty soil. Evidence of subsidence is common where limestone and dolomite underlie the fans. Artificial cuts and excavations are subject to sloughing and collapse.
	sc	Sandy clay: *Residual sand and clay deposits formed on the Shady Formation; includes some with weathered phyllite and quartzite debris (shown in cross-section only; exposed in Crimora surface mine). Thickness: undetermined.*	Thick, impermeable sandy clay is covered by alluvial fan and talus deposits along the western foothills of the Blue Ridge. Iron and manganese ores have been mined from these deposits. Clay deposits having economic potential may also be present locally. The sandy clay is subject to severe erosion where the overlying fan and talus deposits have been removed.
TRIASSIC	d	Diabase dikes: *Dark greenish-gray to black diabase. Thickness: 0-50 feet (0-15 m).*	Dikes weather to large boulders and red clay near ground surface and may be difficult to excavate.
ORDOVICIAN	Omb c	Martinsburg Formation: *Black, very fine grained, graptolitic, calcareous slate member with a few thin beds of dark-gray calcareous argillite. Thickness: 200 feet (61 m).*	Calcareous slate underlies gently rolling open land with shallow soil and moderate slopes. Severe soil erosion is common on steep, denuded slopes, particularly where slate is predominant. Construction restrictions are imposed on the type and location of waste-disposal facilities in areas of shallow soil, rapid run-off of storm water, and clayey subsoil. Artificial cuts and excavations may be unstable where bedding or cleavage are undercut. This land is well suited for agriculture, particularly pasture. Water wells generally provide small yields from depths less than 150 feet (46 m). Ground water is moderately hard and may be slightly acidic or contain iron.
	Ol	Lincolnshire Formation: *Dark-gray, fine-grained limestone-cobble conglomerate with argillaceous limestone matrix and dark-gray, coarse-grained, bioclastic limestone. Thickness: 0-20 feet (0-6 m).*	A low, gently rolling land surface with low, discontinuous ridges has developed on limestone. The soil is shallow, locally cobbly, and subject to severe erosion. Construction restrictions are imposed on type and location of waste-disposal facilities in areas of thin soil and solution channels and caves in the bedrock. Occurrence of bedrock pinnacles restricts all but very shallow excavations. Ground-water availability is generally fair to poor, and the water may be very hard.
	Obul Obud Obml Obld Obll	Beekmantown Group: Obul *(upper limestone and dolomite unit), dove gray, thin-bedded, ultrafine-grained limestone interbedded with light-gray, fine- to medium-grained, thick beds of laminated dolomite and a few thin beds of gray to tan shale and pink calcareous mudrock. Thickness: 300 feet (91 m)* Obud *(upper dolomite unit, light- to dark-gray, fine- to medium-grained, thick-bedded, laminated siliceous dolomite interbedded with coarse-grained, locally brecciated siliceous dolomite with beds and nodules of black to tan chert. Thickness: 250 feet (76 m).* Obml *(middle limestone and dolomite unit), dark-gray, medium- to coarse-grained, fossiliferous, bioclastic limestone with algal structures, oolites, cross-lamination and flat-pebble conglomerates interbedded with limestone and dolomitic limestone with burrow structures, silty calcarenite, and laminated dolomite. Thickness: 900 feet (275 m).* Obld *(lower dolomite unit), massive, dark-gray, coarse-grained, locally brecciated, siliceous dolomite with thin, dark-gray chert beds, chert nodules, quartz veins and quartz crystal-lined vugs; interbedded with light- to dark-gray, fine- to medium-grained, massive to laminated siliceous dolomite. Thickness: 1,200 feet (366 m).* Obll *(lower limestone unit), dark-gray, fine-grained, thick-bedded limestone interbedded with light-gray, fine-grained, thick-bedded limestone interbedded with light-gray, fine-grained, laminated dolomite in upper part; dark-gray, ultrafine-grained, limestone with black chert nodules, undulose laminations, burrow structures and flat-pebble conglomerate in lower part. Thickness: 400 feet (122 m).*	Gently rolling land surface with a few low, round hills and linear ridges has formed over limestone and dolomite generally covered with deep, well-drained soil. Appreciable soil creep and severe erosion may occur in modified land areas on steep slopes, whereas on gentle slopes, the soil is generally stable. There is great variation in thickness of the soil over short distances; clay subsoil has a moderately high shrink-swell potential. Common sinkhole and cave development, particularly in the limestone units, necessitates restriction of choice in the determination or the type and location of waste-disposal facilities and other construction. Ground-water availability is good to fair, and the water is generally hard. The ground water in these carbonate rocks is susceptible to contamination from surface sources where sinkholes are present or where the soil is thin; contaminants induced into the sinkholes may be transmitted for considerable distances through solution channels and fractures in the rock. Obul, Obml, Obll, Ꞓeu, and Ꞓel—rock ledges are exposed in most areas and rockland (areas where ledges are less than 10 feet or 3 m apart) occurs locally on thick sequences of alternating limestone and dolomite. Obud and Obld—residual chert debris covers the rounded hills and lowlands underlain by siliceous dolomite. s, in Ꞓco—deep residual, sandy soil formed from thin, calcareous sandstone beds that commonly occur on linear ridge crests and slopes.
CAMBRIAN	Ꞓco s	Conococheague Formation: Ꞓco, *dark-gray, fine-grained limestone with algal structures alternating with flat-pebble limestone conglomerate, thin-bedded limestone with siliceous partings, laminated limestone and laminated to thick-bedded, fine-grained, light-gray dolomite.* s, *thin (0-5 feet or 0-2 m) beds of tan to brown, medium- to coarse-grained, cross-laminated quartz sandstone. Thickness: 2,400-2,800 feet (732-853 m).*	
	Ꞓeu Ꞓel	Elbrook Formation: Ꞓeu *(upper member), medium- to dark-gray (orangish yellow on weathered surface), fine- to medium-grained, medium- to thick-bedded, massive or laminated dolomite interbedded with thin, dark-gray, algal limestone, flat-pebble limestone conglomerate, platy dolomitic siltstone, and a few thin sandstone beds. Thickness: 1,600 feet (488 m).* Ꞓel *(lower member), pale-green, laminated to thin-bedded platy dolomite; light- to dark-gray (buff where weathered), fine-grained, laminated dolomite; laminated maroon phyllite near base. Thickness: 1,200 feet (366 m).*	The limestone and dolomite, which underlie the alluvial fan deposits in a 1- to 2-mile (2- to 3 km) wide belt west of the foot of the Blue Ridge, have been penetrated by several drill holes. These rock units appear to comprise a major, relatively untapped aquifer system that is recharged by the percolation of surface water run-off from the Blue Ridge. The potential for large yields from deep wells is good, but well construction may be difficult and the cost for all wells, particularly for municipal or industrial use, is relatively high because of the unstable, deeply weathered bedrock and the thick unconsolidated deposits overlying it. The ground water is generally hard but otherwise of good quality; the aquifer is susceptible to contamination by unsanitary surface sources.
	Ꞓwb	Waynesboro Formation: *Maroon, tan and yellow phyllite and argillite interbedded with limestone, dolomite and thin sandstone (only maroon phyllite exposed). Thickness: 1,000-1,200 feet (305-366 m).*	
	Ꞓs	Shady Formation: *Dolomite and limestone (in cross section only). Thickness: 1,000-1,200 feet (305-366 m).*	
	Ꞓa	Antietam Formation: *Massive, ledge-forming, white to light-gray, medium- to fine-grained, vitreous* Skolithos*-bearing quartzite with minor amounts of interbedded phyllite in upper portion. Thickness: 800 feet (244 m).*	Resistant quartzites weather to form steep, rocky terrain with cliffs, talus, and thin, very permeable, excessively drained soil. Excavations are subject to slumping. These conditions severely restrict most uses of the land, which is woodland. Ground-water availability is poor and drilling conditions are difficult in the resistant and abrasive quartzite.
	Ꞓh fs	Harpers Formation: *Dark-green, quartz-chlorite-sericite phyllite and fine-grained, even-bedded sandstone with interbedded bluish-gray to white, medium-grained, cross-laminated quartzite.* fs, *purple to black, coarse-grained, metamorphosed ferruginous sandstone (0-20 feet or 0-6 m thick).* Skolithos *and worm borings, bioturbated beds, tracks and trails common in most of the sandstone and quartzite. Thickness: 1,600 feet (488 m).*	Steep rocky land with thin, permeable, excessively drained soil is associated with weathered talus deposits; cliffs and ledges of quartzite are present. Artificial cuts and excavations are moderately susceptible to erosion. Thin soil, rapid run-off, and dense, fine-grained bedrock provide only poor availability of ground water. Such restrictive conditions necessitate caution in selection of the type, location, and density of waste-disposal sites and other construction.
	Ꞓw	Weverton Formation: *Massive, ledge-forming, medium-gray, fine- to coarse-grained, locally ferruginous, pebbly quartzite and interbedded green, pebbly, quartz-sericite phyllite. Thickness: 200-400 feet (61-122 m).*	Steep, rocky land with thin soil is associated with weathered talus deposits; many cliffs and rock ledges of quartzite and metabasalt are present. These factors provide fair to poor ground-water availability and severely restrict all forms of construction or development of this land.
PRECAMBRIAN	ꞒpꞒcu ꞒpꞒcl	Catoctin Formation: ꞒpꞒcu *(upper member), mottled, purplish-green, phyllitic metatuff at top; dark-green, massive to schistose actinolite or epidote-chlorite-albite metabasalt and interbedded metamorphosed sandstone, phyllite, and cobble conglomerate. Thickness: 350 feet (107 m).* ꞒpꞒcl *(lower member), dark-green, fine-grained, massive ledge-forming metabasalt interbedded with minor amounts of purple metatuff, epidosite, phyllite, and quartz-epidote metabasalt breccia. Thickness: 2,700 feet (823 m).*	
	ꞒpꞒs	Swift Run Formation: *Phyllite and metasandstone (in cross section only). Thickness: 20-50 feet (6-15 m).*	
	pꞒp	Pedlar Formation: *Metamorphosed granite (in cross section only).*	

▨ Modified land: *Extensive cut and fill due to grading.*

X Sinkhole: *Area of known or potential sinkhole development, subsidence, and cave openings.*



Base map from U.S. Geological Survey, 1965
Crimora Quadrangle, 7½ Minute Series

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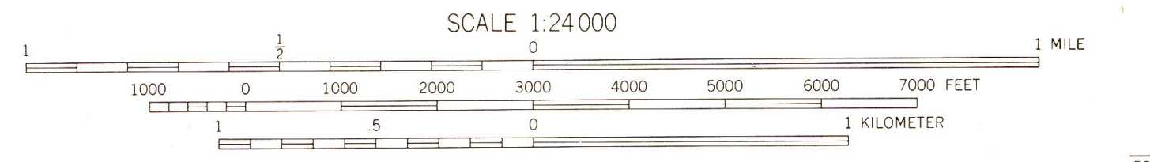
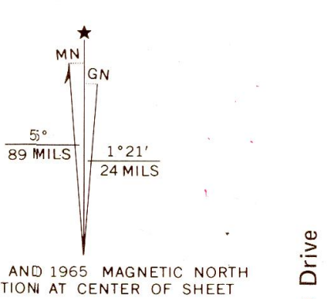
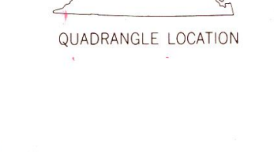


CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

1978



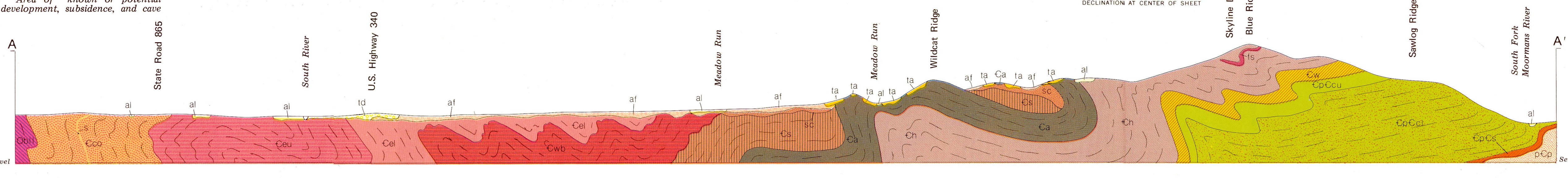
UTM GRID AND 1965 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET



QUADRANGLE LOCATION

CROSS SECTION DESIGN

1. No vertical exaggeration.
2. Subsurface structure interpreted from surface measurement.
3. Thickness of terrace deposits, talus, alluvial fans, and alluvium diagrammatic.



KEY

CONTACTS

- —— Exposed or approximate
- - - - Indefinite contact along collapse breccia zone

FOLDS

- Anticline—trace; direction of plunge
- Syncline—trace; direction of plunge
- Overturned anticline—trace; direction of plunge
- Overturned syncline—trace; direction of plunge
- 11 Direction and angle of plunge of minor anticline
- 15 Direction and angle of plunge of minor syncline
- 18 45 Direction and angle of plunge of minor fold showing strike and dip of axial plane

FAULTS

- U D Black line where exposed or approximate; gray line where covered or inferred; U, upthrown side, D, downthrown side

ATTITUDE OF ROCKS

- 45 Strike and dip of beds
- 50 Strike and dip of overturned beds
- Strike of vertical beds
- ⊕ Horizontal beds

FOLIATION

- 20 Strike and dip of schistosity

LINEATION

- 20 Direction and angle of plunge of rodding, boudinage, and crinkle folds
- 15 Direction, angle of plunge, and symmetry of crenulation

MINES, QUARRIES, AND PROSPECTS

- ⚒ Active quarry
  - Sand and gravel
- ⚒ Abandoned mine or quarry
  - m—mine (manganese)
  - Crushed stone quarry (limestone and dolomite)
- X Prospect
  - m—prospect (manganese)
- △ *R-7082* R, repository number of rock sample on file at Virginia Division of Mineral Resources.
- △ *F-939* F, repository number of fossil sample on file at Virginia Division of Mineral Resources
- ⑭ Reference locality described in discussion

STRATIGRAPHIC DISCUSSION

Metamorphosed Volcanic and Sedimentary Rocks

The *Catoctin Formation* is a thick, multi-layered sequence of resistant metavolcanic and epidote-cemented metasedimentary rock that makes up most of the Blue Ridge slopes southeast of Skyline Drive. Within the metavolcanic sequence the ancient lava flows are the most resistant beds and are exposed as benches on the east side of the Blue Ridge (REFERENCE LOCALITY 1). Metavolcanic breccias or slaty ash beds mark the boundaries between the flows in many areas. The most extensive metasedimentary bed (REFERENCE LOCALITY 2), which lies between the uppermost lava bed and the main body of the Catoctin Formation, constitutes the lower half of the upper member of the formation.

Quartzite, Sandstone, and Phyllite

The *Weverton Formation* (REFERENCE LOCALITY 2) contains coarse basal clastic beds that were deposited along stream channels on a large alluvial plain that once covered the older volcanic and sedimentary rocks of the Catoctin Formation. The Weverton clastic rocks can be distinguished from similar rocks within the Catoctin by the lack of epidote in the rock matrix.

The *Harpers Formation* contains burrowed beds (REFERENCE LOCALITY 3) that are the earliest evidence of marine life preserved in the rocks of the Blue Ridge. The Harpers was formed from fine sand and terrigenous mud deposits that accumulated in coastal mud flats and lagoons at the continental edge during Cambrian time. While the mud flats along the shelf were subsiding, coarser sandstones were being deposited as local sand-shoal areas and barrier beaches. The clean, well-sorted quartzite of the *Antietam Formation* (REFERENCE LOCALITY 4) is indicative of the most extensive development of beach and off-shore barrier-bar environments during early Cambrian time. The quartzite contains a profusion of worm borings (Skolithos) that are preserved as straight, tube-like fossil forms 3 to 5 mm. in diameter and up to 1 meter (3.3 feet) in length which were oriented perpendicular to the original bedding surfaces.

Limestone and Dolomite

Carbonate rocks form the floor of the valley northwest of the Blue Ridge mountains. The east to west change in lithofacies from the metamorphosed clastic sedimentary rocks of the Blue Ridge to limestone and dolomite in the valley to the west indicates a transition from a coastal environment that received abundant terrigenous sediment from the continental highlands to a very low-relief continental shelf environment. Through a combination of the shelf configuration, a warm climate, and lime-secreting organisms, a shallow-water carbonate platform (Figure 1) was established in early Cambrian time.

Characteristics of limestone and dolomite strata in the carbonate rocks exposed west of South River are similar to the cyclic sedimentation of Recent platform carbonate rocks. Their lithofacies and the inferred depositional environments are generally similar to the subfacies and related subenvironments described in detail by Root (1968) and Reinhardt and Hardie (1976) in Pennsylvania and Maryland. It is through analysis of the differences in cyclic sediments, and by inference of the differences in depositional environments that the Cambro-Ordovician carbonate sequence has been divided for mapping as groups, formations, members and units. It must be emphasized that these are strictly lithostratigraphic units that may be time-transgressive.

The oldest Cambrian carbonate units *(Shady and Waynesboro formations)* are covered by confluent alluvial fans along the western foot of the Blue Ridge. Depressions in these alluvial fans, the presence of sandy clay residuum, and collapse breccia exposed in the manganese pits at Crimora mines indicate that portions of these formations have been dissolved and removed by ground water. The Shady Formation is not exposed in the quadrangle, and saprolite of maroon, tan and yellow phyllite (REFERENCE LOCALITY 5) is the only Waynesboro observed. The upper contact of the Waynesboro is covered in this area and may be intergradational with the overlying maroon phyllite and green, thin-bedded, platy dolomite in the lower member of the Elbrook Formation.

Cyclic deposition of the *upper member of the Elbrook Formation* is delineated by alternating limestone layers and thin, platy dolomite beds (REFERENCE LOCALITY 6). The cycles are 7- to 10-feet (2-3 meters) thick and consist of thin algal limestone *(lower intertidal to upper subtidal)* overlain by thin, laminated, wavy-bedded limestone and dolomite *(upper intertidal algal flat)* that are gradational upwards into thin-bedded, laminated dolomite (supratidal) (Figure 1). The succession of subenvironments that can be inferred from Elbrook sedimentation shows a strong affinity to arid supratidal conditions and is notably deplete in the calcarenite and intraclast conglomerate subfacies that characterize the overlying Conococheague limestones.

At some localities laminated dolomite interbeds near the top of the Elbrook contain well rounded and sorted "floating" quartz sand grains and thin quartz sand stringers. The upper contact of the Elbrook is placed above the uppermost laminated dolomite (supratidal) that can be related to the recognized "Elbrook cycle", and generally the contact is at the base of a coarse calcarenite, the beginning of a more marine Conococheague cycle.

The Conococheague Formation consists almost entirely of interbedded limestone and dolomite layers that range from a few inches (centimeters) to several feet (meters) in thickness (REFERENCE LOCALITY 7). Repetition of a distinctive subfacies succession (subtidal to intertidal to supratidal) occurs in cycles 12 to 15 feet (4 to 5 meters) thick and is a dominant characteristic of the formation. The individual cycles, deposited by a regressive sea, are bounded by erosional breaks that may represent an intermittently transgressive sea. Erosion between cycles is responsible for the elimination of certain subfacies of the previous cycle and makes the cyclic record incomplete, although not so abbreviated as in the underlying Elbrook. A composite succession of subfacies begins with a 0- to 1.5-foot (0-.5 m) interval of medium to coarse-grained, cross-bedded, commonly oolitic calcarenite (subtidal) succeeded by 1 to 3 feet (.3 to 1 m) of algal stromatolitic limestone (lower intertidal to upper subtidal). The algal limestone has irregular boundaries with coarse carbonate sand and flat-pebble conglomerate layers above that comprise part of a thick interval (6 to 7 feet, or 2 meters) of thin, interbedded "ribbon" limestone and dolomite (lower intertidal). The thin, interbedded subfacies commonly becomes more dolomitic towards the top and grades upward into an interval of wavy, interlaminated, ultra fine-grained limestone and dolomite (upper intertidal) into laminated, mud-cracked dolomite (supratidal) at the top of the cycle.

Sandy dolomite and thin (1-3 feet or 0.3-1 m) beds of carbonate-cemented, cross-bedded quartz sandstone are interlayered in the upper Conococheague along Patterson Ridge and other discontinuous ridges to the southeast (REFERENCE LOCALITY 8). The high degree of sorting, rounding and frosting of sand grains in these layers, combined with the steep inclination of the cross laminations, suggest reworking of dunal sand transported across the supratidal flat by strong westerly winds from the landmass to the west.

The contact between the Conococheague Formation and the overlying Beekmantown Group is placed at the top of the uppermost thinly laminated, supratidal dolomite that can be related to the last Conococheague cycle. Where the contact is poorly exposed it has been placed at the break in slope adjacent to massive limestones in the base of the Beekmantown Group.

Limestone and dolomite of the *Beekmantown Group* have been subdivided into five unnamed formations and are exposed in the northwestern corner of the quadrangle. Beds in the *lower limestone unit* previously mapped in the adjacent Waynesboro West quadrangle as the Chepultepec Formation (Gathright, et al, 1977), are transitional with the underlying Conococheague Formation. The basal Beekmantown beds (REFERENCE LOCALITY 9) are generally a thick-bedded calcarenite or algal limestone and seem to represent a lower intertidal to lower subtidal environment similar to the one in the Conococheague cycle. In comparison with the Conococheague beds, the lower Beekmantown limestone is much thicker indicating a longer period of intertidal or subtidal deposition, or a more rapid subsidence of the carbonate shelf. Interlaminated limestone and dolomite beds, similar to the upper intertidal subfacies of the Conococheague occur sporadically within the lower limestone unit, but there are few complete cycles in the Beekmantown Group. Alternating limestone and dolomite beds in the upper part of the unit are similar to cyclic beds described in the middle limestone and dolomite unit. The contact between the lower limestone unit and the lower dolomite unit is placed at the top of the uppermost limestone, which occurs stratigraphically below a very thick section composed of siliceous and vuggy dolomite.

The *lower dolomite unit* (REFERENCE LOCALITY 10) is resistant to erosion and forms the linear chert-covered ridge northeast and southwest of Mt. Horeb Church. The unit contains mud cracks, algal lamination, and thin dolomite intraclast layers and is considered to be largely supratidal to intertidal in origin, having been deposited on an algal flat similar to an environment of the Elbrook Formation. Frosted-quartz sand grains and the relatively high silica content (bedded and nodular chert) suggest recurrent wind transportation of fine silica across the supratidal flats from the craton to the west.

The contact between the lower dolomite unit and the *middle limestone and dolomite unit* is placed at the base of the lowest limestone bed that is the beginning of cyclic limestone and dolomite strata which comprise the middle unit. A typical middle Beekmantown limestone cycle contains a calcarenite with thin, flat-pebble conglomerate zones near the base that may be channeled down into the underlying dolomite. Cross-bedded, oolitic carbonate sands (lower intertidal to upper subtidal) have also been observed in the lower part of the cycle. Mottled, partly dolomitized limestone with burrow structures, and thin-bedded to laminated, silty calcarenite beds may alternate in the upper part. At the top of the cycle partly dolomitized limestone with burrow structures grades upwards into mottled, then thin, laminated dolomite. The calcarenite beds are generally fossiliferous and in addition to algal biostromes contain cephalopods, gastropods, fragments of crinoids, brachiopods, and trilobites. The sediments were deposited on a relatively high-energy, subtidal, wave-swept platform that graded upwards into a supratidal zone. The frequency of environmental changes may indicate a more tectonically active shelf during Beekmantown time.

The contact between the middle limestone and dolomite unit and the upper dolomite unit is placed at the top of the uppermost limestone in the middle unit, underlying a thick section composed entirely of siliceous dolomite. The *upper dolomite unit* is generally similar to the lower dolomite unit, but is not as thick. Each contains evidence (mud cracks, algal lamination, thin dolomite intraclast layers) of an algal flat inundated infrequently during major storms. Vuggy, mottled and internally disrupted beds may indicate crystal growth under evaporative conditions, and the high silica content suggests input by an external (aeolian) depositional system operative during dust storms.

The contact between the upper dolomite unit and the upper limestone and dolomite unit is placed at the base of the lowest limestone above the massive dolomite section. The *upper limestone and dolomite unit* contains incomplete, eroded cycles of massive micritic limestone, micritic limestone with abundant burrow structures, a few thin layers of shale, and calcareous mudrock overlain by thin laminated dolomite. Characteristic structures are bird's-eye texture, mud cracks, lamination, and intraformational conglomerates and burrows. Environmental conditions seem to have fluctuated between intertidal and supratidal zones, with the culmination being a prolonged period of erosion. The New Market Limestone is not present in this quadrangle, and the unconformable contact between the Beekmantown Group and the Lincolnshire Formation is placed at the base of a dark-gray calcarenite that is preserved in a narrow channel (Figure 2) cut down into the upper limestone and dolomite unit between State Road 608 and Middle River (REFERENCE LOCALITY 11). The *Lincolnshire Formation* contains coarse, rounded limestone cobbles in the trough of this channel, and Lincolnshire limestone on the southeastern flank of the channel contains dinorthid brachiopods. The Edinburg Formation, which overlies the Lincolnshire Formation in some other areas, is not present in this quadrangle.

Slate*

A portion of the basal *calcareous black slate member* of the *Martinsburg Formation* occurs in a submarine channel deposit that can be traced southwestward from REFERENCE LOCALITY 11. Within the channel the slate overlies calcarenite and conglomerate of the Lincolnshire Formation, and the succession of lithofacies (Figure 2) suggests a very abrupt facies change from the carbonate platform (Beekmantown, Lincolnshire) to a still-water, restricted basin (basal Martinsburg).

Igneous Rock

A swarm of north-northwest trending, near-vertical *diabase dikes* were intruded into the Paleozoic and Precambrian rocks during the Mesozoic Era. The dikes are composed of fine-grained, greenish-black to black olivine diabase that weathers to large, round boulders and orange-red soil.

Surficial Deposits

Thin *lowland alluvial deposits* are present in the flood plains of most streams and rivers. They are composed of sediment derived from the weathering and erosion of siliceous rocks in the Blue Ridge and, to a lesser degree, the chert and sandstone-bearing rocks of Shenandoah Valley. The deposits grade from silt or sandy silt at the top to coarse quartzite cobbles and pebbles in a sand matrix at the base along rivers and the smaller streams that originate in the mountainous areas. Silty clay deposits with chert gravel at the base are common in the flood plains of streams draining areas of cherty carbonate rocks.

Upland alluvial deposits are generally present in stream valleys of the Blue Ridge mountains. They are composed of pebbles, cobbles, and boulders derived from the rock outcrops on adjacent slopes. The sediment in these deposits is coarser upstream; the deposits grade into the finer-grained lowland alluvium downstream.

Extensive, train-like *talus deposits* of angular quartzite boulders are present on the slopes and in the hollows below prominent quartzite ledges of the Antietam and Harpers formations. These thin deposits contain angular boulders that range up to 3 feet (1 m) in length, and are relatively uniform in size within a single deposit. Generally, little matrix material is present between the boulders, and the talus slopes are mostly devoid of vegetation. Phyllite and sandstone bedrock beneath the talus deposits is more deeply weathered than in adjacent areas with no talus cover.

Between South River and the west foot of the Blue Ridge a series of overlapping *alluvial fan deposits* form a broad, westward-sloping apron of unconsolidated clay, silt, sand, gravel and coarser quartzite debris. These materials, together with the flood plain alluvium and terrace deposits along South River, form an almost unbroken cover over the bedrock. The fan deposits are thinnest where they overlie phyllite and argillite of the Waynesboro Formation, and are thickest where they overlie limestone and dolomite of the Waynesboro and Shady formations. The base of this unconsolidated material has been penetrated by only a few water wells and is difficult to recognize as it appears to grade into the residual clay derived from the deeply weathered carbonate bedrock. The residual clay, shown as *sandy clay* in cross sections, may exceed 100 feet (30.5 m) in thickness on portions of the Shady or Waynesboro formations; such thicknesses have also been reported in adjacent areas with similar geologic conditions (King, 1950, Figure 16, Section S—S', and Knechtel, 1943, p. 181-184). Bedrock was encountered at a depth of 370 feet (113 m) in one water well drilled near the foot of the Blue Ridge (personal communication, 1977, Gary Burner, Burner Well Drilling Co., MaGaheysville, Va.). The alluvial fans are locally incised by streams flowing westward from the Blue Ridge. Some streams are debris-filled and braided, and some sink into the fans before reaching South River. In places large springs emerge from the alluvial fans to form streams, or to flow directly into South River.

The deeply weathered, dissected remnants of ancient flood plains form discontinuous *terrace deposits* above the flood plains of the rivers and some of the larger streams. These deposits, like the lowland alluvium, have silt and sand in the upper part and a layer of gravel at the base.

GEOLOGIC STRUCTURES AND METAMORPHISM

The quadrangle is located on the mutual, folded flank of the Blue Ridge anticlinorium and the Massanutten synclinorium. The fold system is characterized by southwestward plunging, asymmetric to overturned, closed to isoclinal, non-cylindrical *folds* that may have non-planar axial surfaces. Strongly attenuated, overturned fold limbs associated with relatively non-attenuated upright limbs have been observed in the Blue Ridge portion of the quadrangle. *Cleavage or schistosity* in the limestones, slates and phyllites is parallel to the axial surfaces, and metamorphic mineral growth (sericite, chlorite, and locally biotite) in the more argillaceous rocks is parallel to schistosity. Dolomites, sandstones, and quartzites also have a well-developed axial-plane cleavage and a well-developed system of *transverse joints*. A pair of northwestward trending, near-vertical *transverse faults* have displaced the rocks and the fold systems in the Blue Ridge southeast of the Crimora surface mine. The fault traces are characterized by quartz-filled gash veins, and slickensides. Rocks to the northeast of the faults appear to have been uplifted with respect to those on the southwest. Between the faults, bedding, schistosity and the axial surfaces of folds have been tilted to the southwest. The fault traces are covered by an alluvial fan at the west foot of the Blue Ridge but faults on the west side of South River and in the adjacent Fort Defiance quadrangle appear to be westward extensions.

MINERAL RESOURCES

Shenandoah Sand and Gravel, Inc. (REFERENCE LOCALITY 12) produces processed sand and gravel from the alluvial deposits of the South River. The open pits and crushing plant are located 1.8 miles (5.5 km) north of Harriston, between State Road 825 and South River.

The Crimora manganese mine (REFERENCE LOCALITY 13), located 2.5 miles (4 km) southeast of the town of Crimora, was at one time the largest producer of manganese in the United States. More than 160,000 tons (145,120 metric tons) of ore were mined between 1867 and 1917 (Watson, 1907 and Stose, et. al., 1919). Many small deposits of manganese and iron ore occur along the west foot of the Blue Ridge, but the larger concentration of ore at Crimora mines may be related to the pair of transverse faults located in Turk Gap.

Impure limestone, dolomitic limestone, and dolomite in the Beekmantown Group and Conococheague Formation may provide sources for crushed stone, agricultural limestone or hydraulic lime. See Edmundson (1945) for additional information.

GEOLOGIC FACTORS AFFECTING LAND MODIFICATION

Areas underlain by similar rock types and areas with comparable surficial deposits, form land units having similar geologic factors that affect land modification. These land units are composed of the individual rock units (groups, formations, members or deposits) or groups of similar rock units shown on the geologic map, and have been evaluated on the basis of physical characteristics of the rock, slope stability, erodability, and response to excavation and ground-water withdrawals. The locations of major sink-holes and areas of modified land are also shown on the map. Although rock units may be used as guides in determining the geologic and economic factors that affect land modification, their internal variation and structure is such that only broad generalizations can be made in evaluating them. In addition to the data presented, detailed examination of individual sites is recommended.

Data on forestry, regional planning, soils and water may be obtained from the following agencies: (1) Virginia Division of Forestry, P. O. Box 3758, Charlottesville, VA 22903; (2) Central Shenandoah Planning District Commission, P. O. Box 1337, 119 West Frederick Street, Staunton, VA 24401; (3) Soil Conservation Service, U. S. Department of Agriculture, P. O. Box 10026, Richmond, VA 23240; (4) State Water Control Board, P. O. Box 268, Bridgewater, VA 22812.

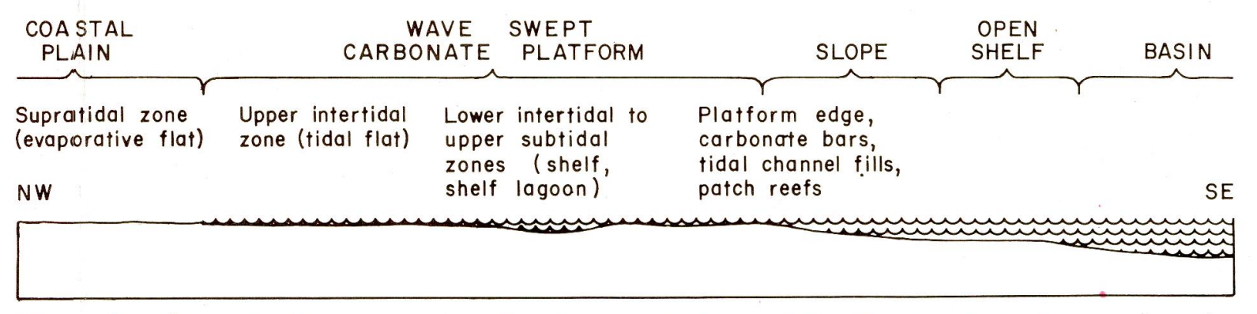


Figure 1. Generalized cross section showing morphology of the Cambro-Ordovician carbonate shelf environment—central Shenandoah Valley, Virginia.

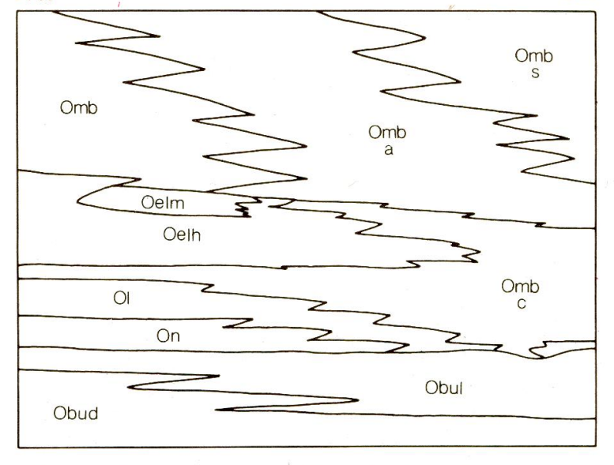


Figure 2. Regional lithofacies diagram of Middle Ordovician rocks—central Shenandoah Valley, Virginia.

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REFERENCE NOTE

Portions of this publication may be quoted if credit is given to the Virginia Division of Mineral Resources. It is recommended that reference to the entire publication be made in the following form:
Gathright, T. M., II, Henika, W. S., and Sullivan, J. L., III, 1978, Geology of the Crimora quadrangle, Virginia: Virginia Division of Mineral Resources Publication 13, text and 1:24,000 scale map

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*Slate as used in text is a compact, fine-grained metamorphic rock formed from such rocks as shale and volcanic ash, which possesses the property of fissility along planes independent of the original bedding (slaty cleavage due to the crystallization of chlorite and white mica along these planes) whereby they can be parted into plates that are lithologically indistinguishable (modified from AGI, 1972).