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The Culpeper Basin[1]

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INTRODUCTION

The Culpeper basin in northern Virginia, a north-northeast-trending faulted half graben, is located at the western margin of the Piedmont province adjacent to the east front of the Blue Ridge province. The basin forms part of a belt of faulted basins, all of Mesozoic age (Triassic and Jurassic), that lie along the east coast of North America from Georgia to Nova Scotia. About 12.5 miles wide, the Culpeper basin extends for about 90 miles from the Rapidan River (boundary line between Orange and Culpeper Counties) north of the Potomac River to near Frederick, Maryland (Wise and Johnson, 1980).

The basin contains Mesozoic age igneous and sedimentary rocks. The sedimentary rocks make-up a distinctive group of clastic rocks that range from Upper Triassic to Lower Jurassic age (Carnian-Hettangian stages). The Triassic age sedimentary rocks are mainly non-marine sandstone and siltstone (red beds) with some conglomerate. The Jurassic units are similar to the Triassic but contain basalt flows in the west-central part of the basin and lacustrine gray and black shales. The sedimentary rocks have been intruded and metamorphosed by emplacement of dikes, sills, and stocks of tholeiitic diabase.

The basin has extensive resources of rock materials suitable for crushed stone, aggregate, dimension stone, flagstone, and building stone. Raw material exists for brick, tile, and other structural clay products. Some minor iron and copper mining has occurred, but no economic deposits are currently known to exist. Barite has also been mined.

[1] This paper was an unpublished manuscript submitted as a class assignment at Radford University. The author updated the original paper incorporating the work of Weems and Olsen (1997).

GENERAL GEOLOGY

The Culpeper basin in Virginia is one basin in a belt of northeast-trending Mesozoic age rift basins in eastern North America (Figure 1). In Virginia the basin is about 12.5 miles wide and extends for 90 miles from the Rapidan River on the south to the Potomac River on the north. The basin continues north from the Potomac River to an area just south of Frederick, Maryland.

The Culpeper basin is part of the western segment of several Mesozoic age basins in Virginia. The western belt of basins in Virginia is comprised of, in addition to the Culpeper, the Barboursville, Scottsville, and Danville basins. The central segment is composed of the Farmville, Briery Creek, Roanoke Creek, Randolph, and Scottsburg basins. The eastern belt is made up of the Taylorsville, Richmond, Deep Run, Flat Branch, Blackheath, Union, and Stonehenge basins (Figure 2) (Johnson, Wilkes, and Gwin, 1985). Several basins are buried under the Coastal Plain sediments onshore and offshore.

The basins were formed in crystalline rocks of the Piedmont Province and lie in "staggered" belts of half-grabens of Early Mesozoic age that extend along eastern North America from Georgia to Nova Scotia (Johnson, Wiener, and Conley, 1985). All of the basins are bounded on the west by faults.

The sedimentary and igneous rocks in the Culpeper basin belong to the Chatham and Meriden Groups that range in age from Late Triassic to Early Jurassic (Weems and Olsen, 1997). The Triassic-age sedimentary rocks are mainly non-marine sandstone and siltstone ("red beds") and minor conglomerate (Wise and Johnson, 1980). The Jurassic rocks also include "red beds", but the sequence is characterized by coarse fluvial conglomerates, black and gray lacustrine shale, siltstone, and sandstone, and interbedded basalt flows in the west-central part of the basin (Leavy, Grosz, and Johnson, 1982). The sedimentary units in the Culpeper basin are intruded by dikes, sills, and stocks of tholeiitic diabase of Early Jurassic age.

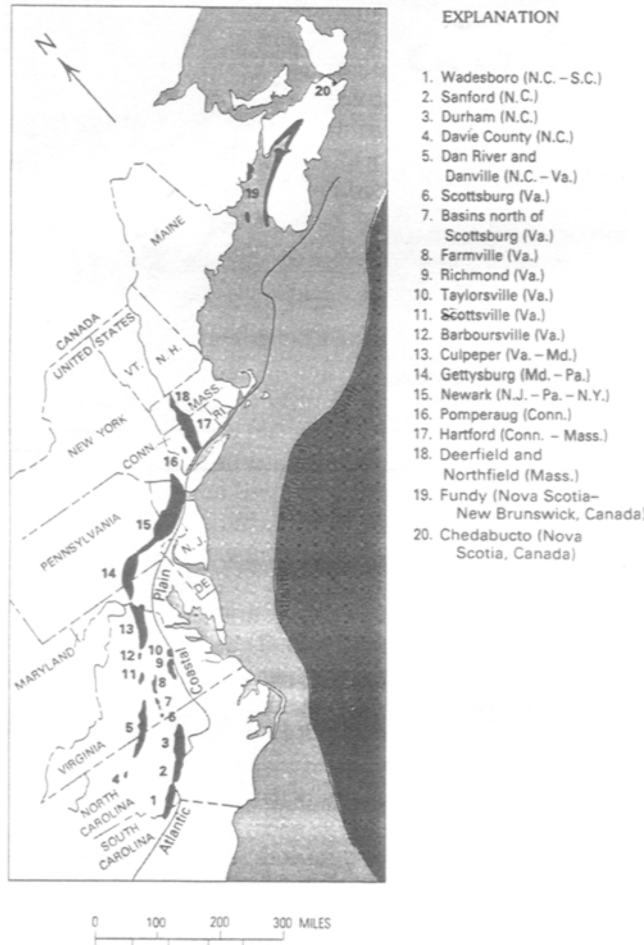


Figure 1. Principal exposed East Coast Mesozoic age basins (from Lee and Froelich, 1989).

Figure 2. Mesozoic age basins exposed in Virginia (from Johnson, Wilkes, Gwin, 1985).

The sedimentary rocks in the basin dip generally westward toward a major extensional fault system that forms the western margin of the basin (Figure 3). The eastern margin of the basin has both high-angle extensional faults of small displacement and unconformable contacts with basement rocks (Leavy, Grosz, and Johnson, 1982). Several types of foliated metamorphic rocks of Precambrian and Early Paleozoic age underlie the basin and are exposed on the basin margin; the basin also contains a "block" of Precambrian age rock in the south-central part. The rocks around the basin margin are metabasalt, arkose, metavolcanics, quartzite, phyllite, schist, gneiss, and marble (Virginia Division of Mineral Resources, 1993; Johnson and Froelich, 1982).

STRATIGRAPHIC UNITS

The Culpeper basin is one of the many basins along the eastern United States where continuous sedimentation occurred from Late Triassic to Early Jurassic time. Lindholm (1979) states that the southern basins (those south of the Culpeper basin) contain only Upper Triassic age rocks. Red beds (sedimentary units – sandstone, siltstone, some shale) were deposited on broad alluvial plains and are dominant in most basins. Lacustrine black shale and limestone represent facies that are present in most basins, but generally make up only a small part of the overall section (Lindholm, 1979). In some of the southern basins, coal swamps were present, but none were present in the northern basins in which the Culpeper basin is placed.

The stratigraphic sequence in the Culpeper basin starts with coarse clastic rocks at the base that fine upward into fine-grained clastic rocks. On the west side of the basin the fine-grained rocks are overlain by coarse clastic rocks that are younger in age. These include large amounts of conglomerates that were deposited as alluvial fans. The conglomerates are overlain by basalt and interbedded sedimentary units and the entire sequence is capped by a conglomerate unit, with interbedded black shale. The sedimentary units were deposited during the early phase of continental breakup that led to the formation of the proto-Atlantic (Lindholm, 1979).

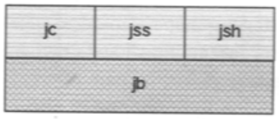
Lee and Froelich (1989) assigned the rock units in the Culpeper basin to the Newark Supergroup, Culpeper Group. They adopted the Culpeper Group for the distinctive complete lithostratigraphic sequence of Upper Triassic and Lower Jurassic rocks that occur in the basin. The Culpeper Group as adopted by Lee and Froelich changed the previously accepted stratigraphic sequence proposed by Roberts (1928). Figure 4 shows the stratigraphic nomenclature of the Culpeper Group in the Culpeper basin (after Lee and Froelich, 1989).

The stratigraphic sequence was later changed by Weems and Olsen (1997) (Figure 5). The new system as proposed by Weems and Olsen (1997) took the nine existing groups in the Newark Supergroup and reduced them to three. This reduction in number, by regrouping, created parallelism between the groups and three major successive tectonic events that created the rift basins. This new grouping uses discrete intervals of synchronous or nearly synchronous volcanic activity that occurred throughout the early Mesozoic age rift systems. The volcanic rocks are the markers upon which the regional groups and boundaries are established.

The new classification of Weems and Olsen (1997) recognizes two groups in Virginia—Chatham and Meriden. The Chatham Group is the oldest in age. In Virginia the rocks in the Scottsburg, Randolph, Roanoke Creek, Briery Creek, Farmville, Richmond, Flat Branch, Deep Run, Taylorsville, Danville, Scottsville, and Barboursville basins are all placed in the Chatham Group. The lower sedimentary units in the Culpeper basin are also grouped in the Chatham.

The overlying Meriden Group contains the lava flows and interbedded sedimentary rocks, and in Virginia, the group name only applies to the Culpeper basin. Lee and Froelich (1989) determined

MESOZOIC BASINS



NEWARK SUPERGROUP
jc conglomerate **jss** interbedded sandstone and siltstone **jsh** interbedded siltstone and shale **jb** basalt

NEWARK SUPERGROUP
c conglomerate, mixed clasts **c1** limestone clasts **c2** greenstone clasts **c3** arkosic matrix **br** breccia, mixed clasts **br1** breccia, mudstone clasts **s** sandstone, undifferentiated **s1** arkosic sandstone **ss** interbedded sandstone, siltstone, and shale **cs** interbedded sandstone, siltstone, shale, and coal **sh** interbedded shale and siltstone

Figure 3. Generalized geologic map of the Culpeper basin (from Division of Mineral Resources, 1993).

that the stratigraphic unit's equivalent to the Meriden Group of Weems and Olsen (1997) attains their greatest thickness (2000m) in the Culpeper basin. Olsen, et al. (1996) indicates that the Meriden Group was deposited over about 550 ± 50 KY. shortly after the beginning of the Jurassic.

The stratigraphic sequence in the Culpeper basin as described by Weems and Olsen (1997) is now the Chatham Group (Upper Triassic) which contains the Manassas Sandstone, Bull Run Formation, and Catharpin Creek Formation and the Meriden Group (Lower Jurassic) which contains the Mount Zion Church Basalt, Midland Formation, Hickory Grove Basalt, Turkey Run Formation, Sander Basalt, and Waterfall Formation.

from fine- to coarse-grained and pebbly, reddish-brown arkose to fine- to coarse-grained light- to dark-gray and bluish-gray calcareous graywacke. In places, the unit contains fossils and is phosphatic, contains six or more fish bearing, gray to black, calcareous lacustrine shale beds. The unit has a maximum thickness of 5,000 feet (includes the Millbrook Quarry Member that is a conglomerate).

The *Sander Basalt* is dark to bluish and grayish black, mostly holocrystalline and equigranular, in part microcrystalline and porphyritic. The Sander is hydrothermally altered and locally mineralized with copper and iron sulfides, as well as zeolites. The Sander Basalt flows are diverse and complex. Some of the flows are high Fe_2O_3, high TiO_2, quartz normative tholeiites, while others are high Fe_2O_3, low TiO_2, quartz normative tholeiites. The Sander Basalt ranges from about 500 feet to 2,264 feet in thickness.

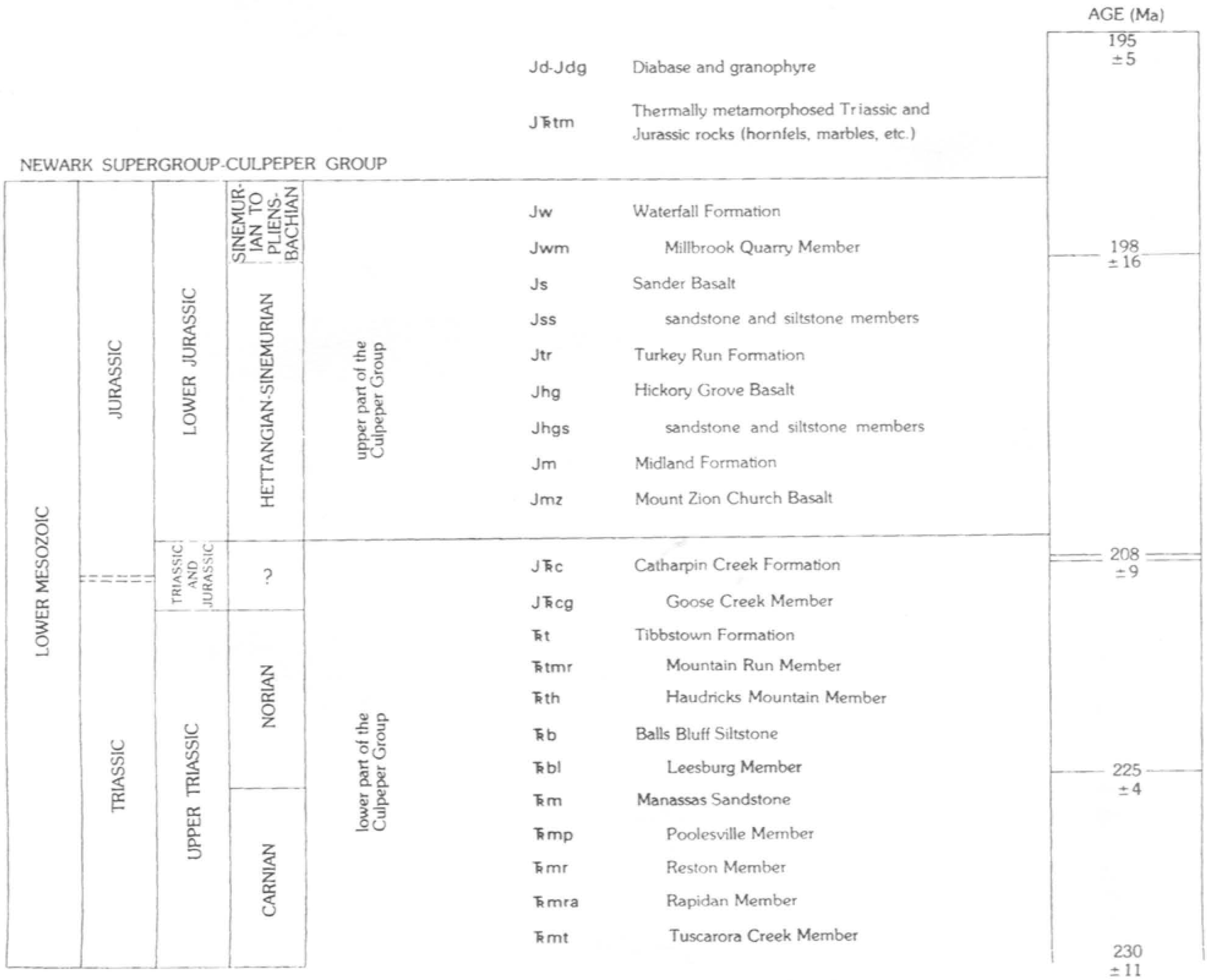


Figure 4. Stratigraphic nomenclature used for the Culpeper basin (Lee and Froelich, 1989).

The following stratigraphic descriptions are taken from Lee and Froelich (1989) and Weems and Olsen (1997). The descriptions are in sequential order, youngest to oldest.

Meriden Group (Lower Jurassic)

The *Waterfall Formation* is composed of interbedded sandstone, siltstone, mudstone, shale, and conglomerate. The sandstone ranges

The *Turkey Run Formation* overlies the Hickory Grove Basalt and is overlain by the Sander Basalt. The formation is mainly a sequence of sandstone, siltstone, and shale. The unit consists mainly of dark-red to medium-dark-grayish green, micaceous, feldspathic, thin- to thick-bedded to very thick bedded, very fine- to coarse-grained sandstone, siltstone, and silty shale. The formation has

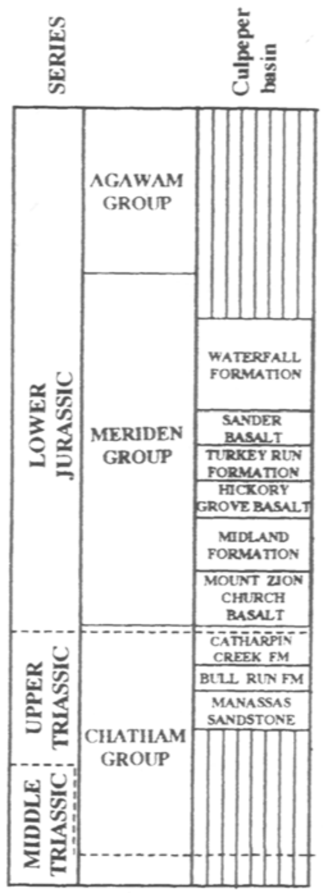


Figure 5. Culpeper basin stratigraphic sequence (modified from Weems and Olsen, 1997).

dinosaur tracks in Loudoun County. The formation has a thickness of about 492 to 1,082 feet.

The *Hickory Grove Basalt* is medium- to dark-gray, very fine- to coarse-crystalline, mostly equigranular and holocrystalline. When compared to the Mount Zion Church and Sander Basalts, the Hickory Grove is the less altered and less mineralized. In one area, this basalt is interbedded with a polymictic marble and basalt-cobble-bearing conglomerate. The Hickory Grove has a thickness of 165 to 1,246 feet.

The *Midland Formation* lies below the Hickory Grove Basalt and above the Mount Zion Church Basalt. The formation is a succession of clastic sedimentary rocks. The unit contains the Midland Fish Bed. The formation is composed of dark-red to reddish-brown micaceous, feldspathic, fine- to medium-grained sandstone interbedded with reddish-brown, micaceous siltstone; dark-red, greenish-gray, and dark gray to nearly black calcareous, silty fossiliferous shale; and thin-bedded argillaceous limestone. The thickness ranges from about 500 to 984 feet.

The *Mount Zion Church Basalt* is medium- to dark-gray, very fine- to medium-crystalline porphyritic, equigranular, and holocrystalline. The Mount Zion Church is a high TiO_2 quartz-normative tholeiite; thickness ranges from 33 feet to 590 feet (Lindholm, 1979).

The three basalts (Sander, Hickory Grove, Mount Zion Church) in the basin are the only extrusive igneous rocks that occur in the Mesozoic basins in Virginia (Virginia Division of Mineral Resources, 1993).

Chatham Group (Upper Triassic)

The Catharpin Creek Formation is composed of very dark-red to dusky-red, micaceous, feldspathic fine- to coarse-grained sandstone and clayey siltstone, locally containing conglomerate layers (lower part). This sequence grades upward into dark-red to gray, micaceous, feldspathic sandstone; thin-bedded clayey siltstone; and laminated, fissile, silty shale. The thickness of the Catharpin Creek Formation may attain a thickness of 1,640 feet (excludes conglomerate member). The Goose Creek Member may exceed 2,950 feet in thickness. The member is mainly a grayish-green to red-brown cobble and pebble conglomerate that grades into a coarse- and fine-grained reddish-brown arkosic sandstone and sandy siltstone.

The *Bull Run Formation* name is reinstated by Weems and Olsen (1997) and includes the Balls Bluff, Groveton, Leesburg, and Cedar Mountain Members (oldest to youngest) and abandons the Tibbstown Formation of Lee and Froelich (1989).

The *Cedar Mountain Member* is dominantly a greenstone conglomerate. The lower sequence of the member is composed of conglomerate with angular to subangular fragments of dusky-yellowish-green to dark-yellowish-green greenstone in a dusky-red to pale-green clayey sand and silt matrix. The upper sequence is mainly greenstone fragments with quartzite and feldspathic sandstone clasts and minor vein quartz fragments (Mountain Run Formation of Lee and Froelich, 1989). Thickness is up to 2,099 feet.

The *Leesburg Member* is composed mainly of angular to subangular and subrounded to rounded cobble of lower Paleozoic light-gray to grayish-black and pinkish-red limestone and dolomitic limestone and contains minor clasts of dolomite, quartzite, vein quartz, schist, slate, and greenstone embedded in a matrix of carbonate-rock granules, red sand, and clayey silt cemented by calcite. In Loudoun County the member attains a thickness of 3,510 feet.

The *Groveton Member* (new name of Weems and Olsen, 1997) contains prominent, laterally persistent, gray cyclic lacustrine sequences. The member is characterized by thin sequences of gray shales interbedded with sequences of red shales, siltstones, and minor sandstone. The member is dominated by shales and siltstone, but intertongues with conglomerates and sandstone at the western border fault. The Groveton attains a thickness of up to 8,200 feet thick.

The *Balls Bluff Member* is mainly a grayish-red and dusky-red, very fine-grained to very coarse-grained calcareous, clayey, micaceous and feldspathic siltstone. The member is thin bedded to massive and extensively bioturbated, with irregular or convolute bedding, ripple marks, and planar or climbing – ripple cross-laminations (Balls Bluff Siltstone of Lee and Froelich 1989). The member attains a thickness of up to 900 m.

The *Manassas Sandstone* contains three discrete and separate conglomerate sequences, each with pebbles and cobbles of distinctive lithologic types — schist and quartzite, greenstone, or limestone. The conglomerates are in the Reston Member, the Rapidan Member, and the Tuscarora Creek Member. Each of these Members unconformably overlies or is in fault contact with pre-Triassic crystalline rocks, and each merges into an overlying sandstone unit (Poolesville Member). The Manassas probably does not exceed 820 feet in thickness.

The *Reston Member* is a dusky-red, very dark-red, and light-gray intermixture of micaceous quartz and feldspar sand and angular to subangular boulders, cobbles, and pebbles of crystalline rock fragments in a clay-silt matrix.

The *Rapidan Member* is the lowest stratigraphic unit of the Manassas Sandstone in Virginia. The Rapidan is characterized by indurated conglomerates that contain fragments of grayish-green and grayish-olive-green to dusty-green metabasalt fragments and minor fragments of light-gray and bluish-gray, metamorphosed, feldspathic sandstone, quartzite, vein quartz, and schist. The fragments are intermixed with greenstone granules and greenish-gray clay, sand, and silt, cemented by clay and silica and in places secondary calcite.

The Tuscarora Creek Member is well-to poorly-sorted, thick-bedded to very thick bedded conglomerate composed of angular to subangular and subrounded pebbles and cobbles of light to dark gray and pinkish-red limestone, dolostone, and dolomitic limestone. The Tuscarora Creek outcrops only in Maryland. The member is the lowest stratigraphic unit of the Manassas Sandstone.

The Poolesville Member is mainly a pinkish-gray, very fine-grained to very coarse-grained feldspar and quartz sand in a very dark red to dusky-red-purple clayey silt matrix, cemented mainly by silica and locally by calcite. It is micaceous and, in part, highly feldspathic. The member is generally intercalated with light gray to gray, highly feldspathic sandstone and quartzite-pebble conglomerate. The thickness of the unit ranges from 656 to 3,280 feet.

Diabase

The diabase in the Culpeper basin occurs chiefly as stocks, sills, saucer-shaped sheets, and dikes. The diabase is medium- to medium-dark-gray, chiefly equigranular and locally coarse- to very coarse-crystalline, but is aphanitic at "chilled" intrusive margins. The diabase is Jurassic age, high TiO_2, quartz-normative tholeiites. Some of the diabase that is thought to be in thin sheets is low TiO_2 quartz-normative.

Thermally Metamorphosed Rocks

The contacts between the diabase intrusives and the country rock are sharp, but in some areas the contacts can be transitional across 20 or more feet. The thermal aureole surrounding the larger intrusive can be up to one-fourth to one-third the thickness of the intrusive. Thermal metamorphism of the country rocks occurs throughout the basin.

The metamorphism of the feldspathic, micaceous, argillaceous, arenaceous, ferruginous, and calcareous sandstone and siltstone and minor conglomerate and shale of the Chatham Group has converted the rocks to hornfel, metaconglomerate, and quartzite. Some marble has been derived from the contact metamorphism of limestone conglomerate.

STRUCTURE

The sedimentary rocks and basalt flows in the basin generally dip westward toward a system of high-angle normal faults. The normal faults form the western margin of the basin. The eastern margin is formed both by high-angle normal faults of small displacement that cross the trend of the basement foliation at moderate angles, and by unfaulted, unconformable contacts between the Triassic rocks and basement rocks (Leavy, 1980). The sedimentary rocks and basalt flows dip westward as much as 70°. The lowest dips occur in the eastern and southeastern parts of the basin (Froelich, 1982).

The Culpeper basin is surrounded by many types of metamorphic rocks of Precambrian and early Paleozoic age. These rocks include schist, phyllite, metagreywacke, and serpentinite east of the basin. To the west, the basin is flanked by phyllite, quartzite, metabasalt, and granite gneiss.

ECONOMIC RESOURCES

Extensive deposits of rock materials suitable for crushed stone, aggregate, and riprap occurs in the Culpeper basin. Deposits of dimension stone, flagstone, and building stone have been mined and still exist. The necessary raw materials for brick, tile, and agricultural lime are abundant(Lee, 1979). Some metallic and non-metallic mineral deposits have been extensively prospected, but only locally mined on a small scale.

The diabase provides extensive sources for crushed stone, dimension stone, and aggregate. The sandstones and siltstones also provide material for crushed stone and aggregate. Subbase material for roads has been provided by crushing hornfels and granulite. The metamorphosed sandstones have been used for flagstone and dimension stone (Lee, 1979).

Copper and iron mineral occurrences have been mined on a very small scale in the past. These "deposits" generally occur in granulite and hornfels in the contact aureoles between the diabase intrusives and country rock. Some of the metallic mineralization occurs in diabase fractures, and as fissure-fillings in sandstone and siltstone (Lee, 1980).

The metallic mineralization is chalcopyrite, magnetite, specularite, bornite, chrysocolla, azurite, chalcocite, and malachite (Froelich and Leavy, 1982). Deposits of barite were mined from fissure-fillings in siltstone and shale near diabase intrusives (Lee, 1979).

CONCLUSIONS

The Culpeper basin of Triassic-Jurassic age initiated and evolved during the early Mesozoic period of continental rifting that preceded the development of the modern Atlantic Continental Margin. The sedimentary rocks in the basin were derived by erosion from the adjacent country rocks and were deposited by streams into the closed basin. The sedimentation was controlled by extensional tectonics and fluctuating semiarid climatic conditions (Lee and Froelich, 1989). The basin is part of a large system of basins that occur along the East Coast of the eastern United States. The basins are elongate, northeast-trending, faulted half grabens. The border fault occurs on the west side of the basin.

The Culpeper basin contains, in addition to the sedimentary units, three basalt flows and large volumes of diabase that occur as stocks, sills, dikes, and sheets. Contact metamorphism has created large zones of altered rocks, of which hornfels, quartzite, and metaconglomerates are dominant.

The basin contains abundant resources for crushed stone, aggregate, and dimension stone from diabase, sandstone, and siltstone. Copper mineralization exists and deposits of barite have been mined in the past.

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53 MILLION YEAR OLD FOSSILS DESCRIBED IN NEW STATE PUBLICATION

One hundred and eighteen species of sharks, rays, bony fish, reptiles, and bird and nine plant taxa are described and illustrated in Publication 152 recently released by the Virginia Division of Mineral Resources of the Department of Mines, Minerals and Energy. The title of the publication, edited by Dr. Robert Weems and Mr. Gary Grimsely, is " Early Eocene vertebrates and plants from the Fisher/Sullivan site (Nanjemoy Formation) Stafford County, Virginia." Vertebrate animals and plants were collected from a geologic unit approximately 53 million years old. Located in eastern Stafford County, the Eocene-age deposit contains several species that were previously unknown. The bird specimens are the first of Eocene age collected from eastern North America.

The publication contains 24 pages of photographs, 65 figures, and several maps and tables. These illustrations are useful to both the professional paleontologist and the amateur collector in the study and identification of ancient life.

Much of the fossil material collected and assembled for the publication was accomplished by members of the mostly amateur Maryland Geological Society with cooperation of several landowners.

Geology of Virginia Educational CD Now Available

Standards of Learning Emphasized on CD, Teacher's Guide

Students, teachers and others who are interested in Virginia's geology can now learn about it using a recently released CD and teacher's guide developed by Radford University in cooperation with the Virginia Department of Mines, Minerals and Energy's Division of Mineral Resources. The high tech CD entitled, *The Geology of Virginia,"* is the first of a planned set of five CDs describing Virginia's geology and emphasizing the Virginia Standards of Learning.

The authors of the CD are Dr. Robert Whisonant, Dr. Parvinder Sethi, and Ms. Karen Cecil. Dr. Whisonant and Dr. Sethi are geology professors at Radford University, and Ms. Cecil is an award-winning Radford High School earth science teacher. The Geology of Virginia CD-ROM project was developed as a high tech educational resource that will help Virginia teachers and students meet state standards of learning guidelines in science.

Whisonant, Sethi, and Cecil have spent their careers in teaching and have ensured that not only were key earth science concepts taught on the CD, but that they were presented in an interesting and attractive way to encourage use by students and their instructors. The first CD, which provides background information on Virginia's geology, incorporates the use of slide shows and video complemented by audio narratives and music.

The Department of Mines, Minerals and Energy's Division of Mineral Resources as a contributing partner has teamed with the authors to review and provide input and material to the project. The Division is also the publisher and sole distributor of the CD-ROM and Teacher's Guide. Other contributors and finanical supporters of the project are the Department of Education, Department of Environmental Quality, and the Virginia Aggregates Association and many of its corporate members.

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Publication 151: Coal, oil and gas, and industrial and metallic minerals industries in Virginia, 1997, by P. C. Sweet and J. E. Nolde, 25 pages, 16 figures, 12 tables, 1998. ***Price: $8.50**

Publication 152: Early Eocene vertebrates and plants from the Fisher/Sullivan site (Nanjemoy Formation) Stafford County, Virginia, edited by R. E. Weems and G. J. Grimsley, 159 pages, 8 papers on various fossils groups, 1999. ***Price: $13.00**

Publication 153: Coal, oil and gas, and industrial and metallic minerals industries in Virginia, 1998, by P. C. Sweet and J. E. Nolde, 25 pages, 14 figures, 13 tables, 1999. ***Price: $8.25**

Geology of Virginia, CD-ROM 1, Introduction and Geologic Background, by P. S. Sethi, R. C. Whisonant, and Karen K. Cecil, 1999. ***Price: $4.65**

Price for Virginia teachers and students when ordered on school letterhead: $1.65 plus $0.50 postage.

Teacher's Guide for Geology of Virginia, by Karen K. Cecil, R. C. Whisonant, and P. S. Sethi, 132 pages, looseleaf, 1999***Price: $9.50**

50th Annual Highway Geology Symposium and TRB Karst Meeting - Proceedings and Field Trip Guide, 1999. ***Price:$40.00**

*** Includes postage; Virginia residents add 4.5% sales tax.**

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