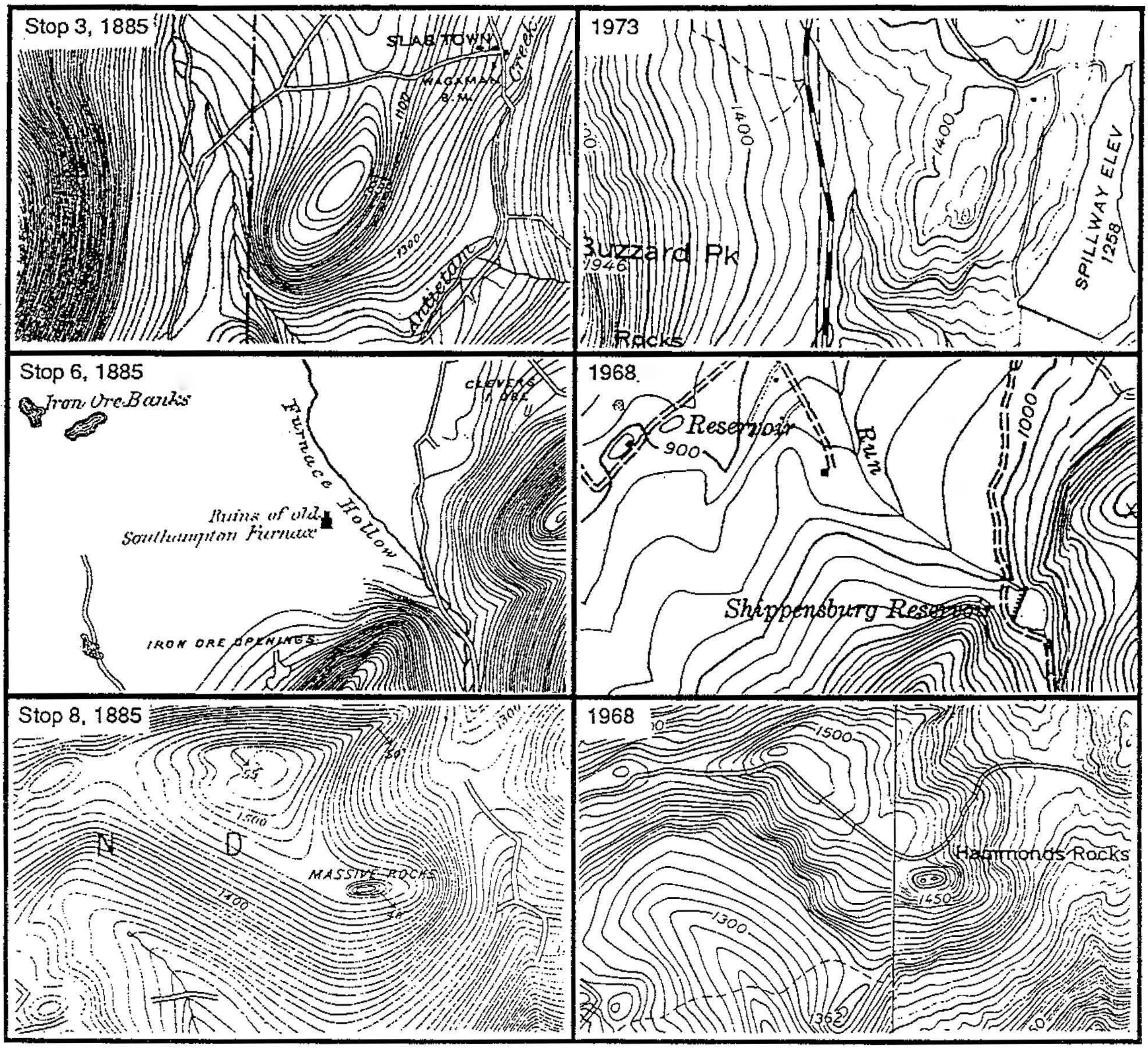
Guidebook

56th Annual Field Conference of Pennsylvania Geologists

Geology in the South Mountain Area, Pennsylvania



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THE LOWER CAMBRIAN CLASTICS OF SOUTH MOUNTAIN, PENNSYLVANIA

by
Marcus M. Key, Jr.
Department of Geology, Dickinson College, Carlisle, PA

INTRODUCTION

The northeast/southwest trending linear ridges of South Mountain are composed of the Lower Cambrian clastic metasedimentary rocks of the Chilhowee Group (Figure 3). The group comprises four formations (from oldest to youngest): Loudoun, Weverton, Harpers, and Antietam. In the South Mountain area, the thickness of the group ranges from roughly 3,000 feet in the Mt. Holly area to 5,000 feet in the Caledonia area. The group consists of lithogenic sediments which originally were shales, litharenites, sublitharenites, quartz arenites, and conglomerates that have been metamorphosed into phyllites, quartzites, and squashed-pebble conglomerates. Currently only the Montalto Member of the Harpers Formation and the Antietam Quartzite are economically important as a source of coarse and fine aggregate, and colored sands for speciality uses.

AGE

The age of the Chilhowee Group has historically been a troublesome issue (Nickelsen, 1956). The problem existed because of a paucity of datable materials in these rocks. The age of the group is now rather certain to be Early Cambrian based on the radiometrically dated, stratigraphically older Catoctin Formation and two biostratigraphically dated formations in the upper and lower units of the Chilhowee Group.

Until recently, the age of the Catoctin Formation was widely disputed with radiometric dates ranging from 420±4 Ma (Silurian) (Nagel and Mose, 1984) to 820 Ma (Precambrian) (Rankin and others, 1969). Recent radiometric ages have been much more consistent. The metarhyolites in the Catoctin Formation from South Mountain have been dated at 597±18 Ma (Aleinikoff and others, 1991). Badger and Sinha (1988) determined the age of the Catoctin in west-central Virginia to be 570±36 Ma. The stratigraphically older Lynchburg Formation in Virginia has been dated at 600 Ma (Mose and others, 1985). All of these recent dates suggest the Catoctin Formation is latest Precambrian in age.

Biostratigraphic contraints on the age of the Chilhowee Group come from fossils in the upper and lower parts of the group. The Early Cambrian age fossils first reported by Walcott (1891) from the Antietam Quartzite have been found throughout the Appalachians in this formation and its stratigraphic equivalents to the south (See Yochelson, this guidebook). The age of the upper Chilhowee rocks has been repeatedly confirmed with different index fossils and in different areas along the Appalachians. The Antietam Quartzite and its stratigraphic equivalents contain a diverse fauna indicative of the Early Cambrian. This fauna contains acritarchs, the worm tube ichnofossil *Skolithos linear-*

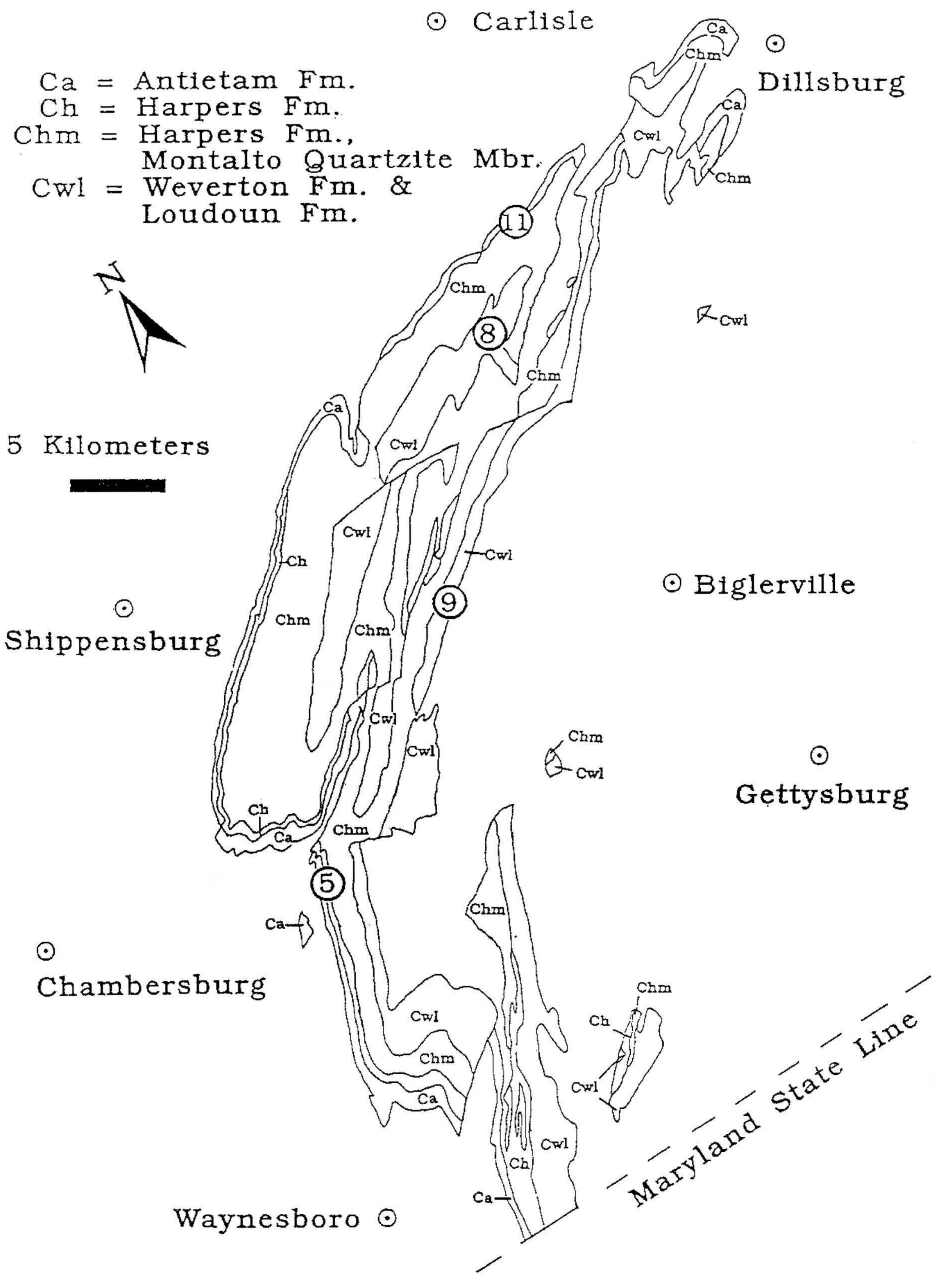

Figure 3. Geologic map of South Mountain area showing distribution distribution of Chilhowee Group formations (Modified from Berg and others, 1980). Numbers refer to Chilhowee Group field trip stops.

is, the inarticulate brachiopod *Obolella*, the articulate brachiopod *Camarella minor*, the trilobite *Olenellus*, the primitive mollusc *Hyolithus communis*, and the ostracod *Indiana tennesseensis*. This fauna has been reported from Pennsylvania to Tennessee (Walcott, 1896; Stose, 1909; Bassler, 1919; Barrell, 1925; Stose and Bascom, 1929; Stose, 1932; Resser and Howell, 1938; Amsden, 1951; Stose, 1953; Stose and Stose, 1957; Laurence and Palmer, 1963; Wood and Clendening, 1982). The occurrence of *Olenellus* constrains the Antietam Quartzite to the *Bonnia-Olenellus* Biozone which existed from 550-540 Ma (Fritz, 1972; Palmer, 1981, 1983). This dates the Antietam Quartzite as latest Early Cambrian.

The presence of Skolithos linearis in the Montalto Member of the Harpers Formation does not provide any biostratigraphic control because this trace fossil occurs in both Cambrian and Precambrian deposits (Fritz and Crimes, 1985). Recently an age diagnostic fauna has been found in the stratigraphic equivalent of the Weverton Quartzite in southwestern Virginia (Simpson and Sundberg, 1987). This depauperate fauna contains many small shelly fossils and the trace fossil Rusophycus which is indicative of earliest Early Cambrian (Fedonkin, 1981). This constrains the age of the lower Chilhowee Group to 570-560 Ma (Sepkoski and Knoll, 1983).

The radiometric dates of the Catoctin Formation place a maximum age on the Chilhowee Group of roughly 570 Ma. The biostratigraphic data suggest an age range of 570-540 Ma. Based on the stratigraphic conformity of all of the Chilhowee Group formations (Nickelsen, 1956; Fauth, 1968), the age of the entire group is considered to be Early Cambrian.

CATOCTIN FORMATION - CHILHOWEE GROUP CONTACT

Underlying the Chilhowee Group is the Catoctin Formation (See the paper by Smith and others, this guidebook). The Catoctin consists of aphanitic, extrusive volcanics (dominantly basalts and rhyolites) that have been subsequently metamorphosed. These represent late Precambrian rift-related volcanism (Badger and Sinha, 1991) which occurred during the opening of the Proto-Atlantic (Iapetus) Ocean (Rankin, 1975). They are inferred to have been generally extruded subaerially based on the absence of pillow lavas and the presence of columnar jointing (Reed, 1955; Fauth, 1968). Petrographic, rare earth element, and major element analyses have confirmed this (Rankin and others, 1969; Dockter, 1990). However, some local subaqueous extrusion has been documented by the presence of pillow lavas in Virginia (Bowring and Spencer, 1987; Kline and others, 1987).

The Catoctin-Chilhowee Group (i.e., Catoctin-Loudoun) contact is not exposed in the South Mountain area (Stose, 1909; Stose and Bascom, 1929; Fauth, 1968). Historically, the contact has been considered both conformable (Bloomer and Bloomer, 1947; Bloomer, 1950; Cloos, 1951; Rankin, 1967) and unconformable (Stose, 1906, 1909, 1932; Stose and Bascom, 1929; King, 1950; Stose and Stose, 1957; King and Fergusen, 1960; Rankin and others, 1969). The absence of a structural discordance between the Catoctin and Loudoun Formations suggests the contact is conformable (Bloomer, 1950; Bloomer and Werner, 1955; Reed, 1955; Fauth, 1968). Both formations exhibit similar deformation patterns (i.e., orientation of cleavage and lineations) (Stose, 1932; King, 1949; Cloos, 1951; Freedman, 1967; Fauth 1968). If there was a period of deformation prior to the deposition of the Loudoun Formation, it would indicate unconformity. Bloomer (1950), Cloos (1951), and Bowring and Spencer (1987) argue that the contact is also conformable due to the interfingering of the Catoctin volcanics with the Loudoun clastics in Virginia.

The presence of Catoctin fragments in the basal clastic sediments of the Loudoun Formation suggests the contact is unconformable [But see Bloomer (1950) for an opposing view]. This indicates the Catoctin was subaerially exposed and eroded prior to deposition of the Loudoun (Freedman, 1967). According to Reed (1955) this period of erosion is preserved by a metamorphosed saprolite at the contact. Another argument for unconformity is that the contact represents a change from terrestrial extrusion of the Catoctin to submarine deposition of the Loudoun (Nickelsen, 1956; Fauth, 1968).

The contact may be unconformable, but it probably represents only a brief time hiatus (Badger and Sinha, 1988). The previously discussed radiometric ages of the Catoctin and the biostratigraphic ages of the Chilhowee suggest little if any time is missing at this contact.

LITHOSTRATIGRAPHY

The basal Chilhowee unit is the Loudoun Formation. The sediments of this formation contain fragments of the underlying Catoctin metarhyolites (Stose, 1906, 1909, 1932; Stose and Bascom, 1929; Freedman, 1967; Fauth, 1968). Thickness in the South Mountain area ranges from 0 to 550 feet (Stose and Bascom 1929, Stose 1932, Freedman 1967, Fauth 1968). In the Caledonia and Mt. Holly areas, this unit crops out along the southeast slope of Piney Mountain. The lithology ranges from a purplish phyllite to a grayish, quartz/phyllite/rhyolite-pebble metaconglomerate (Stop 9). The grains are subrounded to subangular ~~grains~~ with fair sorting (Fauth, 1968).

Overlying the Loudoun Formation is the Weverton Quartzite whose thickness in the South Mountain area ranges from 600 to 1,400 feet (Stose and Bascom, 1929; Stose, 1932; Freedman, 1967; Fauth 1968). In the Caledonia area, this unit crops out along the crests of Piney Mountain and Big Pine Flat Ridge and along the southeast slope of East Big Flat Ridge. In the Mt. Holly area, it crops out along the crest of Mt. Holly (including Hammond's Rocks, Stop 8) and along the southeast slope of Piney Mountain. The lithology ranges from grayish-green and purplish quartzites and quartzose graywackes with occasional thin zones of graywacke conglomerate, quartzite, and phyllite. The grains are subrounded to subangular with moderate sorting (Fauth, 1968).

Overlying the Weverton Quartzite is the Harpers Formation whose thickness in the South Mountain area ranges from 1,500 to 3,000 feet (Stose and Bascom, 1929; Stose, 1932; Freedman, 1967; Fauth, 1968). In the Caledonia area, this unit crops out along the crests of Piney Mountain and Big Pine Flat Ridge. In the Mt. Holly area, it crops out along the crest of Piney Mountain and around the nose of Mt. Holly. There are two distinct lithologies present. The lower light-gray quartzite has good sorting with subrounded grains (Fauth, 1968). This unit is called the Montalto Quartzite Member, and it is 1,200 to 2,500 feet thick. The Montalto is crossbedded and has numerous *Skolithos linearis* worm tubes (Figure 2). In the upper part of this member is a distinctive bluish quartzite unit that ranges from 15 to 25 feet thick and is useful in mapping (Fauth, 1968). The upper greenish graywacke/phyllite is moderately sorted with subrounded grains. It is 300 to 500 feet thick (Fauth, 1968; Root, 1978).

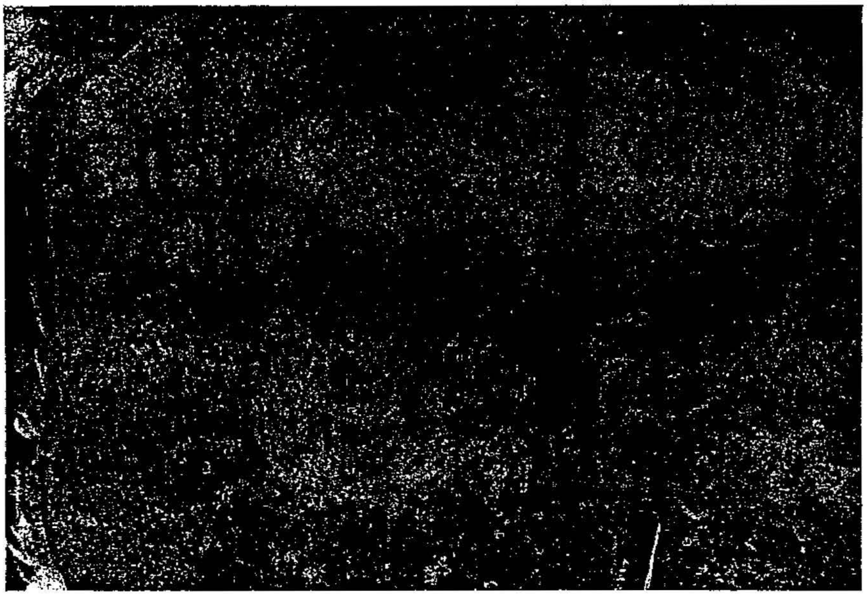

Figure 2. *Skolithos linearis* worm tubes from the Antietam Formation.

Overlying the Harpers Formation is the youngest Chilhowee unit, the Antietam Quartzite whose thickness in the South Mountain area ranges from 440 to 900 feet (Stose, 1909; Stose and Bascom, 1929; Stose, 1932; Freedman, 1967; Fauth, 1968; Root, 1978). The Pennsylvania Geological Survey is currently studying core from an angle hole that penetrated the entire thickness of the Antietam north of Caledonia Park. In the Caledonia area, this unit crops out around the nose of Big Pine Flat Ridge. In the Mt. Holly area, it crops out along the northwest slope and the nose of Mt. Holly. The lithology is dominated by white to grayish quartzite which is medium- to coarse-grained, subrounded to rounded, with good sorting (Fauth, 1968). *Skolithos linearis* worm tubes (Figure 2) are abundant with some up to 15 inches long (Shirk, 1980; Wilshusen and Sevon, 1981, 1982). Megaripples are present in the Mt. Cydonia area (Wilshusen and Sevon, 1981, 1982) (Stop 5). There are numerous abandoned aggregate pits and quarries developed in the Antietam in the South Mountain area. Significant active aggregate operations in the Antietam occur at Mt. Cydonia (Stop 5) and Mt. Holly Springs (Stop 11) as well as Toland.

CHILHOWEE GROUP - TOMSTOWN DOLOMITE CONTACT

Overlying the Chilhowee Group is a thick sequence of Cambrian through Ordovician carbonates. The oldest of these carbonates is the Tomstown Dolomite which rests upon the Antietam Quartzite. The Tomstown is dominantly dolomitic with some minor limestone. The contact between the Antietam Quartzite and the Tomstown Dolomite is apparently gradational as evidenced by a calcareous basal shale in the Tomstown (Brezinski, 1991). In the South Mountain region, this contact is marked by the presence of kaolinite-rich white clays (Berkheiser and others, 1982). This clay formed either from dissolution of the Tomstown which resulted in the concentration of its contained lithogenic sediment (Stose, 1907) or from hydrothermal alteration of the Tomstown (Hosterman, 1968, 1969).

The contact is often assumed to be conformable even though it is not exposed in the South Mountain area (Stose, 1909; Stose and Bascom, 1929; Fauth, 1968; Freedman, 1968; Brezinski, 1991). Besides the lithologic argument for conformity mentioned above, there is also biostratigraphic support for conformity. The Tomstown Dolomite has been dated as latest Early Cambrian due to the presence of the trilobite Olenellus (Fauth, 1968). As the Tomstown and Antietam are of the same age based on the available biostratigraphic control, the contact is probably conformable (Fauth, 1968).

PALEOGEOGRAPHY

The Chilhowee Group was deposited in rift-induced sedimenttary basins that formed as a result of the opening of the Iapetus Ocean in the late Precambrian (Bond and others, 1984). In the Early Cambrian, clastic sediments (including the Chilhowee Group) were deposited along the newly-formed southern and eastern edges of the North American craton (Thomas, 1977). These sediments represent the basal transgressive sediments of the Sauk Sequence (Sloss, 1963; Brown, 1970; Schwab, 1972). The sediments were eroded from the craton, transported to the southeast (Kay, 1951; Whitaker, 1955; Brown, 1970; Schwab, 1970; Whisonant, 1970), and were deposited in shallow marine environments of the Iapetus Ocean along the coast of North America. During this time, the South Mountain area was located at roughly 15^{o} south latitude (Scotese and others, 1979).

Deposition of the Chilhowee Group began with the transgression of the Cambrian sea which onlapped from the southeast and inundated the subaerially exposed Precambrian Catoctin Formation (Nickelsen, 1956; Fauth, 1968). The first sediments resulted in the Loudoun Formation which was partially derived from and deposited on the Catoctin Formation. This is evidenced by the clasts of Catoctin metarhyolites which were incorporated into the basal Loudoun sediments.

Evidence of a northwestern cratonic source area for the Chilhowee Group comes from stratigraphic thicknesses, paleocurrent indicators, and facies distributions. The Loudoun Formation and the Weverton Quartzite thicken to the west (Swartz, 1948). The Montalto Quartzite Member of the Harpers Formation thickens to the north (Fauth, 1968). Stose and Bascom (1929) reported that the entire Chilhowee Group thickens to the northwest. Crossbedding in the Weverton Quartzite indicates a western source area (Whitaker, 1955), while ripple marks in the Antietam Quartzite suggest a northwestern source area (Wilshusen and Sevon, 1981, 1982). The upper Chilhowee formation grades eastwardly from the Antietam Quartzite in the Blue Ridge Mountains to the Chickies quartz-mica schist in the Piedmont (Freedman, 1968). This facies change suggests deeper water to the east and a westward source area.

The depositional environments represented by the Chilhowee Group in the South Mountain area are dominantly shallow marine on continental shelf environments (Nickelsen, 1956). This is evidenced by the presence of trilobites, brachiopods, ostracods, and worm tubes. Water depth increased to the southeast toward the deep-marine Wissahicken basin (Thomas, 1977) where the Chilhowee Group was deposited below storm-wave base (Freedman, 1968; Simpson and others, 1991).

The depositional environment of the Antietam Quartzite can be further refined as a shallow marine beach setting. The Antietam's clean, well-rounded quartz sand and the presence of mega-ripples led Wilshusen and Sevon (1981, 1982) to interpret this formation as reflecting a near-shore to offshore, below normal wave-base setting. Based on the outcrop pattern and the morphology of the sand bodies, Kauffman and Frey (1979) inferred that the Antietam was deposited in a barrier island environment. The occurrence of *Skolithos linearis* worm tubes in the Antietam places this formation in the *Skolithos* ichnofacies. This facies is indicative of the intertidal to subtidal zone of a shallow, high energy, coastal, beach environment (Seilacher, 1967; Crimes, 1970). The Montalto Quartzite Member of the Harper Formation has identical worm tubes, and it is interpreted to have a similar depositional environment.

Fluctuations in local relief, rate of uplift, and rate of erosion in the source area relative to the rate of subsidence and deposition in the depositional basins resulted in local fining and coarsening trends within the Chilhowee Group. On a regional scale over the course of Chilhowee deposition, sediments generally became finer as well as texturally and mineralogically more mature in response to rising sea level and increasing tectonic stability of the east coast of the North American craton (Fauth, 1968; Patterson and Simpson, 1991). The maturing upward trend is evidenced by a general increase in the degree of sorting and roundness as well as an increase in the amount of quartz clasts relative to those of feldspar (Fauth, 1968). In the South Mountain area, this can be grossly seen by comparing the immature Loudoun conglomerates (Stop 9) with the mature Antietam quartz arenites (Stops 5 and 11). The fining upward trend continued after Chilhowee deposition into the Tomstown Dolomite. Before the end of the Early Cambrian, the sediment became finer until little or no lithogenic sediment was entering the sea and carbonate biogenic sedimentation was initiated (Freedman, 1967, 1968).

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