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Geologic Map of the Piedmont in the Savage and Relay Quadrangles, Howard, Baltimore, and Anne Arundel Counties, Maryland

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INTRODUCTION

The Piedmont in the Savage and Relay quadrangles (fig. 1) is largely in Howard County, Maryland. The northeasternmost part is in Baltimore County, Maryland and about 0.03 square miles is in Anne Arundel County. Most of the area is suburban and almost all outcrops are restricted to the Patapsco, Middle Patuxent, Little Patuxent, and other stream valleys. Crystalline rocks of the central Appalachian Piedmont within these quadrangles are overlain in many places by Coastal Plain deposits of Cretaceous age. Alluvium occurs along most streams. The geology of adjacent quadrangles on the west and south has been mapped by Drake (in press, unpublished data, 1991-1997) and J.N. Roen and A.A. Drake, Jr. (in press), and that to the north and east by Crowley (1976). The tectonics of the area were interpreted by Crowley (1976) and Drake (1995). Aeromagnetic and gravity surveys of the area were interpreted by Bromery (1968).

REGIONAL GEOLOGY

This part of the Maryland Piedmont is on the east limb of the Baltimore structural culmination, a major internal basement massif in the central Appalachian orogen (Drake and others, 1988; Rankin and others, 1989, 1993). This culmination exposes Mesoproterozoic basement and its Cambrian continental margin sequence cover in several antiformal windows through an obducted sequence of metamorphosed sedimentary and igneous rocks (fig. 1). These relations were mapped in the Clarksville (Drake, in press) and Sykesville (Roen and Drake, in press) quadrangles to the west (fig. 1). Here, the obducted sequence consists of the Loch Raven-Laurel tectonic motif and the arc rocks of the Baltimore and Soapstone Branch thrust sheets. These rocks have been intruded by granitoids of Late Ordovician and Late Devonian age and a dike of Early Jurassic age.

LOCH RAVEN-LAUREL TECTONIC MOTIF

The Loch Raven-Laurel tectonic motif consists of a precursory sedimentary melange, the Laurel Formation (Ꞓl), and the Loch Raven thrust sheet, which are separated by the Burnt Mills thrust fault. The Loch Raven thrust sheet consists of the Loch Raven Schist (ꞒZl) and Oella Formation (ꞒZo). The Laurel precursory melange contains fragments of the overlying Loch Raven thrust sheet that calved from it during its emplacement during the sedimentation of the melange matrix. The motif is a major tectonic unit in the Maryland Piedmont, the Loch Raven thrust sheet underlying about 400 square miles, and the Laurel Formation about 80 square miles.

Loch Raven Thrust Sheet

In this area, rocks of the Loch Raven thrust sheet were mapped as oligoclase-mica schist facies of the Wissahickon Formation by Cloos and Broedel (1940) and called Wissahickon Formation, eastern sequence by Hopson (1964). Throughout the Maryland Piedmont, these rocks were called the lower pelitic schist facies of the Wissahickon Formation (Southwick and Fisher, 1967).

There are no outcrops of Loch Raven Schist (ЄZl) in this map area. Fortunately, soil in areas underlain by this unit characteristically contains abundant flakes of coarse muscovite; therefore, it can be reasonably well mapped. In adjacent areas (Drake, 1998; unpublished data, 1991-1997) it consists mostly of quartz, muscovite, and biotite and much lesser plagioclase. Chemically, it is rich in alumina and alkalies, has a high Na-K ratio, and has a low silica content (Hopson, 1964). The schist contains meta-arenite beds identical to those in the overlying Oella Formation (ЄZo).

In the adjacent Clarksville quadrangle (Drake, in press) the Loch Raven Schist contains both mappable and unmappable layers of amphibolite as well as mappable blocks of serpentinized pyroxenite and amphibolite that have a spreading-center chemistry.

There is only one known outcrop of Oella Formation in this map area, but in adjacent areas (Drake, 1998, unpublished data, 1991-1997) it consists of meta-arenite and interbedded semipelitic schist and schist. The meta-arenite is fine grained and contains abundant quartz and plagioclase. In most exposures, it has a fair to good schistosity marked by aligned biotite flakes. The interbedded schist and semipelitic schist intervals are identical to those in the underlying Loch Raven Schist. Bedding can be determined easily at most places, particularly where meta-arenite and schist are closely interbedded.

The meta-arenite is not graded, nor does it possess other sedimentary structures characteristic of turbidites. An extensive study of these rocks by Hopson (1964) showed that they have the composition of graywacke and subgraywacke.

The Oella also contains some light-gray quartzite that contains no relict detrital sand grains. Chemical analyses of quartzite (Hopson, 1964) compare well with those of chert, or possibly, highly siliceous shale. Some quartzose beds contain clinozoisite (Drake, 1998) and are probably metamorphosed calcareous cherty sediment.

As interpreted by Drake (1998), the Loch Raven Schist and Oella Formation must have been deposited in a deep, quiet basin as there is no evidence of current activity in the arenitic rocks. The schist is most likely a metamorphosed sodic shale. The quartzite is most likely a metamorphosed highly siliceous shale and (or) impure chert as it occurs in thin, continuous beds and lacks relict detrital sand grains. The interlayered amphibolite could be either metamorphosed basalt or basaltic tuff. The discontinuous few inch-thick interlayers demand a tuffaceous origin. The mappable bodies probably had the same origin.

In this area, rocks of the Loch Raven thrust sheet are at kyanite grade and typically contain large garnets. Fibrolite occurs sporadically. In adjacent areas (A.A. Drake, Jr., unpublished data), muscovite and garnet are oriented in the schistosity, whereas kyanite and fibrolite have grown randomly across the schistosity surfaces, suggesting that heating outlasted deformation in this area.

Laurel Formation

The Laurel Formation is the precursory melange of the Loch Raven-Laurel tectonic motif. It is very poorly exposed in this area, and outcrops are largely confined to major drainages. Much of the Laurel was mismapped as oligoclase-mica facies of the Wissahickon Formation by Cloos and Broedel (1940), perhaps because of the abundant coarse muscovite resulting from its high metamorphic grade.

The upper part of the Laurel (Ɛlo) in the Washington West (Fleming and others, 1994), Kensington (Drake, 1998), and Clarksville (Drake, in press) quadrangles to the southwest contains more than 50 percent of previously deformed meta-arenite and schist olistoliths. That map unit was traced into and through this area on the basis of float.

BALTIMORE THRUST SHEET

In the Maryland Piedmont, the Baltimore thrust sheet consists of the Baltimore Complex. In Baltimore County, the Baltimore Complex consists of the Mount Washington Amphibolite, the Raspburg Amphibolite, and the Hollofield Ultramafite (Crowley, 1976). The Mount Washington and Raspburg are probably the same unit, but this could not be determined because of the Coastal Plain cover.

Mount Washington Amphibolite

In this area, the Mount Washington Amphibolite (Om) constitutes the Baltimore thrust sheet. The Mount Washington is the metamorphosed gabbro part of the Baltimore Complex (Crowley, 1976; Higgins, 1977). The ultramafic part of the Baltimore Complex, the Holofield Ultramafite and the Raspburg Amphibolite crop out to the north and east (Crowley, 1976). There are excellent outcrops of amphibolite along the major drainages and essentially none on the uplands where its presence is marked by scattered cobbles and boulders of amphibolite in clay-rich, red soil. The amphibolite contains interlayers of metapyroxenite, and a body of soapstone (Omsp) was mapped along Soapstone Branch. The amphibolite commonly contains veins and sheets of plagiogranite. Bodies of plagiogranite (Omp) were mapped in a tributary to Soapstone Branch and along the railroad below All Saints Convent in the northwestern corner of the map.

Chemistry of the Mount Washington Amphibolite was presented by Hanan (1980). Two new analyses are given in Table 1. Chemically, the bulk of the unit is basalt, some is picrobasalt, and one trachybasalt was sampled (fig. 2).

A geophysical study of the Baltimore thrust sheet by Bromery (1968) found that it constituted a slab, about 10,000 feet thick, both contacts of which dipped steeply west. Bromery (1968) interpreted this slab to be an intrusive sill, as had all previous workers. Crowley (1976), however, in a major contribution to Appalachian geology, found that the Mount Washington Amphibolite and Hollofield Ultramafite constitute a thrust sheet. The principal evidence for a fault is the truncation of map units both within the Baltimore Complex and within the surrounding rocks. This fault, the Baltimore thrust fault, has overrun the Laurel Formation and the Burnt Mills thrust fault in the Ellicott City quadrangle to the north (fig. 1) where it also cuts out the Hollofield Ultramafite (Crowley and Reinhardt, 1979). In addition, there is no evidence anywhere of contact metamorphism in the metasedimentary rocks adjacent to the Baltimore Complex.

SOAPSTONE BRANCH THRUST SHEET

In this area, the Soapstone Branch thrust sheet consists of the Druid Hill Amphibolite (Od), Relay Felsite (Or), and Carroll Gneiss (Oc).

Druid Hill Amphibolite

The Druid Hill Amphibolite (Od) originally was included in the Baltimore Complex (Mount Washington Amphibolite as used herein) by Knopf and Jonas (1925). It, however, is clearly layered, contains interlayered felsite, is finer grained than amphibolite of the Mount Washington Amphibolite, contains probable pillows, and clearly interfingers and replaces the Carroll Gneiss to the northeast in the Baltimore West quadrangle (Crowley and Reinhardt, 1979). Crowley (1976), in another major contribution to Appalachian geology, recognized that the Druid Hill was a volcanic rock and called it the Druid Hill Amphibolite Member of the James Run Formation. Drake (1998) removed the Druid Hill from the James Run Formation and promoted it to formational status. Outcrops of Druid Hill Amphibolite are restricted to the Patapsco Valley.

Two chemical analyses of Druid Hill Amphibolite were presented by Hanan (1980) and three new analyses are given in table 1. All rocks are basalt except for one dacite (fig. 2).

The contact of the Druid Hill Amphibolite with the Mount Washington Amphibolite, the Soapstone Branch thrust fault, is marked by mylonitic foliation. Abundant pegmatites appear in the Mount Washington north of the contact and are very sparse in the Druid Hill. Red soil has formed on the Mount Washington, whereas it has not on the Druid Hill.

Relay Felsite

The Relay Felsite (Or) originally was mapped as Relay Quartz Diorite by Knopf and Jonas (1925) and described as such by Hopson (1964). In addition, Hopson (1964) included in the unit the plagiogranite that has been intruded into the Mount Washington Amphibolite. Higgins (1972) interpreted the Relay to be a metamorphosed volcanic-volcaniclastic rock and assigned it to the James Run Formation. Crowley (1976) agreed with Higgins (1972) and named the unit the Relay Gneiss Member of the James Run Formation. Drake (1998) removed the Relay from the James Run Formation and promoted it to formational status as Relay Felsite. In this quadrangle, outcrops of Relay are restricted to the Patapsco Valley.

My study shows that although some of the Relay is fine grained and layered and passes down into the Druid Hill Amphibolite by interlayering, other parts are medium grained and unlayered and have all the characteristics of an intrusive rock. The Relay outcrop belt is linear (see fig. 1) suggesting a layered rather than an intrusive body. The Relay is here interpreted to consist of volcanic and subvolcanic rock that has intruded its own ejecta.

Chemistry of the Relay Felsite was published by Hopson (1964) and Higgins (1972). A new analysis is given in table 1. Chemically, the Relay Felsite is trondhjemite or quartz keratophyre (fig. 3).

Carroll Gneiss

The Carroll Gneiss (Oc) originally was mapped as Baltimore Gneiss by Knopf and Jonas (1925). Hopson (1964) recognized that these rocks differed greatly from the Baltimore Gneiss and called them paragneiss. Southwick (1969) recognized that these rocks were similar to the volcanic and volcaniclastic rocks in the James Run Formation and, therefore, were younger than the Baltimore Gneiss. Crowley (1976) accepted the volcanic origin of these rocks and named them the Carroll Gneiss Member of the James Run Formation. The Carroll Gneiss does not crop out in this quadrangle, but is important to an understanding of the regional geology.

INTRUSIVE ROCKS

The metamorphic rocks have been intruded by the Ellicott City Granodiorite (Oe) and related pegmatite (Op), the Guilford Granite (Dg) and related pegmatite (Dp), and a diabase dike (Jd).

Ellicott City Granodiorite

The Ellicott City Granodiorite is mostly granodiorite but has monzogranite phases (fig. 4). Of chemically analyzed samples, one is granite from the interior of a pluton, and one is granodiorite from the border of a pluton (fig. 2). There are no exposures of Ellicott City Granodiorite in the large plutons in this quadrangle, but Hopson (1964) reported that monzogranite appears to be restricted to the interior of rock bodies presumably resulting from igneous zoning. Sheared rocks on the margins of rock bodies, such as along the Patapsco River, have microcline crystals growing across the foliation, suggesting K-metasomatism by fluids passing along the mylonitic foliation. This is similar to relations in the Kensington Tonalite to the south (Fleming and others, 1994; Drake, 1998). The abundant pegmatites (Op) that intrude the Mount Washington Amphibolite (Om) appear to be related to Ellicott City plutonism. A chemical analysis of pegmatite is given in Table 1. The contact zones between Ellicott City Granodiorite and Mount Washington Amphibolite are characterized by dikes of Ellicott City and screens of Mount Washington, making geologic mapping quite difficult as it follows the fold forms in the metamorphic rocks. This is particularly well shown in the adjacent Ellicott City quadrangle (Crowley and Reinhardt, 1980). The Ellicott City contains primary epidote (Hobbs, 1889; Keyes, 1893, Hopson, 1964), suggesting that the granodiorite crystallized in a temperature-pressure regime of over 600°C and 8 kb (Zen and Hammarstrom, 1984).

Guilford Granite

The Guilford Granite (Dg) is monzogranite (fig. 3), although chemically some rock is granodiorite and quartz monzonite (fig. 2). The Guilford forms numerous elongate plutons in the western part of the map area. Most of these trend east-northeast to northeast but a few trend north. In 1993, new construction along Route 29 near the north border of the map exposed a pavement outcrop within which a dike of Guilford Granite (Dg) could be seen within Ellicott City Granodiorite (Oe).

The Guilford magma apparently was quite fluid as pegmatite occurs as discordant and sparse concordant seams, pods, and lenses within the granite. One pegmatite (Dp) has intruded the Laurel Formation (Ꞓl). Some outcrops, such as one in the Middle Patuxent River about 3,750 feet from the west margin of the map, contain dikes of aplite, some of which parallel the flow foliation. Other dikes fill joints that cut the flow foliation and parallel dikes. At least one quartz body (Dq) appears to be related to Guilford magmatism.

The Guilford Granite is clearly post-kinematic as it cuts the regional foliation, as well as the Baltimore thrust fault. There is no evidence of Devonian tectonism in this part of the Piedmont, so the Guilford probably formed by decompressional melting (Pitcher, 1982).

Diabase

One diabase dike (Jd) was mapped on the basis of float in the northwestern corner of the map. The rock is typical of other diabase dikes in the Piedmont.

STRUCTURAL GEOLOGY

The stacked thrust sheets in this map area have been obducted onto the Laurentian basement and continental margin sequence in the area to the west on the Loch Raven thrust sheet (Drake, 1995, 1998, in press; Roen and Drake, in press). The thrust stack, bottom to top, consists of the Loch Raven-Laurel tectonic motif, the Baltimore thrust sheet, and the Soapstone Branch thrust sheet. Regionally most of these rocks dip west because they are on the overturned east limb of the Baltimore culmination.

Structures in the Loch Raven-Laurel Tectonic Motif

The Loch Raven Sheet and Oella Formation were emplaced above the Laurel Formation on the Burnt Mills thrust fault, which was first mapped in the Kensington quadrangle about 15 miles to the southwest (Drake, 1998). The Laurel was deposited during the emplacement of the thrust sheet as shown by abundant olistoliths of previously metamorphosed and deformed meta-arenite and schist. The Burnt Mills thrust fault, like the thrust faults in the other tectonic motifs in the Virginia-Maryland Piedmont, is visualized to have formed near the base of a trench slope where it was stretched over the thrust toe generating debris that slumped to the base of the scarp (Drake, 1985a). With continuing deformation, the debris was overrun by the thrust fault, forming the tectonic motif.

There are far too few exposures of Loch Raven Schist and Oella Formation in this map area to permit mapping of macroscopic structures. Most outcrops of Laurel Formation have two foliations. At several places, one or both of these foliations have been folded into north-northwest to northwest plunging, upright antiforms and synforms. These folds are here called Columbia folds for the "new town" of that name. Columbia folds may well be the same as Rock

Creek folds mapped in the Washington West (Fleming and others, 1994) and Kensington (Drake, 1998) quadrangles to the southwest. Rock Creek folds were interpreted to have formed by transpression related to dextral slip along the Rock Creek shear zone (Fleming and others, 1994; Fleming and Drake, 1998; Drake, 1998). I (Drake, unpublished data, 1992-1997) have been unable to trace the Rock Creek shear zone north of the Patuxent River, so it is uncertain if Rock Creek and Columbia folds are correlative.

One east-northeast plunging fold of foliation was mapped in the Laurel Formation between Jonestown and Oakland Mills. Similar folds were called Middle Patuxent folds in the Clarksville quadrangle to the west where they fold axial surfaces of northwest to north-northwest plunging folds (Drake, in press). Here, they probably post-date Columbia folds, but that cannot be proved.

Structures in the Baltimore Thrust Sheet

The Baltimore thrust fault has placed the Mount Washington Amphibolite and, to the north, the Hollofield Ultramafite (Crowley, 1976), onto the Loch Raven-Laurel tectonic motif. The Baltimore thrust fault is overturned from the point where it is covered by Coastal Plain deposits in the Laurel quadrangle to the south (A.A. Drake, Jr., unpublished data, 1993) to the point near Columbia where it becomes upright. The overturning is consistent with the steep west-dipping contact of the Mount Washington Amphibolite as interpreted from geophysical data by Bromery (1968). The thrust fault is overturned again in the Ellicott City quadrangle to the north (Crowley and Reinhardt, 1980). It remains overturned throughout Baltimore and Harford Counties to the northeast (Southwick, 1969; Crowley, 1976). To the north, it has overrun the Laurel Formation (Crowley and Reinhardt, 1980). Small horses of Laurel, called Sykesville Formation, were mapped between the Baltimore and Burnt Mills thrust faults in the Ellicott City (Crowley and Reinhardt, 1980) and Baltimore West (Crowley and Reinhardt, 1979) quadrangles. The Laurel Formation emerges from beneath the Baltimore thrust fault in Harford County, Maryland (Southwick, 1969), where it was called Deer Creek melange by Drake (1985b).

Bromery (1968), on the basis of geophysical data, interpreted that the rocks here called Mount Washington Amphibolite occupied a synform. He was correct. The axial trace of this synform passes about 1,000 feet west of Ilchester. It is a Columbia phase fold. A Columbia antiform and synform fold the Mount Washington Amphibolite and Ellicott Granodiorite east of that axis. Columbia synforms and antiforms also fold the Ellicott City Granodiorite just east of the Baltimore thrust fault.

The foliation in the Mount Washington Amphibolite and Druid Hill Amphibolite, and the overturned Soapstone Branch thrust fault were deformed by an anticline-synform pair. These folds are overturned to the east and plunge north. They are here called Patapsco folds for the Patapsco River. Their relation to Columbia folds is uncertain.

Zones of mylonite are common in the Mount Washington Amphibolite and Ellicott City Granodiorite along the Patapsco River. Mylonitization is especially severe near the north border of the map, Ellicott City Granodiorite being reduced to a material resembling quartzite. Most mylonite strikes west-northwest to northwest. It is impossible to trace these zones within this map area. Mylonite was not mapped in the Ellicott City quadrangle to the north (Crowley and Reinhardt, 1980). It will not be possible to interpret this mylonite without additional work in the surrounding area.

Structures in the Soapstone Branch Thrust Sheet

The Druid Hill Amphibolite and Relay Felsite are folded together by several Patapsco folds. Mesoscopic folds and wedge structures confirm the clockwise rotation sense of these folds. Much of the Relay Felsite is sheared and contains numerous mesoscopic thrust faults that parallel the mylonitic foliation. Many of the thrust zones form mesoscopic duplexes. In the Baltimore West (Crowley and Reinhardt, 1979) and Baltimore East (Reinhardt and Crowley, 1979) quadrangles, rocks of the Loch Raven thrust sheet, called Jones Falls Schist, are exposed in a window through the Soapstone Branch thrust fault. It is uncertain at this time what the relation of the Soapstone Branch thrust fault to the Baltimore thrust fault is in the area beneath the Coastal Plain to the east of the outcrops along the Patapsco River.

TECTONIC SYNTHESIS

Recent geologic work in the northern Virginia-Maryland Piedmont (Drake, 1995), in part in the Savage and Relay quadrangles, led to the following synthesis. A stack of tectonic motifs was emplaced tectonically onto the Laurentian continental margin early in the Taconic orogeny. The tectonic motif and Laurentian basement and continental margin sequence rocks then were folded recumbently. In the south, rocks both east and west of the Mesoproterozoic core were intruded by numerous plutons that were interpreted to constitute a magmatic arc that had been built on the Laurentian margin (Drake and Fleming, 1994). This interpretation is supported by xenocrystic zircons from the intrusive rocks that yielded Mesoproterozoic ages (J.N. Aleinikoff, U.S. Geological Survey, written commun., 1996, 1997). The intrusive rocks range in age from 481 Ma to 457 Ma, which constitutes early Taconic age as visualized by Drake and others (1989). That time agrees with the first appearance of flysch in the Martinsburg foreland basin in the central Appalachians (Drake and others, 1989).

The Baltimore thrust sheet appears to have been emplaced onto the Loch Raven-Laurel tectonic motif subsequent to the motif's obduction onto the Laurentian margin as it cuts out units, has nearly overrun the motif in areas to the north and east (Crowley, 1976) and does not appear on the west limb of the culmination. If the discrimination diagram (fig. 4), is accepted rocks of the Baltimore thrust sheet were generated within an ensialic basin.

The Soapstone Branch thrust sheet probably was emplaced onto the Baltimore thrust sheet subsequent to its emplacement onto the Loch Raven-Laurel tectonic motif because the Connewingo melange separates the thrust sheets along the Susquehanna River to the northeast (Southwick, 1969; Higgins and Conant, 1986). If the discrimination diagram (fig. 5) is accepted, rocks of the Soapstone Branch thrust sheet were generated within an island arc.

After all the thrust sheets were emplaced, they and the Laurentian basement and continental margin sequences rocks were backfolded into a major east-verging massif. The emplacement of the thrust sheets and recumbent folding was interpreted to be the result of the east-dipping subduction of Laurentia beneath an oceanic sequence (Drake, 1995). This subduction, however, was aborted because of Archidmedic buoyancy leading to subduction flip (Roeder, 1973) and east-verging retrocharriage. This deformation was completed by 368 Ma, the age of the Guilford Granite, which crosscuts the Taconic structures.

REFERENCES CITED

Bowring, S.A., Grotzinger, J.P., Isachsen, C.E., Knoll, A.H., Pelechaty, S.M., and Kolosav, P., 1993, Calibrating rates of Early Cambrian evolution: Science, v. 261, p. 1293-1298.

Bromery, R.W., 1968, Geological interpretation of aeromagnetic and gravity surveys of the northeastern end of the Baltimore-Washington anticlinorium, Harford, Baltimore and part of Carroll County, Maryland: Unpublished Ph.D. dissertation, Johns Hopkins University, Baltimore, Maryland, 124 p.

Cloos, Ernst, and Broedel, C.H., 1940, Geologic map of Howard County and adjacent parts of Montgomery and Baltimore Counties: Maryland Geological Survey, scale 1:62,500.

Crowley, W.P., 1976, The geology of the crystalline rocks near Baltimore and its bearing on the evolution of the eastern Maryland Piedmont: Maryland Geological Survey Report of Investigations 27, 40 p.

Crowley, W.P., and Reinhardt, Juergen, 1979, Geologic map of the Baltimore West quadrangle, Maryland: Maryland Geological Survey, scale 1:24,000.

____1980, Geologic map of the Ellicott City quadrangle, Maryland: Maryland Geological Survey, scale 1:24,000.

Drake, A.A., Jr., 1985a, Tectonic implications of the Indian Run Formation--a newly recognized sedimentary melange in the northern Virginia Piedmont: U.S. Geological Survey Professional Paper 1324, 12 p.

____1985b, Sedimentary melanges of the central Appalachian Piedmont [abs.]: Geological Society of America Abstracts with Programs, v. 17, no. 7, p. 566.

____1995, Tectonic studies in the central Appalachian Piedmont--new findings: Geological Society of America Abstracts with Programs, v. 27, no. 1, p. 41.

____1998, Geologic map of the Kensington quadrangle, Montgomery County, Maryland: U.S. Geological Survey Geologic Quadrangle Map GQ-1774, scale 1:24,000.

____in press, Geologic map of the Clarksville quadrangle, Howard, Montgomery, and Prince Georges Counties, Maryland: U.S. Geological Survey Open-File Report, scale 1:24,000.

Drake, A.A., Jr., and Fleming, A.H., 1994, The Dalecarlia Intrusive Suite and Clarendon Granite in the Potomac Valley, Washington, D.C., Virginia, and Maryland, in Stratigraphic Notes, 1992: U.S. Geological Survey Bulletin 2060, p. 25-33.

Drake, A.A., Jr., Hall, L.M., and Nelson, A.E., 1988, Basement and basement-cover relation map of the Appalachian orogen in the United States: U.S. Geological Survey Miscellaneous Investigations Series Map I-1655, scale 1:1,000,000.

Drake, A.A., Jr., Sinha, A.H., Laird, Jo, and Guy, R.E., 1989, The Taconic orogen, in Hatcher, R.D., Jr., Thomas, W.A., and Viele, G.W., eds., The Appalachian-Ouachita orogen in the United States: Boulder, Colorado, Geological Society of America, v. F-2, p. 101-177.

Fleming, A.H., Drake, A.A., Jr., and McCartan, Lucy, 1994, Geologic map of the Washington West quadrangle, District of Columbia, Montgomery County, Maryland, and Arlington and Fairfax Counties, Virginia: U.S. Geological Survey Geologic Quadrangle Map GQ-1748, scale 1:24,000.

Fleming, A.H., and Drake, A.A., Jr., 1998, Structure age, and tectonic setting of a multiply reactivated shear zone in the Piedmont in Washington, D.C. and vicinity: Southeastern Geology, v. 37, no. 3, p. 115-140.

Hanan, B.B., 1980, The petrology and geochemistry of the Baltimore Mafic Complex, Maryland: Unpublished Ph.D. thesis, Blacksburg, Virginia Polytechnic Institute and State University, 218 p.

Hanan, B.B., and Sinha, A.K., 1989, Petrology and tectonic affinity of the Baltimore mafic complex, Maryland, in Mittwede, S.K., and Stoddard, E.F., eds., Ultramafic rocks of the Appalachian Piedmont: Geological Society of America Special Paper 231, p. 1-18.

Higgins, M.W., 1972, Age, origin, regional relations, and nomenclature of the Glenarm Series, central Appalachian Piedmont: A reinterpretation: Geological Society of America Bulletin, v. 83, p. 989-1026.

____1977, The Baltimore Complex, Maryland and Pennsylvania, in Sohl, N.F. and Wright, W.B., Changes in stratigraphic nomenclature by the U.S. Geological Survey, 1976: U.S. Geological Survey Bulletin 1435-A, p. A127-A129.

Higgins, M.W., and Conant, L.C., 1986, Geologic map of Cecil County: Maryland Geological Survey, scale 1:62,500.

Hobbs, W.H., 1889, On the paragenesis of allanite and epidote as rock-forming minerals: American Journal of Science, 3rd series, v. 38, p. 223-228.

Hopson, C.A., 1964, The crystalline rocks of Howard and Montgomery Counties, in The geology of Howard and Montgomery Counties: Baltimore, Maryland Geological Survey, p. 27-215.

Horton, J.W., Jr., Aleinikoff, J.N., Drake, A.A., Jr., and Fanning, M.C., 1998, Significance of Middle to Late Ordovician volcanic-arc rocks in the central Appalachians: Geological Society of America Abstracts with Programs, v. 30, p. A125.

Keyes, C.R., 1893, Epidote as a primary component of eruptive rocks: Geological Society of America Bulletin, v. 4, p. 305-312.

Knopf, E.B., and Jonas, A.I., 1925, Map of Baltimore County and Baltimore City showing the geological formations: Maryland Geological Survey, scale 1:62,500.

Knopf, E.B., and Jonas, A.I., 1929, Geology of the crystalline rocks Baltimore County, in Baltimore County: Maryland Geological Survey, p. 97-129.

Landing, Ed, 1994, Precambrian-Cambrian boundary global stratotype ratified and a new perspective of Cambrian time: Geology, v. 22, p. 179-182.

LeBas, M.J., LeMaitre, R.W., Streckeisen, A., and Zanettin, B., 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram: Journal of Petrology, v. 27, p. 745-750.

O'Connor, J.T., 1965, A classification for quartz-rich igneous rocks based on feldspar ratios: U.S. Geological Survey Professional Paper 525-B, p. B79-B84.

Pitcher, W.S., 1982, Granite type and tectonic environment, in Hsü, K.J., ed., Mountain Building Processes: New York, Academic Press, p. 19-40.

Plumb, K.A., 1991, New Precambrian time scale: Episodes, v. 14, no. 2, p. 139-140.

Rankin, D.W., Drake, A.A., Jr., Glover, L., III, Goldsmith, Richard, Hall, L.M., Murray, D.P., Ratcliffe, N.M., Read, J.F., Secor, D.T., Jr., and Stanley, R.S., 1989, Pre-orogenic terranes, in Hatcher, R.D., Jr., Thomas, W.A., and Viele, G.W., eds., The Appalachian orogen in the United States: Boulder, Colorado, Geological Society of America, The geology of North America, v. F-2, p. 7-100.

Rankin, D.W., Drake, A.A., Jr., and Ratcliffe, N.M., 1993, Proterozoic North American (Laurentian) rocks of the Appalachian orogen, in Reed, J.C., Jr., Bickford, M.E., Houston, R.S., Link, P.K., Rankin, D.W., Sims, P.K., and Van Schmus, W.R., eds.: Precambrian: Conterminous U.S., Boulder, Colorado, Geological society of America, The Geology of North America, v. C-2, p. 378-422.

Reinhardt, Juergen and Crowley, W.P., 1979, Geologic map of the Baltimore East quadrangle, Maryland: Maryland Geological Survey, scale 1:24,000.

Roeder, D.H., 1973, Subduction and orogeny: Journal of Geophysical Research, v. 78, no. 23, p. 5005-5024.

Roen, J.N., and Drake, A.A., Jr., in press, Geologic map of the Sykesville quadrangle, Howard, Carroll, and Baltimore Counties, Maryland: U.S. Geological Survey Open-File Report, scale 1:24,000.

Shaw, H.F., and Wasserburg, G.J., 1984, Isotopic constraints on the origin of Appalachian mafic complexes: American Journal of Science, v. 284, p. 319-349.

Sinha, A.K., Hannan, B.B., and Wayne, D.M., 1997, Igneous and metamorphic U-Pb ages from the Baltimore Mafic Complex, Maryland Piedmont, in Sinha, A.K., Whalen, J.B., and Hogan, J.P., eds., The nature of magmatism in the Appalachian orogen: Boulder, Colorado, Geological Society of America Memoir 191, p. 275-286.

Sinha, A.K., Hund, E.A., and Hogan, J.P., 1989, Paleozoic accretionary history of the North American plate margin (central and southern Appalachians): constraints from the age, origin, and distribution of granitic rocks, in Hillhouse, J.W., ed., Deep structure and past kinematics of accreted terranes: American Geophysical Union Geophysical Monograph 50, p. 219-238.

Southwick, D.C., 1969, Crystalline rocks, in Geology of Harford County, Maryland: Maryland Geological Survey, p. 1-76.

Southwick, D.C., and Fisher, G.W., 1967, Revision of stratigraphic nomenclature of the Glenarm Series in Maryland: Maryland Geological Survey Report of Investigations, no. 6, 19 p.

Streckeisen, Albert, 1976, To each plutonic rock its proper name: Earth Science Reviews, v. 12, p. 1-33.

Williams, G.H., 1895, General relations of the granitic rocks in the middle Atlantic Piedmont Plateau: U.S. Geological Survey 15th Annual Report, p. 657-684.

Zen, E-an and Hammarstrom, J.M., 1984, Magmatic epidote and its petrologic significance: Geology, v. 12, p. 515-518.

Table 1 -- Chemical analyses and C.I.P.W. norms of some rocks from the Savage and Relay quadrangles

Sample	1	2	3	4	5	6	7
Field No.	R-G-2-10	R-G-2-11	R-G-2-13	SA-A-2-6	SA-H-6-3	R-G-2-9	SA-H-6-1
			Major oxide composition (weight percent)				
SiO_2	50.6	66.8	46.9	46.3	49.1	78.8	73.5
Al_2O_3	16.5	14.0	15.1	16.4	13.3	12.1	14.3
Fe_2O_3	2.6	2.1	3.9	2.4	2.4	0.3	0.2
FeO	5.7	3.9	11.7	9.3	5.9	0.5	0.1
MgO	8.5	1.9	4.8	8.1	8.4	0.5	0.1
CaO	11.3	5.1	9.5	12.8	10.3	0.2	0.1
Na_2O	2.4	3.4	2.3	1.3	2.1	6.5	1.8
K_2O	0.2	0.4	0.2	0.1	3.1	0.09	9.6
H_2O+	1.4	0.7	1.6	1.5	1.8	0.2	0.06
H_2O-	0.1	0.1	0.1	0.1	0.4	0.03	0.1
TiO_2	0.5	0.6	2.5	1.0	1.4	0.07	0.03
P_2O_5	0.05	0.1	0.5	0.1	0.6	0.05	0.05
MnO	0.2	0.1	0.3	0.2	0.1	0.01	0.1
CO_2	0.10	0.5	0.01	0.1	0.6	0.1	0.01
Total	100.15	99.7	99.7	99.7	99.5	99.4	99.9
			CIPW norms (weight percent) Based on analyses recalculated				
Q	0.7	30.6	3.0	--	--	39.9	26.1
C	--	--	--	--	--	1.2	1.0
or	1.3	2.6	1.4	0.4	18.9	0.5	57.0
ab	20.2	29.6	20.1	11.1	18.4	55.6	14.9
an	34.3	21.7	30.6	39.5	18.10	0.09	0.03
di	17.3	2.5	10.2	18.3	21.	--	--
hy	21.1	8.3	22.2	19.2	4.1	1.7	0.4
to	--	--	--	2.5	7.5	--	--
ta	--	--	--	1.9	2.6	--	--
mt	3.8	3.0	5.8	3.5	3.6	0.4	0.4
hm	--	--	--	--	--	--	--
il	0.9	1.2	4.8	2.0	2.8	0.1	0.06
ap	0.1	0.2	1.9	0.3	1.5	0.1	0.1
cc	0.2	0.1	0.02	0.3	1.4	0.3	0.02
Total	99.9	99.8	100.02	99.0	100.1	99.8	100.0

Table 1 (cont.)

			Trace-element abundances Large cations[2]				
Rb	4	18	9.8	8	85	1.3	736
Ba	38	205	48	30	1200	30	80
Sr	116	140	166	130	1000	42	23
			High valence-cations				
Th[4]	0.83	5.42	0.35	0.14	8.1	18.0	3.81
Zr[2]	0.29	200	32	16	240	130	24
Hf[4]	0.78	5.61	0.73	0.57	6.22	6.11	1.71
Nb[3]	10	10	10	10		21	23
Ta	0.11	0.78	0.3	0.1	0.65	2.6	2.1
			Metals[4]				
Cr	113	11	2.7	72.3	252	1.2	1.1
Co	38.9	15.1	30.9	47.0	38.6	0.31	0.35
Ni	56.0	10	12	530	140	10	2.0
Cu	48	56	62	46	140	10	3.0
Sc	37.2	20	45.1	47.7	31.7	1.34	0.34
Zn	57	46	130	91	61	10	3.7
As	0.6	0.6	1.1	0.8	0.7	0.7	0.48
Mo	--	--	--	--	--	--	2
			Rare-earth elements				
La[4]	3.3	16.3	6.2	3.1	69.1	2.7	2.7
Ce[4]	6.4	34.5	15	8.2	129	7.4	4.6
Nd[4]	6.5	17	15	6.7	57	3.8	2.1
Sm[4]	1.38	5.14	4.2	2.4	11	1.99	1.17
Eu[4]	0.47	1.17	1.78	0.96	2.32	0.2	0.057
Tb[4]	0.31	0.98	0.81	0.54	0.83	0.6850	0.29
Yb[4]	1.3	4.4	2.4	2.0	1.8	6.3	0.32
Lu[4]	.17	0.635	0.35	0.3	0.25	0.9440	0.033
Y[2]	16	38	26	20	22	34.0	9

[1]XRF Analyses by D.F. Siems and J.E. Taggart, Jr. FeO, CO2, H2O+, H2O- analyses by J.W. Marinenko
[2]Analyses by J.K. Evans
[3]Analyses by M.W. Doughten
[4]Analysis of sample 4 by J.N. Grossman. All others by J.S. Mee

Table 1 (cont.)

Description of Samples

1. Amphibolite of Druid Hill Amphibolite from outcrop of interbedded amphibolite and metafelsite on southwest bank of the Patapsco River about 4,400 feet west-northwest of Interstate I-95 bridge in the Relay, Md. 7.5-minute quadrangle at lat. 39°13'53"N. and long. 76°43'24"W.
2. Amphibolite of Druid Hill Amphibolite from outcrop of fine-grained amphibolite that contains some interlayered metafelsite on southwest bank of the Patapsco River about 700 ft west-northwest of sample 1 in the Relay, Md. 7.5-minute quadrangle at lat. 39°13'35"N. and long. 76°43'34"W.
3. Amphibolite of Druid Hill Amphibolite from outcrop on southwest band of Patapsco River about 850 ft west-northwest of sample 2 in the Relay, Md. 7.5-minute quadrangle at lat. 39°13'41"N. and long. 76°43'43"W.
4. Coarse-grained amphibolite of Mount Washington Amphibolite from outcrop in Hammond Branch about 6,750 ft N.86°E. from intersection of Interstate 95 and Route 198, Savage, Md. 7.5-minute quadrangle at lat. 39°07'48"N. and 76°50'20"W.
5. Coarse-grained biotite-hornblende metagabbro of Mount Washington Amphibolite from outcrop on west bank of Patapsco River at a right angle bend about 1,450 ft south of north border of Savage, Md. 7.5-minute quadrangle at lat. 39°14'48"N. and long. 76°45'54"W.
6. Medium-coarse grained Relay Felsite from outcrops on southwest bank of Patapsco River about 1,200 ft. west-northwest of Interstate 95 bridge in Relay, Md. 7.5-minute quadrangle at lat. 39°13'32"N. and long. 76°43'21"W. Rock probably is a trondhjemite intrusion.
7. Muscovite-albite-quartz-microcline pegmatite from outcrop on west bank of Patapsco River about 500 ft south of the north border of the Savage, Md. 7.5-minute quadrangle at lat. 39°14'56"N. and 76°45'56"W.

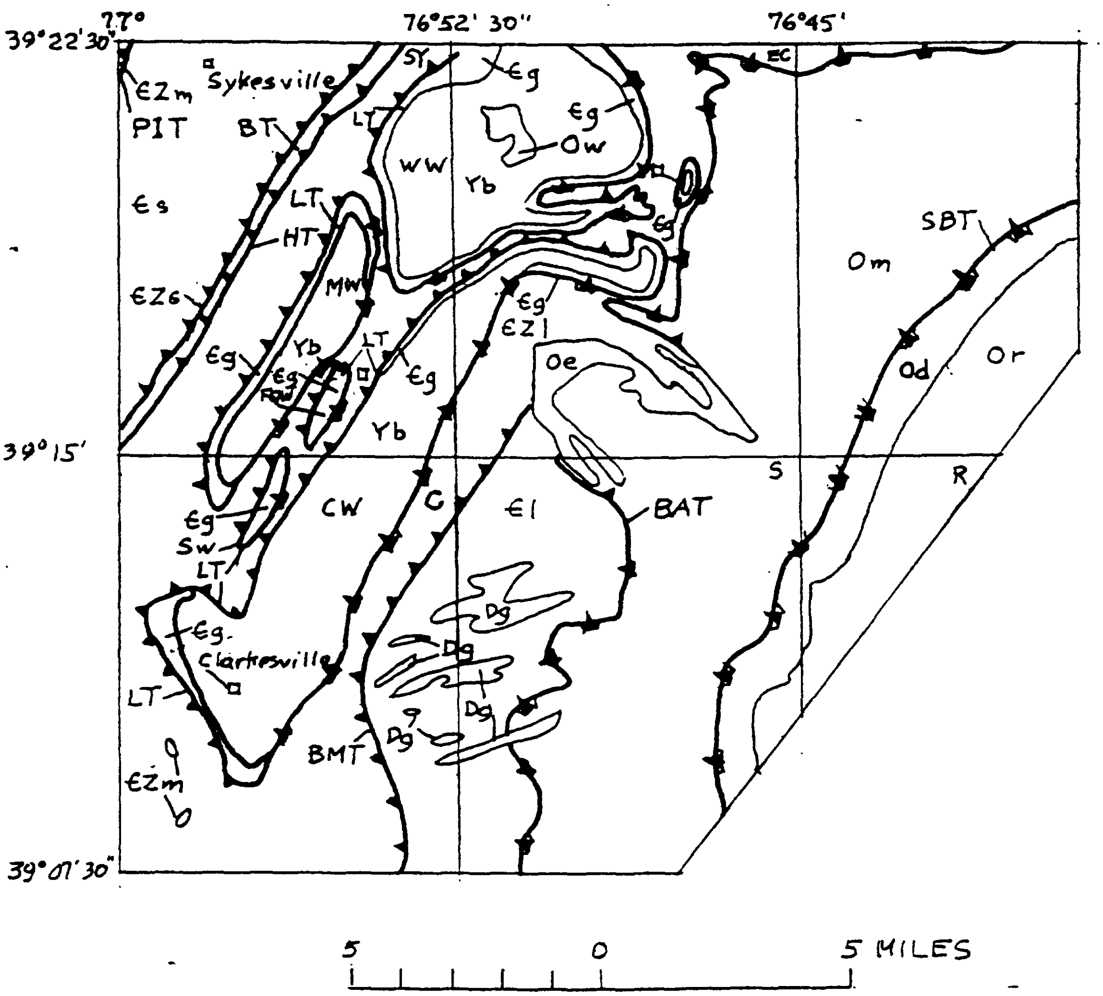


Figure 1. Highly generalized geologic map of the east-central Maryland Piedmont showing the southern part of the Baltimore culmination.

EXPLANATION OF SYMBOLS

Intrusive Rocks

Dg	Guilford Granite (Late Devonian)
Ow	Woodstock Granite (Late Ordovician(?))
Oe	Ellicott City Granodiorite (Late Ordovician)

Obducted Rocks

Ꞓs	Sykesville Formation (Cambrian)
Ꞓl	Laurel Formation (Cambrian)
ꞒZl	Rocks of the Loch Raven thrust sheet, undivided (Lower Cambrian and (or) Neoproterozoic)–Includes Oella Formation, Loch Raven Schist, and Northwest Branch Formation
ꞒZs	Soldiers Delight Ultramafite (Lower Cambrian and (or) Neoproterozoic)
ꞒZm	Mather Gorge Formation (Lower Cambrian and (or) Neoproterozoic)
ꞒZu	Ultramafic rocks (Lower Cambrian and (or) Neoproterozoic)

Laurentian basement and continental margin deposits

Ꞓg	Glenarm Group (Lower Cambrian)–Includes Rush Brook Formation, Cockeysville Marble, and Setters Formation
Yb	Baltimore Gneiss (Mesoproterozoic)

Magmatic Arc Rocks

Or	Relay Felsite (Middle Ordovician)
Od	Druid Hill Amphibolite (Middle Ordovician)
Om	Mount Washington Amphibolite (Lower Ordovician)
	Contact
	Thrust fault–Sawteeth on upper plate. BT, Brinklow thrust fault; BAT, Baltimore thrust fault; BMT, Burnt Mills thrust fault; HT, Henryton thrust fault; LT, Loch Raven thrust fault; PIT, Pleasant Grove fault; SBT, Soapstone Branch thrust fault
	Overturned thrust fault

Quadrangles

SY	Sykesville (Roen and Drake, in press)
E	Ellicott City (modified from Crowley and Reinhardt, 1980)
BW	Baltimore West (modified from Crowley and Reinhardt, 1979)
C	Clarksville (A.A. Drake, Jr., unpub. data, 1993)
S	Savage (this report)

R	Relay (this report)			
		Tectonic Windows		
CW	Clarksville		MW	Mayfield
DW	Dogwood		SW	Shepherds Lane
FQW	Folly Quarter		WW	Woodstock

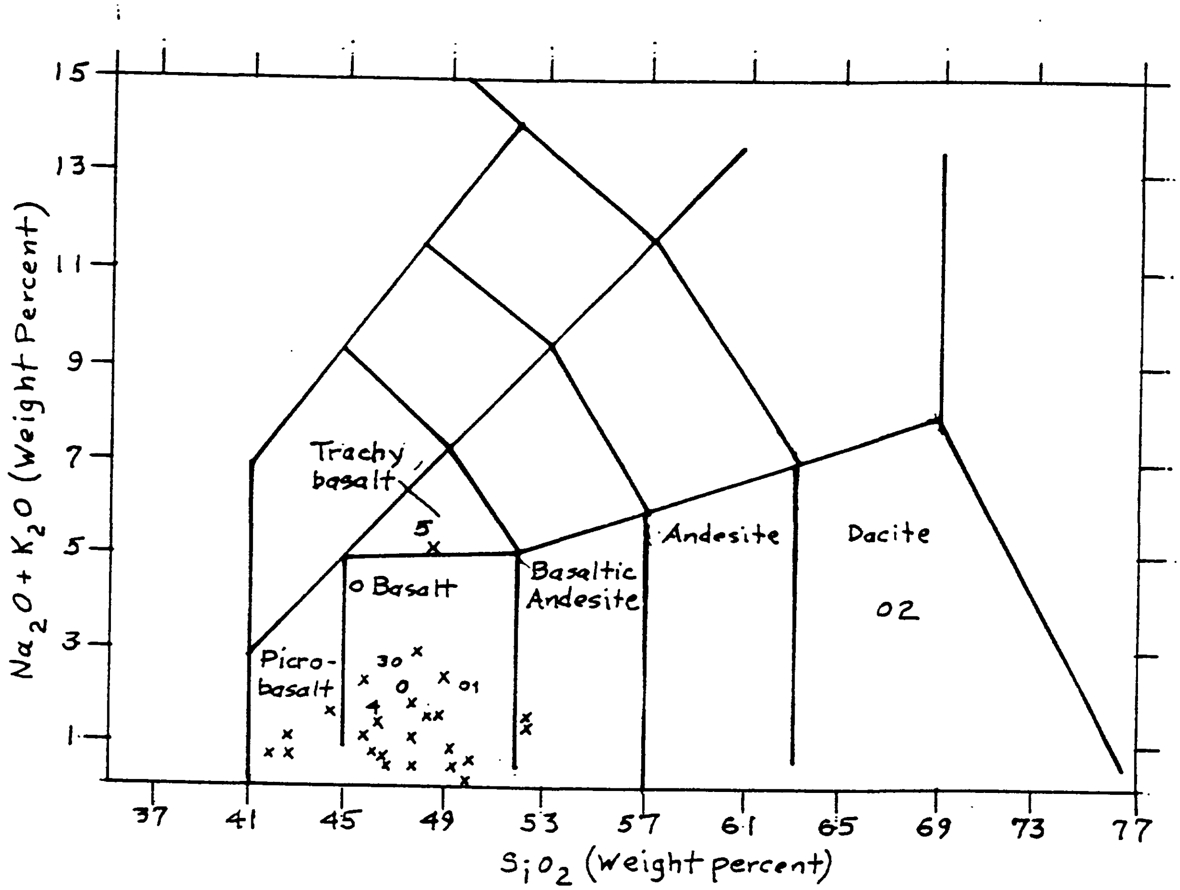


Figure 2. Total alkali-silica (TAS) plot (LeBas and others, 1986) of Druid Hill Amphibolite, o; numbered samples from this study, others from Hanan (1980). Mount Washington Amphibolite, x; numbered samples from this study, others from Hanan (1980).

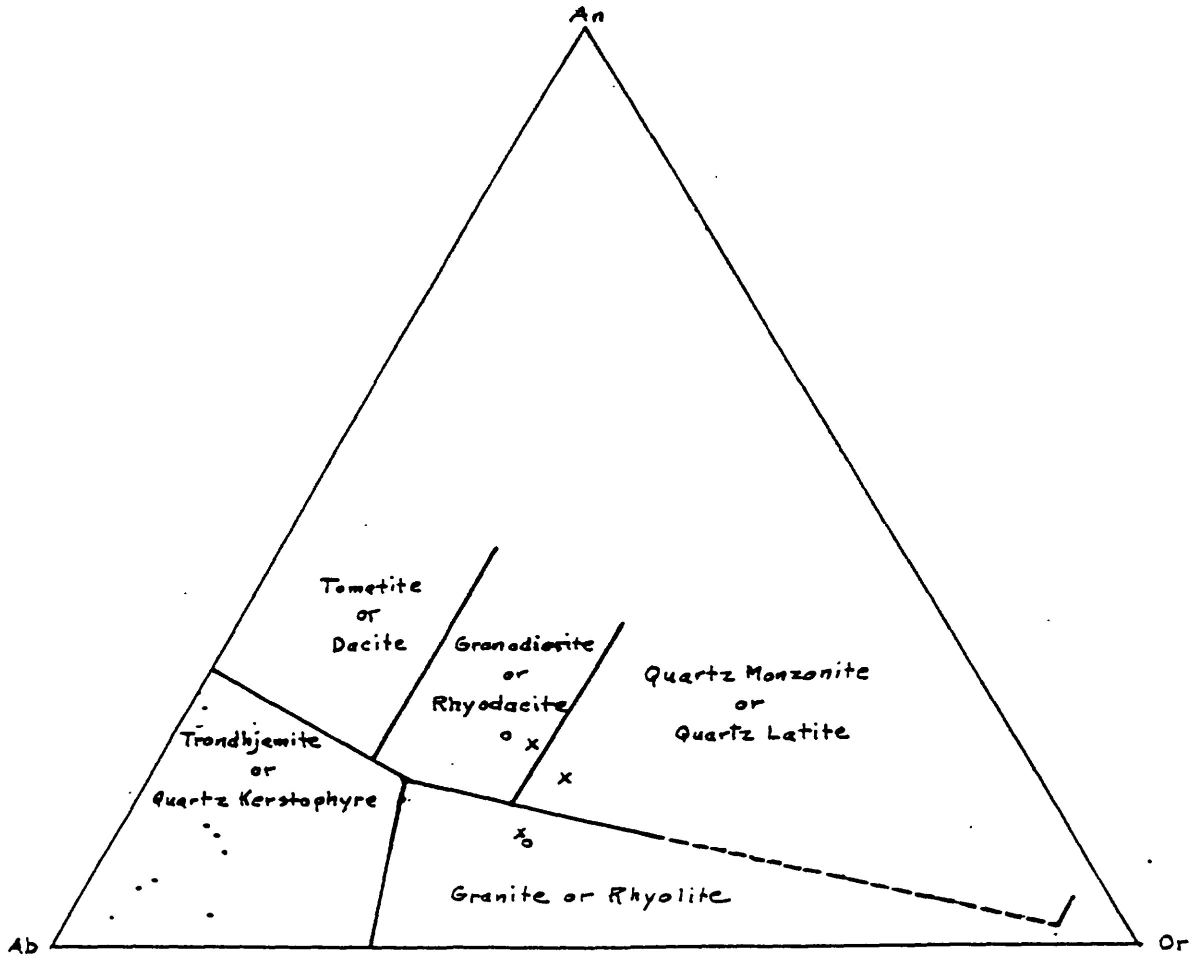


Figure 3. Normative feldspar plot (O'Connor, 1965) for some rocks of the Relay felsite, ●; Guilford Granite, x; and Ellicott City Granodiorite, ○. Data from this study, Roen and Drake (in press), Higgins (1972), Hopson (1964), and Williams (1895).

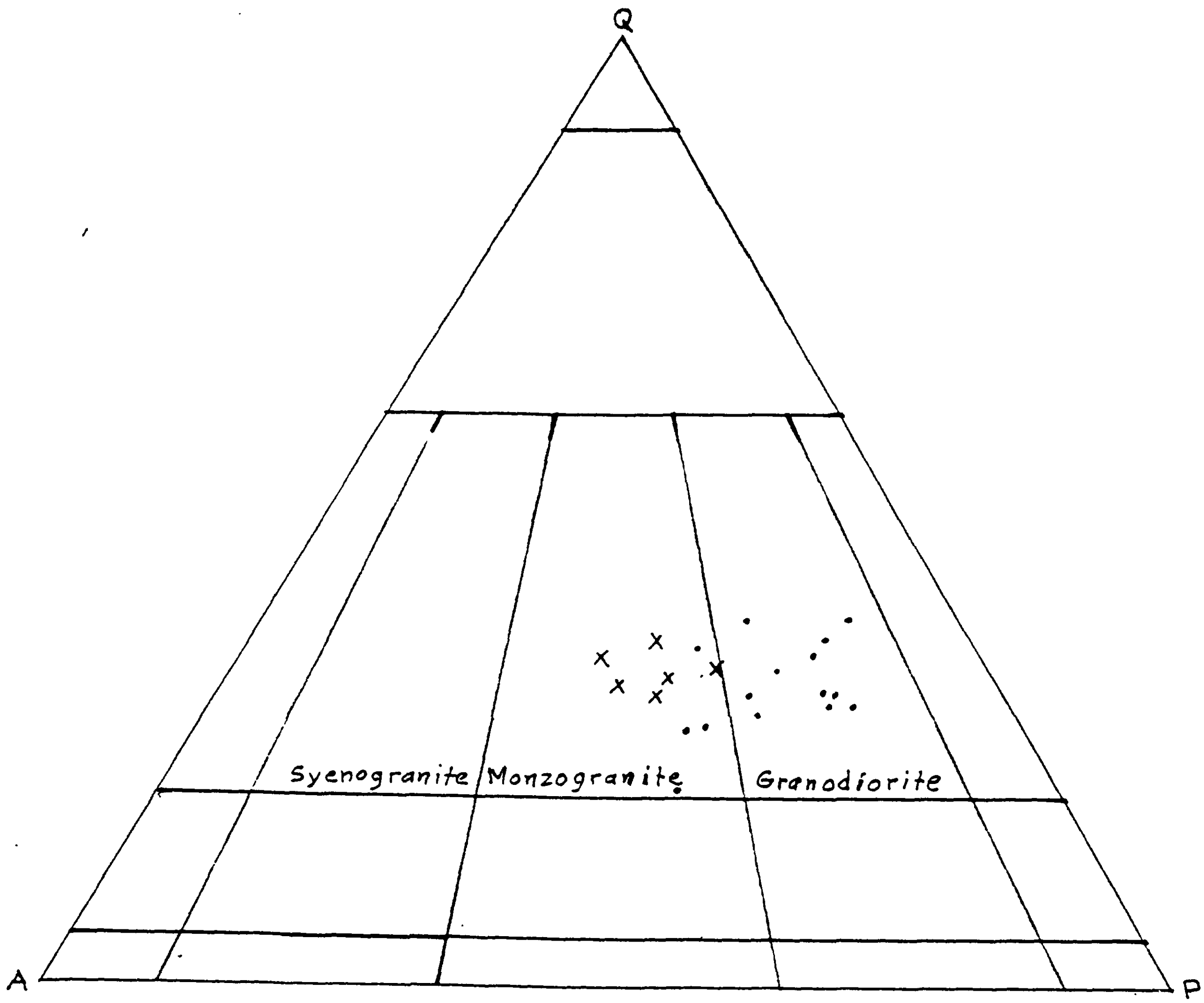


Figure 4. Q-A-P plot (Streckeisen, 1976) plot of Ellicott City Granodiorite, ●, and Guilford Granite, x. Data from this study and Hopson (1964).

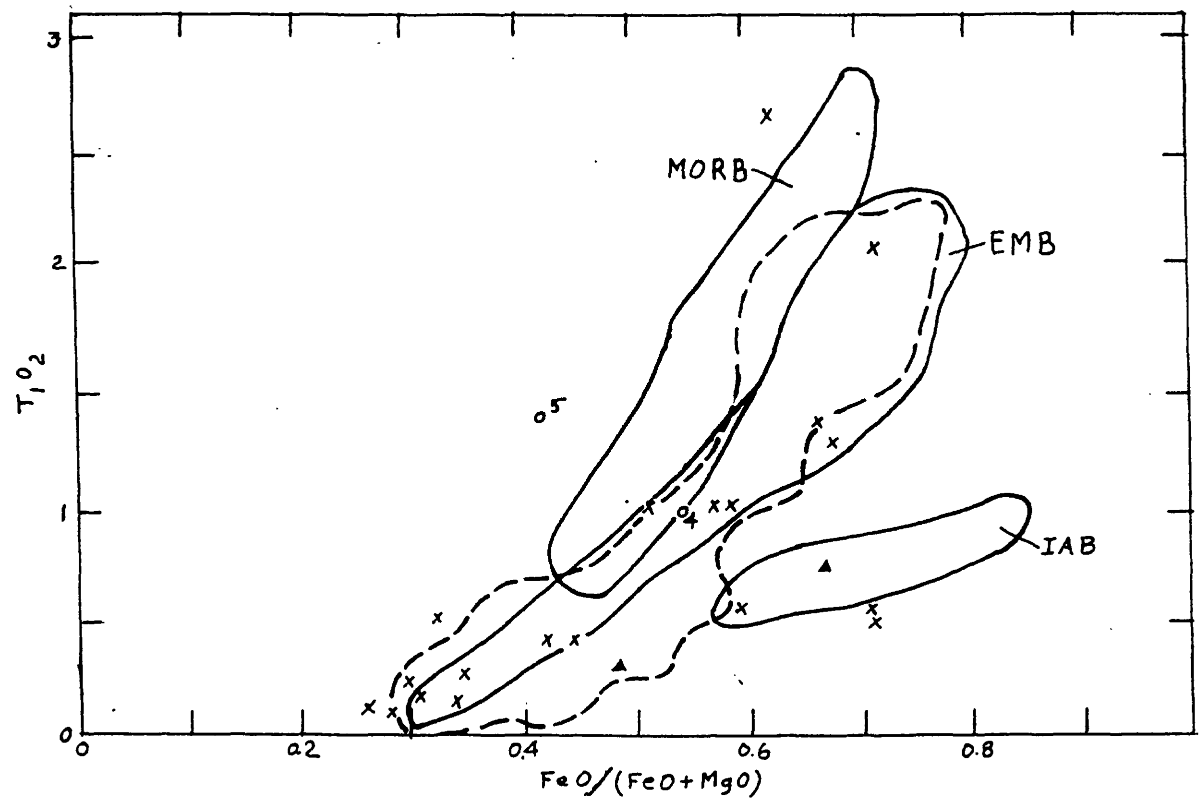


Figure 5. Plot of TiO2 against (FeO/FeO+MgO) comparing Mount Washington Amphibolite samples 8 and 9, ○, presented herein with those reported by Hanan (1980), x, as well as samples of Raspburg Amphibolite, ▲, Hanan (1980). The fields for spreading center basalts (MORB), ensialic marginal basin basalts (EMB), and island arc basalts (IAB) after Hannan and Sinha (1989). The dashed field is that of metagabbro of the Baltimore and State Line Complexes (Hannan and Sinha, 1989).

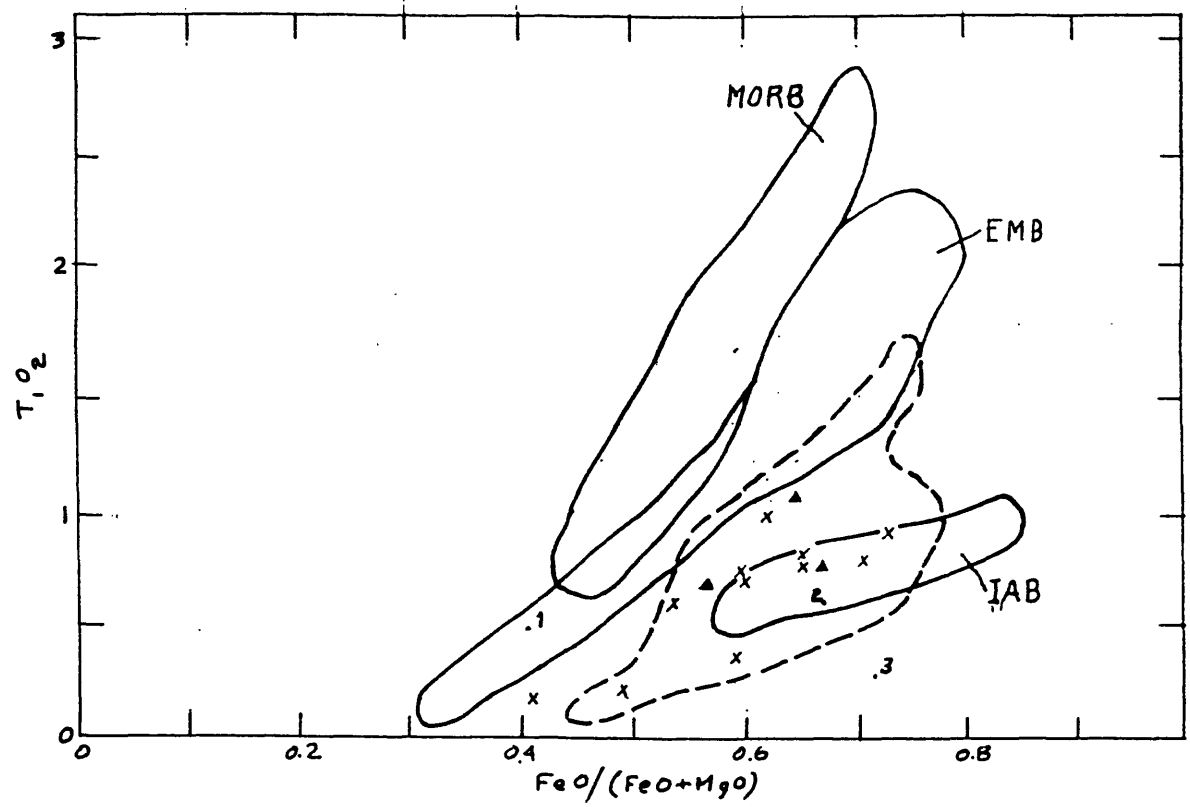
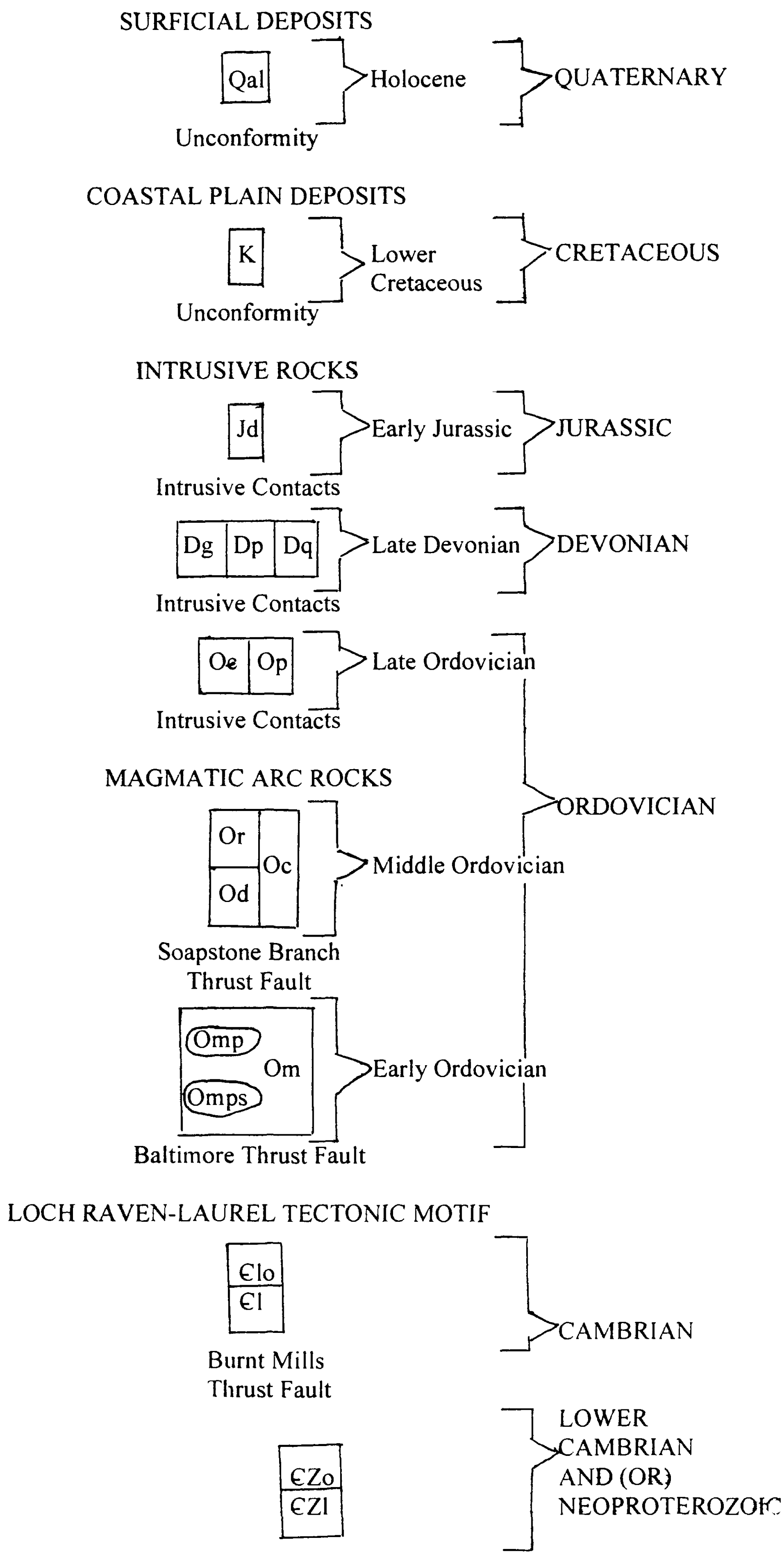


Figure 6. Plot of TiO2 against FeO/FeO+MgO comparing samples 1-3, •, presented herein with amphibolites of the Bradshaw Amphibolite, x, (Hanan, 1980), and James Run Formation, ▲ (Southwick, 1969). The fields for spreading center basalts (MORB), ensialic marginal basin basalts (EMB), and Island Arc basalts (IAB) after Hanan and Sinha (1989). The dashed field is that of volcanic amphibolites of the Baltimore and State Line Complexes (Hanan and Sinha, 1989).

CORRELATION OF MAP UNITS[4]



DESCRIPTION OF MAP UNITS[1]

SURFICIAL DEPOSITS

Qal — Alluvium (Holocene)--Sand, silt, gravel, and clay in lensoid layers underlying sinuous floodplains along most streams. Sediments consist of yellowish-brown, fairly well bedded, poorly to moderately well-sorted, graded sand and silt deposits with gravel commonly filling scours at the base of upward-fining sequences. Consists of micaceous silts and sands, and quartz and crystalline rock pebbles, cobbles, and boulders

COASTAL PLAIN DEPOSITS

K — Cretaceous rocks undifferentiated--Variegated gravel, sand, silt, and clay. Unconformably overlies crystalline Piedmont rocks

INTRUSIVE ROCKS

Jd — Diabase (Early Jurassic)--Medium- to dark-gray, fine-grained, largely equigranular diabase

Dg — Guilford Granite (Cloos and Broedel, 1940) (Late Devonian)--Light-gray, medium- to fine-grained, exceptionally homogeneous monzogranite. About equal parts of microcline, plagioclase, and quartz constitute about 90 percent of the rock. Remainder consists of equal amounts of biotite and muscovite and minor amounts of apatite, garnet, clinozoisite, zircon, and magnetite. Contains dikes and thin stringers of pegmatite and, at places, aplite that fill early formed joints or constitute ill-defined masses. The pegmatite has a nearly ideal granite composition, suggesting that it formed from residual Guilford magma. At places, the Guilford has a flow foliation, but neither a tectonic foliation nor lineation. Zircons from the Guilford have a SHRIMP II age of 368±4 Ma (J.N. Aleinikoff, U.S. Geological Survey, written commun., 1997). This age is the weighted average of 16 spot analyses on 16 grains. Two other grains had ages of about 1.2 and 1.4 Ga showing that the Guilford magma had passed through Mesoproterozoic rocks

Dp — Pegmatite (Late Devonian)--Light-gray to pinkish-gray pegmatite petrographically identical to that associated with Guilford Granite

Dq — Quartz body (Late Devonian)--Quartz probably related to Guilford magmatism

Oe — Ellicott City Granodiorite (Late Ordovician) (Knopf and Jonas, 1929)--Pinkish-gray, medium- to coarse-grained biotite granodiorite and lesser monzogranite. Rock contains primary epidote. Unit has a well-developed flow foliation where not sheared. Monzogranite appears to be restricted to the interior parts of Ellicott City bodies. The granodiorite has an upper intercept U-Pb age of 458 Ma (Sinha and others, 1989). A regression of Sinha and others (1989) data, however, shows that the 458 Ma age has a MSWD of 50 (J.N. Aleinikoff, U.S. Geological Survey, written commun., 1996)

Op — Pegmatite (Late Ordovician)--Light-gray to pinkish-gray muscovite-microcline-albite-quartz pegmatite. Locally contains minor amounts of biotite, tourmaline, allanite, monzonite, magnetite, and pyrite. Most of the microcline is microperthite. The pegmatite is probably related to the Ellicott City Granodiorite

MAGMATIC ARC ROCKS

Or — Relay Felsite (Middle Ordovician) (Knopf and Jonas, 1929; Drake, 1998)--Well-foliated, fine- to medium-grained, grayish-orange-pink plagioclase-quartz-biotite felsite that at places contain minor amounts of chlorite, epidote, muscovite, and garnet. Some of the rock is layered, but other parts are more massive and coarser grained suggesting that the unit consists of both metamorphosed quartz-keratophyre and subvolcanic trondhjemite. Much of the rock has been sheared and silicified. Grades down into Druid Hill amphibolite, the contact being placed above the highest amphibolite layer. Apparently grades upward and laterally into Carroll Gneiss. The Relay has a single crystal SHRIMP II U-Pb age of 461±5 Ma (weighted average of 13 grains, MSWD=1.1) (Horton and others, 1998)

Od — Druid Hill Amphibolite (Middle Ordovician) (Crowley, 1976; Drake, 1998)--Dark-green to black, fine- to medium-grained, well-foliated, layered amphibolite. Contains interlayered felsite identical to the Relay Felsite. Layers range from a few inches to a few feet in thickness. Grades northeastward into Carroll Gneiss (Crowley, 1976)

Oc — Carroll Gneiss (Middle Ordovician) (Crowley, 1976) (Shown in section only)--Fine- to medium-grained oligoclase-quartz-biotite gneiss and granofels that at places contains muscovite and (or) magnetite. The felsic rock is interlayered with subordinate amphibolite. Rock layers range from an inch to more than 20 feet in thickness. Unit is a facies equivalent of both the Druid Hill Amphibolite (Od) and Relay Felsite (Or). The Carroll has a single crystal SHRIMP U-Pb age of 464±5 Ma (weighted average of 16 grains, MSWD=0.732) (Horton and others, 1998)

Omp, Omps, Om — Mount Washington Amphibolite (Lower(?) Ordovician) (Crowley, 1976)--Fine- to medium-grained, dark-green to black amphibolite and minor pyroxene amphibolite. At places, contains thin interlayers of clinopyroxenite. Contains one mappable body of steatized pyroxenite (Omps). Commonly contains thin veins and two mappable bodies of plagiogranite (Omp). Most of the amphibolite is well foliated and recrystallized, but at places, relict gabbroic textures have been preserved. Shaw and Wasserburg (1984) published a model Nd-Sm isochron age of 490±20 Ma for rocks equivalent to the Mount Washington, which they interpreted to be an igneous crystallization age, but noted that it might record a metamorphic event. More recently, Sinha and others (1997) obtained an U-Pb upper intercept age of 489±7 (MSWD=0.75) for zircons from the Mount Washington Amphibolite. The Mount Washington is here considered to be Lower Ordovician in age

LOCH RAVEN-LAUREL TECTONIC MOTIF

Ꞓlo, Ꞓl — Laurel Formation (Cambrian) (Hopson, 1964)--Light- to medium-gray, medium- to coarse-grained, moderately to well-foliated sedimentary melange consisting of a quartzofeldspathic matrix that contains quartz "eyes" and fragments of meta-arenite (◆) and schist (□). Typically spangled with very large muscovite porphyroblasts. Upper part of unit (Ꞓlo) contains more than 50 percent olistoliths of metaarenite and schist. Thickness is indeterminate

ꞒZo — Oella Formation (Lower Cambrian and (or) Neoproterozoic) (Crowley, 1976)--Light-gray, medium-grained, well-bedded quartz-plagioclase-biotite meta-arenite and lesser quartzite and calc-silicate rock. Beds range from 5 in to 4 ft in thickness. Contains interbedded schist similar to the underlying Loch Raven Schist. Both the meta-arenite and quartzite have a good schistosity marked by biotite flakes. Thickness is indeterminate

ЄZl Loch Raven Schist (Lower Cambrian and (or) Neoproterozoic) (Crowley, 1976)--Thin-bedded, medium-gray, lustrous, medium- to coarse-grained quartz-muscovite-biotite-plagioclase schist that at places contains garnet and (or) staurolite and (or) kyanite. Contains some interbedded semipelitic schist and meta-arenite similar to the overlying Oella Formation (ЄZo) into which it grades. Thickness is indeterminate

[1]The term "Neoproterozoic" follows the usage of Plumb (1991) and applies to rocks ranging in age from 1000 Ma to ~544 Ma (base of Cambrian following Bowring and others, 1993; and Landing, 1994)

EXPLANATION OF MAP SYMBOLS

Contact--Dotted where concealed

Distribution and concentration of structural symbols indicates degree of reliability

Faults--Dotted where concealed

Thrust--Sawteeth on upper plate

Overturned thrust--Sawteeth in direction of dip; bar on tectonically higher plate

Small fault seen in outcrop showing dip

FOLDS
(Dotted where concealed)

Fold phases are designated from oldest to youngest: PA, Patapsco; MP, Middle Patuxent; CL, Columbia

Antiform--Showing crest line and direction of plunge

Overturned antiform--Showing trace of axial surface, direction of dip of limbs, and direction of plunge

Synform--Showing trace of trough line and direction of plunge

Overturned synform--Showing trace of axial surface, direction of dip of limbs, and direction of plunge

MINOR FOLDS
(F indicates fold of foliation)

15 Minor asymmetric fold--Showing bearing and plunge of axis, and rotation sense viewed down plunge

10 Minor M-shaped fold--Showing bearing and plunge of axis

20 Minor anticline--Showing bearing and plunge of axis

PLANAR FEATURES
(Symbols intersect at point of observations. May be combined with linear features)

65 Layering

Strike and dip of crystallization foliation

65 Inclined

Vertical

75 Mylonitic foliation

Flow foliation

Inclined

Vertical

Shear band foliation--Showing relative movement

Schistosity

Spaced schistosity

Strike and dip of joints

Inclined

Vertical

LINEAR FEATURES

(May be combined with planar features)

Mineral lineation

Elongation lineation

OTHER FEATURES

Abandoned quarry--Building stone, bs; Crushed stone, cs

Location of chemically analysed sample

Location of isotopically dated sample

Float