Stratigraphy and Deposition of the Price Formation Coals in Montgomery and Pulaski Counties, Virginia

by

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CHAPTER 1

INTRODUCTION

The Southern and Central Appalachian Mountains are divided into three structural provinces. These are, from southeast to northwest: the Piedmont of low lying, largely crystalline rocks; the Blue Ridge of Precambrian crystalline and Late Precambrian and Early Cambrian metasedimentary rocks; and the Valley and Ridge of folded and thrust faulted Paleozoic sedimentary rocks. The study area of this paper is within the Southern Appalachian Valley and Ridge Province of southwestern Virginia (Fig. 1). Specifically, the area is confined to Montgomery and Pulaski Counties, Virginia.

The early Paleozoic history of southwestern Virginia begins with the formation of a continental shelf, dominantly composed of carbonate rocks, extending southeastward into an early Atlantic Ocean. By Ordovician time a highland, the forerunner of the Blue Ridge, developed on the southeastern margin of the shelf. Syntectonically, the foreland basin on the shelf subsided and filled with clastics, from Middle Ordovician through Carboniferous time (Markello, Tillman and Read, 1979).

Land plants evolved to populate the margins of the interior sea, and in Early Mississippian time the geologically oldest minable coal seams began to form as accumulations of peat on the Price delta. Alleghanian folding and thrust faulting (Hatcher and Odom, 1980) metamorphosed these coals to "semi-anthracite" rank (Campbell and Others, 1925).

Along with Ms. Gayle R. Ingram, the writer mapped Mississippian

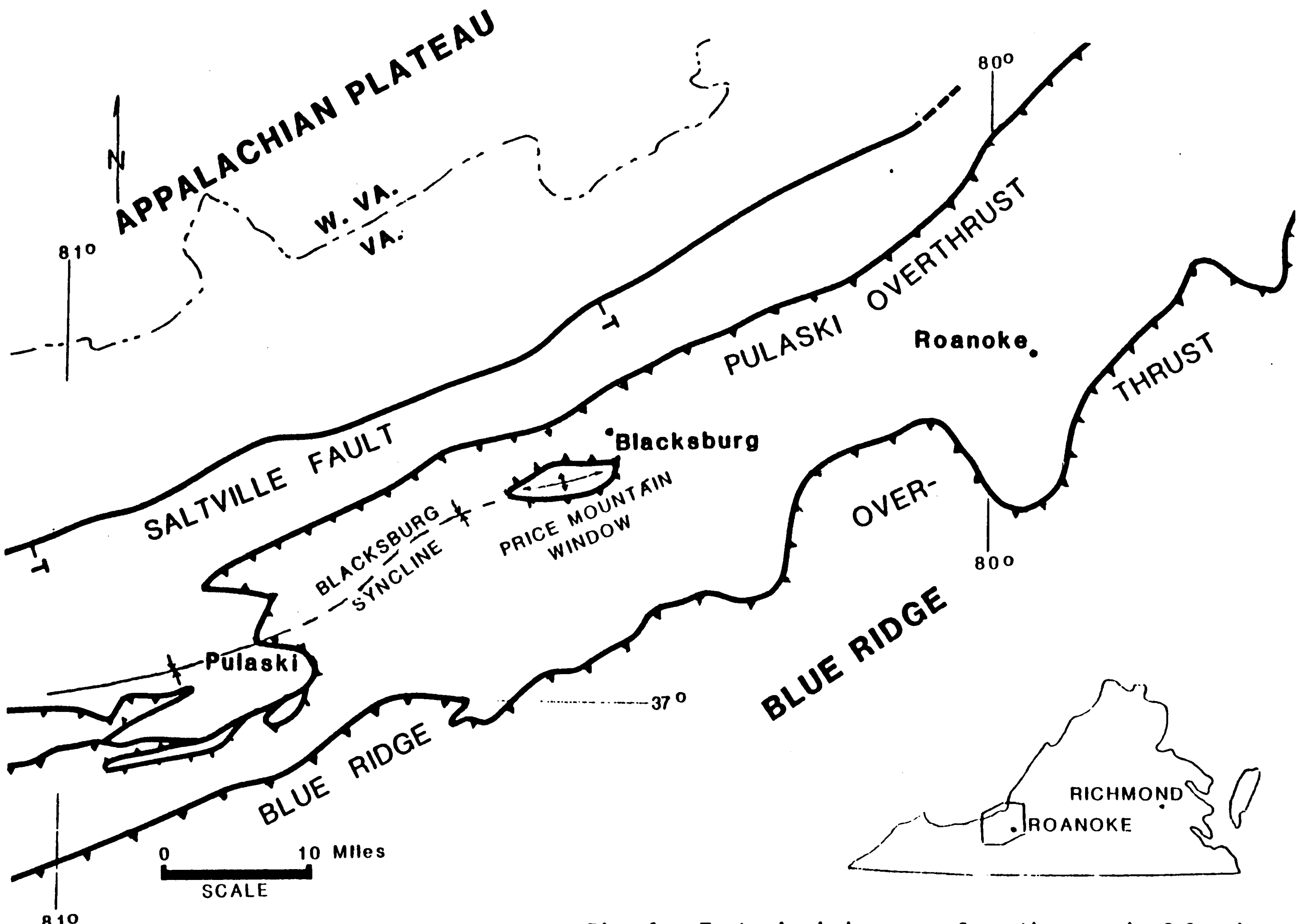

Fig. 1 Tectonic index map of northern end of Southern Appalachians.

rocks of the Saltville fault block within Montgomery and Pulaski Counties. Special attention was given to the Price Formation, which contains the once economic coal. The purpose of this study was to develop a model for the depositional environment of the Price coal measures which could help geologists predict characteristics of the coal where it is still buried beneath the Pulaski thrust sheet.

Field mapping was done from June through September 1980, in connection with the Virginia Division of Mineral Resources' project to map the Price coal field and the Pulaski thrust sheet. Map scale was 1:24000, on 7.5-minute quadrangles with 20-foot contour intervals. The field crew included Dr. M. J. Bartholomew, supervisor; Mr. A. P. Schultz, who mapped the Pulaski thrust sheet; and Ms. G. R. Ingram and the writer, who mapped the Mississippian, and in places, the Devonian units.

Physiographic Setting

The Mississippian outcrop belt trends northeast through Montgomery and Pulaski Counties. These rocks and the underlying Devonian sandstones form the linear ridge of Little Walker-Cloyds-Brush Mountain. The ridge extends across the Long Spur, Pulaski, White Gate, Staffordsville, Radford North, Blacksburg, Newport and McDonalds Mill 7.5-minute quadrangles. Mississippian strata also crop out in the southwestern part of the Pulaski quadrangle and the southeastern part of the Long Spur quadrangle on Tract Mountain, Brushy-Chestnut Mountain, Caseknife Ridge and Draper Mountain. In the southern part of the Blacksburg quadrangle and in the southeastern part of the Radford North quadrangle, Mississippian rocks crop out on Price Mountain.

Mapping credits, by quadrangle, are shown on Fig. 2.

Structural Setting

The study area includes parts of the Saltville and Pulaski thrust sheets (Fig. 1). The Pulaski fault is the northwest boundary of the Southern Appalachian Overthrust Belt. This Belt includes all faults from the Pulaski southeast to the Blue Ridge Structural Front (Lowry, 1979). The Saltville fault block is included with other northeast-trending structures in a zone bounded on the southeast by the Pulaski fault and on the northwest by the St. Clair fault at the Allegheny Structural Front.

All Mississippian rocks in the study area (Plates 1 and 2) are part of the Saltville block. The main outcrop belt is the northwestern limb of the Blacksburg synclinorium. In Montgomery County and much of Pulaski County the trough of this structure is under the Pulaski thrust sheet; however, the Price Formation is in the trough in western Pulaski County. In Montgomery County, a small anticline is exposed in the Price Mountain window of the Pulaski thrust sheet (Fig. 1). This exposure, located approximately five miles southwest of Blacksburg, was described by Campbell (1894) as the type locality of the Price Formation. In Pulaski County, the Price and overlying Maccrady Formations are also exposed in the asymmetric Tract Mountain anticline, the Pulaski syncline and the Draper Mountain anticline.

The Pulaski thrust fault is the most important structure in the study area. It may be part of a master fault developed in the Precambrian core of the Blue Ridge (Lowry, 1971). In the Blacksburg area

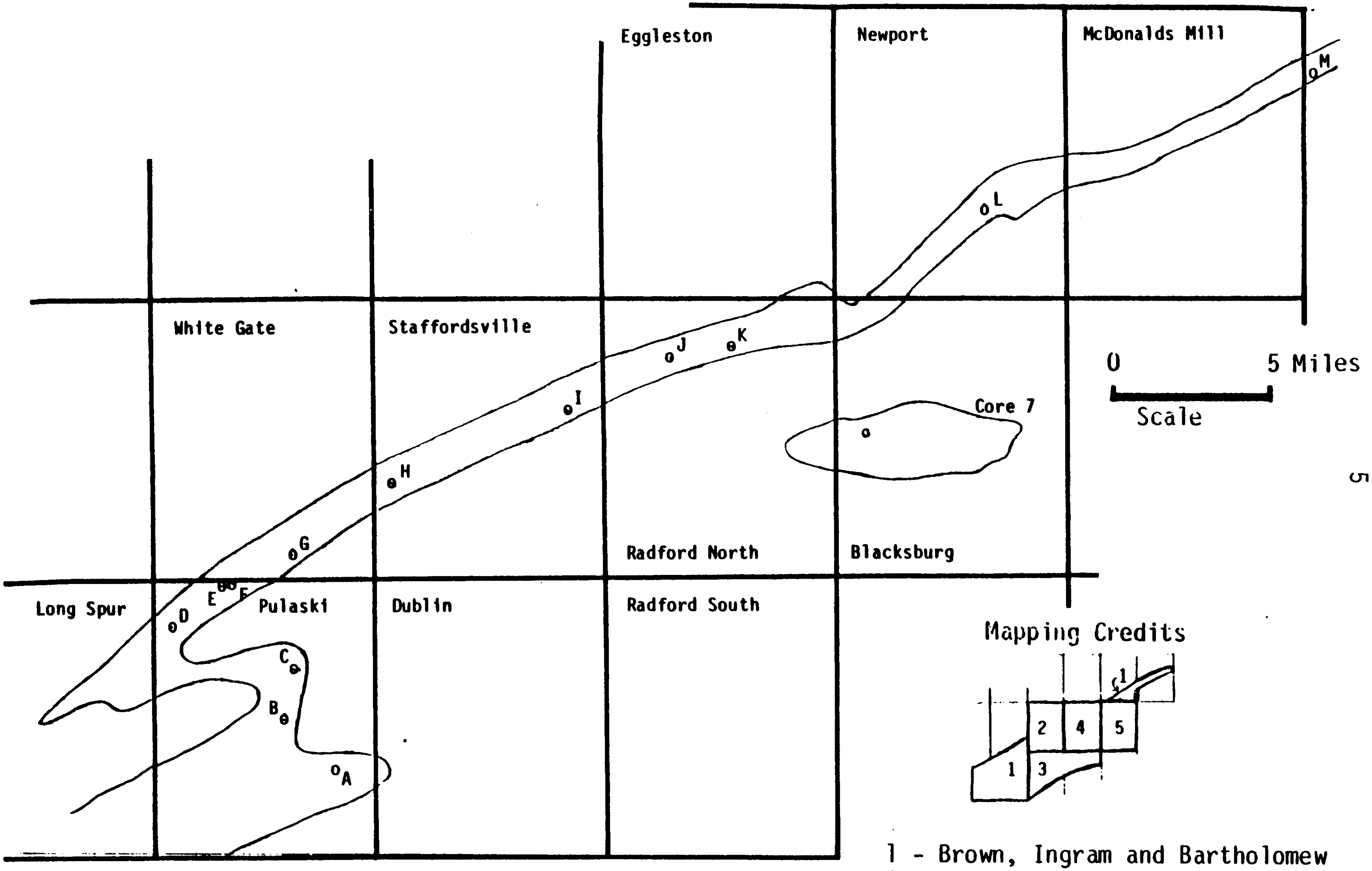

Fig. 2 Mississippian outcrop belt in Montgomery and Pulaski Counties.

"A" through "M" indicate measured section locations.

1 - Brown, Ingram and Bartholomew
2 - Bartholomew and Schultz
3 - Schultz
4 - Schultz and Bartholomew
5 - Bartholomew and Lowry

its minimum horizontal displacement is ten miles (Lowry, 1971).

It was noted during mapping that the Pulaski fault cuts across the northwestern limb of the Blacksburg synclinorium. In Pulaski County and much of Montgomery County, the Middle Cambrian Elbrook Dolomite of the Pulaski thrust sheet lies on overridden Mississippian Maccrady red beds. However, no Maccrady was mapped in the McDonalds Mill quadrangle. At reference locality 3 (Plate 2) Elbrook Dolomite is in thrust contact with coal of the Price Formation. At Section M (Fig. 2), west of the Montgomery-Roanoke County line, the decollement surface has cut down to a position stratigraphically lower than the coal.

CHAPTER 2

PREVIOUS INVESTIGATIONS

Stratigraphy

A thorough review of literature dealing with Price Formation stratigraphy has been compiled by Bartlett (1974). Bartlett reviews the Rogers brothers' (1858) Vespertine Series, which included the Price Formation, Campbell's (1894) description of the Price at the type locality, and many other works dating to Kreisa and Bambach's (1973) detailed paleoecologic model of the Price Formation.

Bartlett's literature survey extends to investigations of Price Formation equivalents in the states of Tennessee, West Virginia, Ohio, Pennsylvania and Maryland.

The most recent Price Formation study (Whitehead, 1979) emphasizes the regional stratigraphy and depositional setting. Whitehead also named seven members of the Price Formation.

Paleobotany

The Price flora has been found across the northern hemisphere (Darrah, 1960) in the Appalachians, northern Alaska, southern Siberia, western Europe, Scotland, and the eastern Arctic region. The flora is also found with endemic groups in Australia, South Africa, Brazil and Argentina (Darrah, 1960). Because of this flora's biostratigraphic importance across the world, a brief history of Price paleobotanical investigations follows.

Rogers (1858) first mentioned the abundant flora of the Pocono

Sandstone, the northern equivalent of the Price Formation. The first detailed description of Price-Pocono plant fossils was done by Lesquereux (1884). Lesquereux believed the dominant genus to be *Archaeopteris*, an Upper Devonian progymnosperm. Many of Lesquereux's genera were redescribed by Read (1955) as *Adiantites* and *Triphyllopteris*. Read suggested that Lesquereux may have been describing fossils of the Devonian Hampshire Formation, rather than the Mississippian Price-Pocono.

Read (1955) identified 22 new species in the Price flora; however, many paleobotanists (Scheckler, personal communication, 1981) believe some of the new species are repetitions of previously named plants. Read's main contribution was the recognition of two floral assemblages in the Price-Pocono Formation. These assemblages were used by Read and Mamay (1964) as floral zones for the lower part of the Mississippian System.

A guidebook for plant fossil localities in Montgomery and Pulaski Counties was compiled by Dr. Steven E. Scheckler (1978).

Lists of fossil flora are included with sections B, C, D, H, and L in Appendices A and B.

Coal in Montgomery and Pulaski Counties

⟨Mining was important to the economy of Montgomery and Pulaski Counties in the late 1800's and early 1900's. Today, interest in the coal of these counties has reappeared because of increasing awareness of hydrocarbon potential in overthrust areas.⟩It is possible that Mississippian coals overlain by the Pulaski thrust sheet may have provided interstitial methane gas to be trapped in anticlinal or fault structures of the thrust sheet.

The only major work on the coal geology of the Price Formation is Virginia Geological Survey Bulletin XXV, The Valley Coal Fields of Virginia (Campbell and Others, 1925). The bulletin contains brief descriptions of structure and stratigraphy in the Great Valley (the plain directly southeast of the Pulaski fault) and gives specific information for counties with mining operations in Price Formation coals. Such information includes geomorphology, transportation facilities and economic statistics for each county. Engineering details and operating methods for individual mines are discussed.

Campbell noted two minable seams which were assumed to be continuous throughout the study area. The older seam was called the Little Bed by miners while the younger was known as the Big Bed. Campbell renamed the seams Langhorne and Merrimac, respectively.

Many coal samples were collected by Campbell and his colleagues for analysis. These analyses are the main source of chemical information on Price coals. Some addition information is available from U.S. Bureau of Mines Bulletins by Eby and Staff (1929, 1931); Fish and Porter (1933), Fish (1935), Shelton (1954) and Stevens (1959) also include later analyses.

Recently, evaluations of the available date were done by G. R. Ingram and J. D Rimstidt. By plotting the percentages of ash, moisture, fixed carbon and volatiles against sample locations (in terms of distance from an arbitrary fixed point in the northeastern part of the field) Ingram and Rimstidt (unpublished progress report, 1981) determined there was no significant correlation between the proximal analyses and sample location. From averaged values of the compiled analyses Ingram calculated 15.19% volatiles and 84.81% fixed carbon for the Price coal on a dry, ash-free basis. The average percent sulfur for the coal was less than 1. These percentages place the rank of the coal at low volatile bituminous. From this data a maximum temperature of diagenesis was calculated to be 150^{o} C. Assuming a geothermal gradient of 25-30^{o}C/km., the depth of burial during the coal's metamorphosis was 5-6 km. The maximum thickness of the Paleozoic section above the Pulaski fault in the Salem synclinorium is aproximately 15-20,000 ft./4.0-5.4 km. (Colton, 1970); thus the depth of burial calculated from chemical analyses is geologically feasible.

Current research is being done by Ingram to determine the effect of weathering on petrographic properties of the coal.

CHAPTER 3

METHODS OF STUDY

Field Mapping

Field mapping was done from June through September under the supervision of Dr. M. J. Bartholomew of the Virginia Division of Mineral Resources. After 60 days in the field, the areal equivalent of one and one-half 7.5-minute quadrangles had been mapped by G. R. Ingram and the writer. Both investigators concentrated on the relative parautochthonous Mississippian rocks of the Saltville thrust sheet.

Using Brunton compasses, Ingram and the writer measured strikes and dips, cleavages and fold axes. Data was plotted on 7.5-minute quadrangle base maps with 20-foot contour intervals.

Mapping Criteria

A diagrammatic cross section of Cloyds Mountain (Fig. 3) illustrates the stratigraphic units mapped and shows how individual units affect mountain topography. Brief descriptionsof the field criteria for recognizing these units are given below, in order of oldest to youngest. Lithostratigraphic descriptions of the Price Formation are given in the chapter on stratigraphy.

Cambrian Rome Formation and Elbrook Dolomite- These formations compose the leading edge of the Pulaski thrust sheet. Where present, the Rome Shale rarely crops out along the thrust contact. It was recognized by noting small hackly, olive-green and light orange phyllitic shale

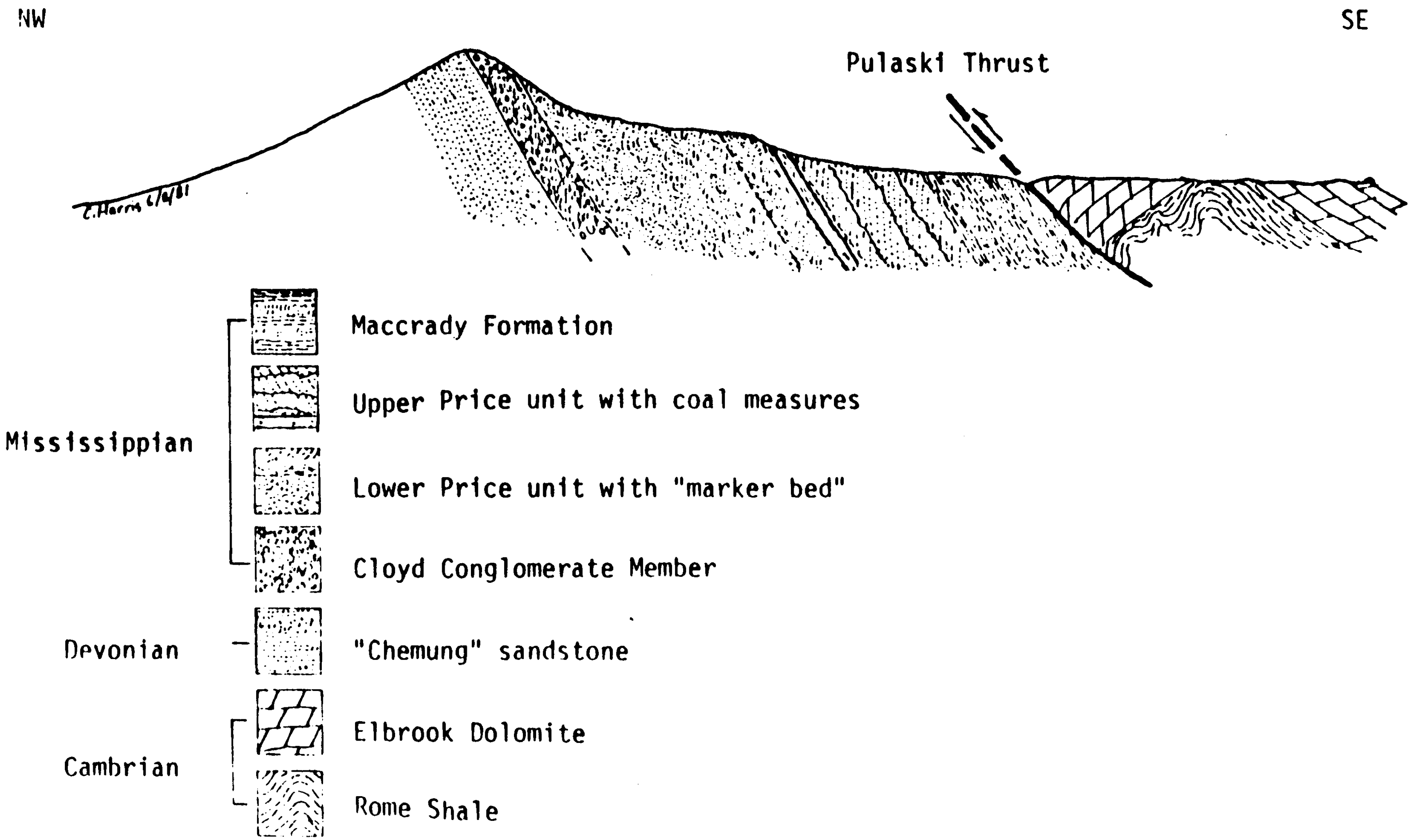

Fig. 3. Diagrammatic cross-section of Cloyd Mountain

chips in light yellow-gray soil.

The Elbrook Dolomite crops out frequently. It is thin-bedded ribbon rock, a tidal lithofacies (Markello, Tillman and Read, 1979) of alternating light gray and buff laminations. Cryptalgal lamination may be recognized in outcrops. Karst topography and a deep orange soil indicate Elbrook bedrock.

When no evidence for either the Elbrook or Rome was available, the Pulaski fault was mapped as the break-in-slope at the foot of the mountain, or where woods mark the limit of cultivation on presumably more fertile carbonate soil.

Devonian "Chemung" sandstones- Either "Chemung" sandstone or the Cloyd Member of the Price Formation caps the ridges of the study area. The "Chemung" was recognized as fine-grained quartzose sandstone, weathering medium brown to light yellowish brown. It is found as blocky pavements along the ridge crests.

Lower Mississippian Cloyd Conglomerate Member- The Cloyd conglomeratic beds are 6 inches to approximately 35 feet thick. The clasts are well rounded, coarse pebble-size, milky quartz grains. The conglomerate beds are underlain and interbedded with a mature, quartzose sandstone which weathers light gray to white.

Where outcrop was limited and float indicated the Cloyd was present, the upper and lower contacts of the Cloyd were located by a steep slope in the correct stratigraphic position.

Lower Price unit and the "marker bed"- The Lower Price unit crops out as thinly cross-bedded, olive-gray to medium gray, fine- to medium-grained argillaceous sandstone with micaceous partings. The "marker bed" is a mappable horizon of thicker bedded, medium gray, medium- to coarse-grained quartzose sandstone at the top of the unit. It was recognized by taking hand samples to note its silica cement and high quartz content. The "marker bed's" resistance to erosion causes it to underlie a steep slope which represents the upper limit of the Lower Price unit.

Upper Price unit and coal measures- The Price Formation coal measures lie directly over the "marker bed." Coal outcrop is rare; coal weathers rapidly to a black soil. Individual coal seams were mapped by marking the location of mine adits. Old collapsed adits occur in the woods as pits, 10-40 feet wide. Rarely adits are open and roof rock exposed. Coal dumps, small gauge railrod track and building foundations are associated with the pits.

A string of pits along strike was assumed to delineate a continuous seam. Adit locations are not plotted on Plates 1 and 2, but will be shown on the Virginia Division of Mineral Resources 7.5-minute geologic quadrangles.

The coal measures are composed of dominantly claystones and siltstones. The Upper Price unit becomes sandier up-section. The sandstones are medium-bedded, medium gray, fine- to medium-grained and are interbedded with dark gray and/or maroon siltstones.

Maccrady Formation- Maccrady beds are dark maroon and gray, fine-grained sandstones and dark gray and olive-green mudstones. The formation is easily identified by a dark maroon soil cover.

The Price-Maccrady boundary is gradational. An arbitrary contact was placed stratigraphically below the first maroon or mottled maroon and gray sandstone. No maroon sandstones were included in the Price Formation.

Measured Sections

Measured sections of the entire Price Formation have been recorded by Cooper (1937), Glover (1953), Kreisa (1972), Schmidt (1973), Bartlett (1974), and Whitehead (1979). Measurements of the Langhorne and Merrimac coal seams were recorded by Campbell and Others (1925).

In this study, partial sections of the Price were measured where coal was exposed. The writer redescribed some of the previous work, and measured new sections. Some sections measured by Bartlett (1974) are used in this paper.

The methods used in measuring sections were Brunton compass and steel tape, Jacob's staff, and detailed study with an inch scale. In all cases, units were described on a smaller scale than previously recorded. Kreisa (1972, pages 11-12) discusses general criteria for determining lithologic units in a measured section.

Locations of the measured sections are shown on Fig. 2. Described sections are given as Appendices A and B.

Cored Drill Holes

Three periods of drilling activity took place between September, 1980 and March, 1981, with increasing success with experience. The first was an attempt by Dr. J. D. Rimstidt, G. R. Ingram, N. Evans and the writer to obtain a core section of the Langhorne seam on Virginia

Route 100. A very small drill rig had been borrowed from the Department of Geology of Old Dominion University. After drilling with a one-inch (AX-type) core barrel for 25 feet, 4 inches of coal were recovered.

The second drilling period was funded by the Virginia Division of Mineral Resources; Virginia Highway Department worked the project. Six holes were drilled along the northwest flank of the Blacksburg syncline. Recovery, using a one-inch (AX-type) core barrel, ranged between 4 and 56 percent.

Finally, a core was taken by the Orogenic Studies Laboratory drill crew (from the Department of Geological Sciences, V.P.I. and S.U.) on Price Mountain. A two-inch (NX-type) core barrel was used with excellent results. Recovery was better that 95 percent!

Location of the O.S.L. core hole is shown on Fig. 2. The core description of this well is included as Appendix C.

CHAPTER 4

PRICE FORMATION STRATIGRAPHY

The Price Formation overlies the Devonian "Chemung" Sandstones. An exact age range for the Price has not been determined, because the Devonian-Mississippian systemic boundary may lie below or within its lowest member (Bartlett, 1974). The name Parrott Formation (Glover, 1953; Cooper, 1961) has been used when describing Mississippian marine sandstones found below the Cloyd Conglomerate. Some sandstones mapped below the Cloyd on Brush Mountain as "Chemung" may be the Parrott Formation.

In Montgomery and Pulaski Counties, paleobotanical evidence suggests a break between the Devonian and Mississippian strata (Scheckler, personal communication, 1980). Because the lower Price beds are marine, the lack of flora seems ecologically controlled. Glover's (1953) identification of Kinderhookian marine fossils in the Lower Price indicates continuous sedimentation from Devonian to Mississippian time. No stratigraphic break between the "Chemung" and Price was identified in the field. Plant fossils from the Price and its northern equivalent, the Pocono Sandstone, range in age from lower Kinderhookian through middle Osage (Read and Mamay, 1964).

Campbell (1894) described the type Price Formation from exposures of coal-bearing rock on Price Mountain, five miles southwest of Blacksburg, Montgomery County. Price Mountain is an anticline in the parautochthonous Satlville block, exposed through a window in the Pulaski thrust sheet. In 1949 (Bartholomew and Lowry, 1979) a test well near the axis of the structure indicated a coarse conglomerate was present in the subsurface which was interpreted as the Cloyd Conglomerate. The Blacksburg geologic quadrangle (Bartholomew and Lowry, 1979) shows Lower Price at the crest of the mountain; however Bartholomew (written communication, 1981) now believes the entire Price Formation and possibly some "Chemung" is exposed.

Because of the uncertainty over the exposures at the type locality, and because there is no easily measurable section of Price on the mountain, Bartlett (1974) suggests the Price exposures along Virginia State Highway 100 (or Virginia Route 100) on Cloyds Mountain be used as the reference section. The entire measured section of the Price Formation on Virginia Route 100 is given as Appendix A, and is illustrated in Fig. 4.

For further information on the evolution of stratigraphic nomenclature of the uppermost Devonian and lower Mississippian strata of Virginia, and on regional equivalents of the Price, the reader is referred to Kreisa (1972), Bartlett (1974) and Whitehead (1979).

Price Formation Members

Whitehead (1979) divided the Price Formation into seven members on the basis of lithofacies recognized in measured sections in Tennessee. These members are, in ascending order: Sunbury Shale Member, "Ceres" Member, "Wooton Gap" Member, "Hayters Sandstone" Member and "Laurel Creek" Member.

In this study, three divisions of the Price Formation were mapped across Montgomery and Pulaski Counties. These units were defined by Bartholomew and Lowry (1979). The Cloyd Conglomerate Member was not recognized by Whitehead in Tennessee. The Lower Price unit includes

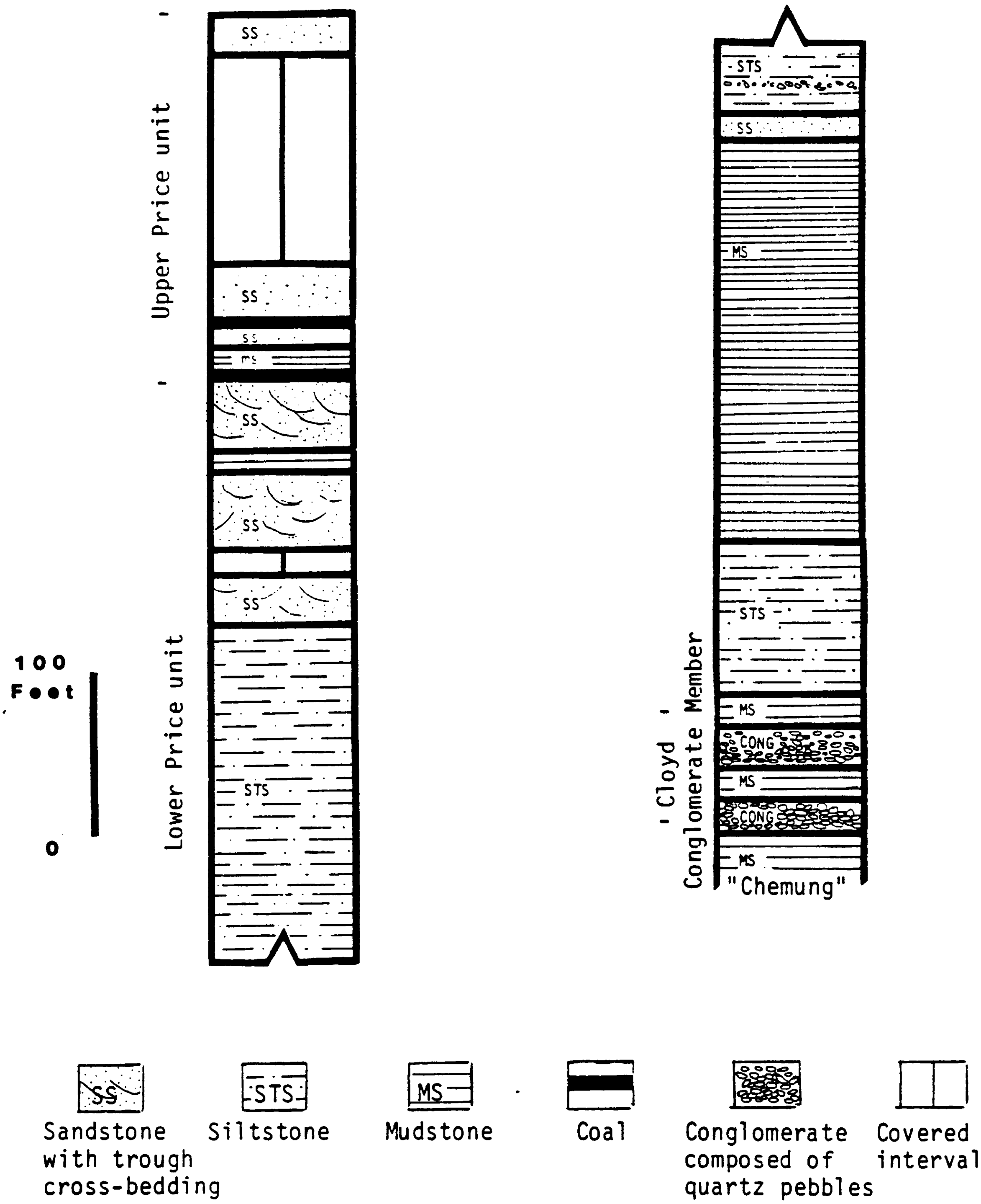

Fig. 4 Stratigraphic column of the Price Formation at the reference section, Virginia Route 100, Dublin, Virginia.

the first six members defined by Whitehead and the Upper Price unit is equivalent to the "Laurel Creek" Member.

In the following descriptions of the field units, Pettijohn's (1957) sandstone classification (Fig. 5) and Selley's (1976) conglomerate terms (Table 1) are used. Bedding thicknesses follow Ingram's (1954) scheme (Table 2). "Coarse," "medium," and "fine" sand sizes are estimations of Phi values 0.5, 1.5 and 2.5, respectively.

Cloyd Conglomerate Member- The basal quartz-pebble conglomerate of the Price Formation was first named the "Ingles" conglomerate by Campbell (1925) for an exposure of conglomerate on Ingles Mountain, south of Radford, Pulaski County. Butts (1940) renamed the member for exposures on Cloyds Mountain, west of the New River water gap, because the type "Ingles" was remapped as Silurian in age.

The Cloyd Conglomerate is a distinctive white to light gray oligomictic, milky quartz-pebble conglomerate and quartz arenite. Chert clasts are found in both the conglomerate and arenite. The conglomerate clasts are 0.8 to 4.0 inches in length. The associated sandstone is commonly coarse- to very coarse-grained and rarely fine-grained orthoquartzite. All clasts are rounded to well rounded. Silica cement is predominant, with some hematite cement noted by Kreisa (1972).

Bedding is medium to thick and includes large trough cross beds. Many beds are graded. Large wave ripples occur in places, on the upper surfaces of large cross beds, commonly on arenite or fine-pebble conglomerate beds.

Generally, the Cloyd is unfossiliferous; however, Kreisa (1972)

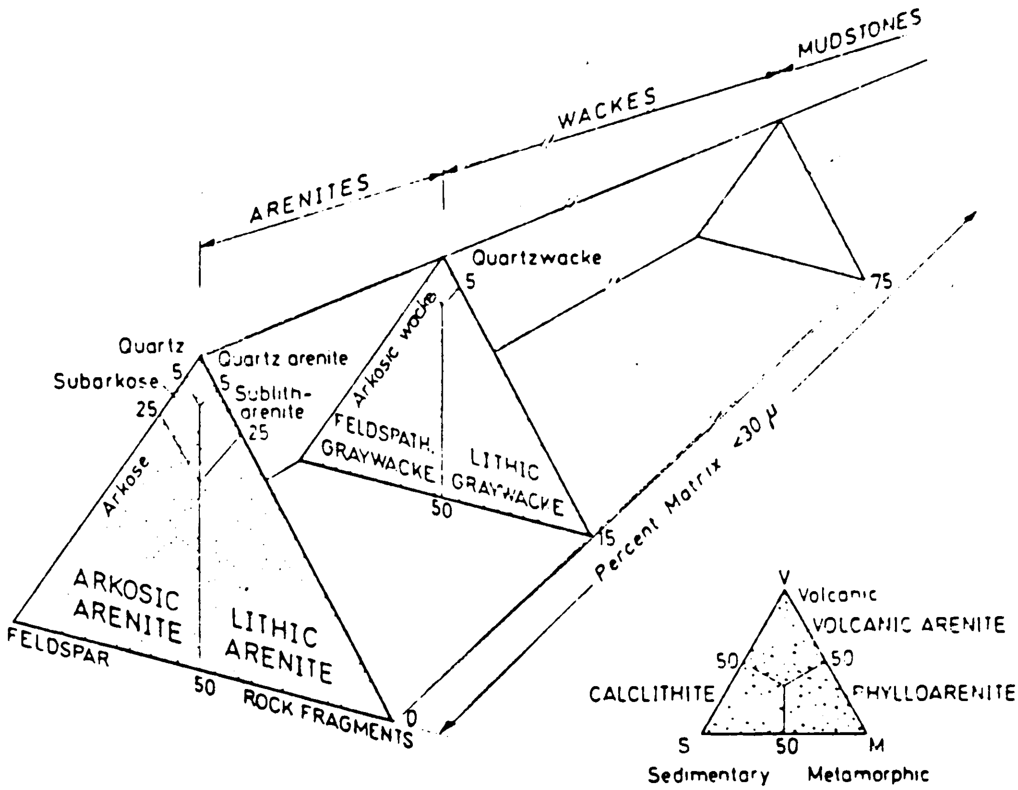

Fig. 5 Classification of terrigenous clastics.

Table 1

Nomenclature of Conglomerates

I.	Texture:	Orthoconglomerate-grain supported
		Paraconglomerate (syn. diamictite)-mud supported
II.	Composition:	Polymicitic-pebbles of several rock types
		Oligomicitc-pebbles of one rock type
III.	Source:	Intraformational-pebbles originate within the basin
		Extraformational (syn. exotic)-pebbles originate from outside the basin

Table 2

Ingram's Classification of Bedding Thickness

Units of Measure: Metric (cm)	Units of Measure: English (in.)	Terms for Bedding Thickness
- 0.3	- 0.1	thinly laminated
0.3- 1.0	0.1- 0.4	thickly laminated
1.0- 3.0	0.4- 1.0	very thinly bedded
3.0- 10.0	1.0- 4.0	thinly bedded
10.0- 30.0	4.0-12.0	mediumly bedded
30.0-100.0	12.0-36.0	thickly bedded
100.0-	36.0-	very thickly bedded

collected unbroken spiriferid and rhychonellid brachiopods and modiomorphid and pterioid pelecypods from sandy conglomerate beds along New River near Parrott, Pulaski County. Bambach, Deemer and Lewis (1974) described these fossils as a benthonic community adapted to living in a turbulent environment.

The amount of conglomerate in the Cloyd varies across the study area. For ten miles on either side of the New River water gap the conglomerate units of the member are developed into thick-bedded to very thick bedded lenses, up to 35 feet thick. The lenses thin abruptly; conglomerate may be thinly interbedded with quartz arenite or pinch out completely. The location of the New River water gap may have been partially controlled by the pinching out of the Cloyd conglomerate lens. Near the river, at reference locatity 2, the conglomerate beds are only 6 to 10 inches thick.

Five to forty feet of conglomerate was mapped northeast of New River to the Montgomery-Roanoke County line. Southwest of the river, conglomerate beds on Cloyds Mountain are well developed; however, farther southwest the lenses thin and grain size decreases. In Pulaski and Long Spur quadrangles, the conglomerate beds are 6 inches to 3 feet thick. Only a few very thin, discontinuous conglomerate lenses were found along the northern slope of Draper Mountain. Instead, a fine-grained light gray orthoquartzite located at the Price-"Chemung" boundary was mapped as the Cloyd.

Prior to and during the development of coal mining in the Price, the Cloyd Conglomerate was economically quarried for millstones (Campbell, 1925).

Lower Price unit- In contrast to the Cloyd Conglomerate Member, the Lower Price unit's lithology does not change greatly across the study area. Its petrography is dominantly very fine-grained to medium-grained sublitharenite (Kreisa, 1972), with abundant detrital mica. Thin trough and planar cross beds within medium to thick beds is characteristic.

Two types of conglomerate are found within the Lower Price unit. Close to the Cloyd-Lower Price boundary 6 to 8 inch beds of sandy quartz-pebble conglomerate occur. Toward the upper contact, intraformational conglomerates of very fine grained sandstone clasts in fine- to medium-grained sandstone occur slightly below the upper contact.

Within the Lower Price unit, a subunit was mapped, and called the "marker bed". This subunit is equivalent to Whitehead's "Hayters Sandstone" Member. The "marker bed" is 20 to 40 feet of medium- to coarse-grained, thick bedded lithic arenite. Trough cross bedding is common and detrital mica partings abundant. The upper limit of the "marker bed" is considered the contact between the Upper and Lower Price units.

Kreisa (1972) observed at least five phyla of marine fossils below the "marker bed". His fossil identifications include chonetid, spiriferid and rhychonellid brachiopds, pterioid and modiomorphid pelecypods, crinoids, gastropods, and bryozoans. Plant fragments are occasionally seen in the Lower Price, especially in the "marker bed" (e.g., on Virginia Route 100.)

Upper Price unit- Fine-grained clastic rocks, ranging from claystone to very fine grained sandstone, and coal seams form the coal measures part of the Upper Price unit. This subunit lies directly on the "marker bed". The top of the coal measures subunit is not precisely defined stratigraphically; very thin coals are found throughout the Upper Price and lower part of the Maccrady Formation. To limit the subunit, the coal measures are defined as the interval of the Price Formation which supported coal mining operations.

Because of the fine-grained nature of the coal measures, exposures of these rocks in the field are rare. The best exposure is within the reference section on Virginia Route 100. Here, both the Langhorne and Merrimac seams are visible on a 100-foot road cut on the east side of the highway, 6 miles north of the town of Dublin, Pulaski County.

Across the study area, the Langhorne seam is reported to be 1.5 to 3 feet thick (Campbell and Others, 1925); however, the seam is 10 feet thick at the reference section. The Langhorne grades above and below into dark gray claystone and contains a high ash content, but few partings.

The Merrimac seam's thickness varies between 6 and 20 feet across the study area (Campbell and Others, 1925). The maximum reported thickness (60 feet) was from the Altoona mine (C48 on Plate 1), and is attributed to tectonic thickening in the trough of a syncline. Clay partings are abundant in the Merrimac coal. Both coals are highly sheared, and rarely show butt and cleat cleavage or dull and bright lamination.

The coal measures on Virginia Route 100 coarsen upward from thinly laminated siltstone and claystone to medium-grained sandstone above the second (Merrimac) seam. Within the interval, grain size coarsens and fines gradationally. Burrows, root structures and wavy lamination are common sedimentary structures, especially in siltstone units. Plant fragments and coarse-sand sized carbonized plant debris are abundant.

Grain size changes across the study area. The coal measures are finer grained, in general, to the southwest. At section B (Fig. 2; Plate 1), the only calcareous bed, two inches of silty limestone or dolomite, occurs. To the northeast, at section L (Fig. 2; Plate 2), fine- to medium-grained feldspathic litharenites (Kreisa, 1972) dominate the coal measures.

Plant fossils are common in the coal measures, and floral listings were prepared for sections B, C, D, H, and L (Appendices A and B). Generally, the fossils are impressions or carbonized; however, in Pulaski Quadrangle upright lycopod tree stumps occur in several places. These trees are best exposed at reference locality 1 (Plate 1).

Above the coal measures, thin- to thick-bedded lithic arenites, interbedded with dark siltstones, compose the section. Thin coal seams are also present. The thick sandstone beds are often cross bedded and Kreisa (1972) observed current ripples. Red coloration increases upsection, first appearing in the mudstone units, as the Price Formation grades into the Maccrady Formation.

CHAPTER 5

DEPOSITIONAL ENVIRONMENTS OF COAL

Delta Plain Model of Coal Formation

Numerous outcrops and well logs have been studied to provide data for exploration and quality prediction of Carboniferous (usually meaning Pennsylvanian) coals of the eastern United States. A popular coal basin model is described by Horne, Ferm, Caruccio and Baganz (1978). In their model, Carboniferous coals formed on the plains of high constructive, elongate (Mississippi-type) deltas (Fig. 6).

Delta-lobe switching was a major step in the process of progradation and the formation of cyclic sediment packages in Carboniferous deltas (Swann, 1964). Basically, delta-lobe switching is the result of flowing water's tendency to reach base level via the steepest gradient.

As a distributary stream extends in the basin over its own lobe of delta front deposits, the stream gradient is reduced to nearly level. Landward, the stream will crevasse its natural levees to flow along a shorter, steeper slope. The abandoned lobe rapidly sinks through compaction of prodelta sediments and/or basin subsidence, and becomes reworked by wave and tidal forces. This destructive event is local in extent, although transgressive sheet sands may be spread over large areas. The redirected stream progrades into the basin while the gradient is sufficient, creating a new lobe. The process of delta-lobe switching is classically illustrated by the modern Mississippi River delta. The reader is referred to Reading (1980, p. 121-125) for a detailed discussion of the process and the Mississippi delta.

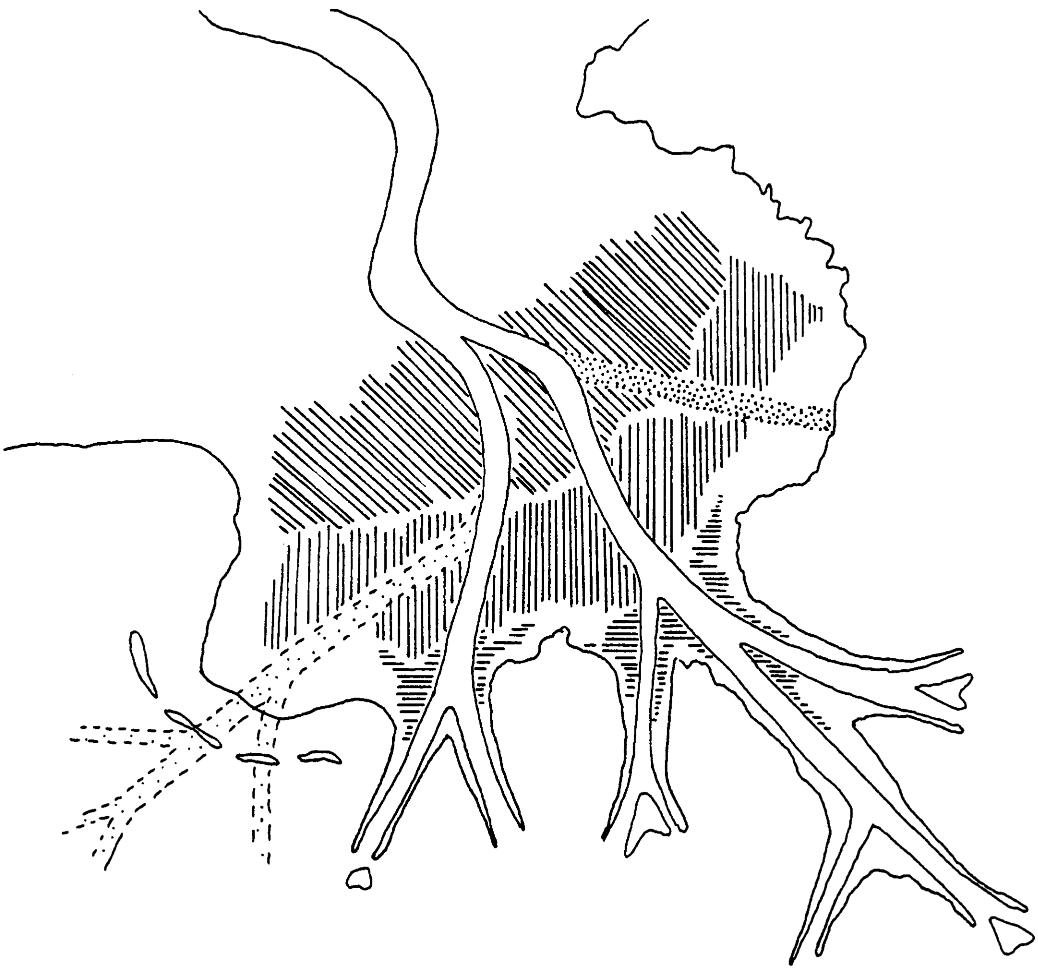

Fig. 6 Mississippi-type delta

Area of upper delta plain coal swamps

Area of transitional delta plain coal swamps

Area of lower delta plain coal swamps

Abandoned distributary

Potential distributary course

In the model for Carboniferous coal, the part of a high constructive elongate delta which prograded and subsided due to delta-lobe switching is called the lower delta plain. Peat accumulated in swamps flanking the distributary levees. The resultant coal seam morphology is elongate parallel to depositional dip. Because these coals were, as peat, under marine and brackish water influence they are high in biogenic sulfur.

Landward of the lower delta plain, subsidence and marine invasion were not as prevalent. This area is called the transitional lower delta plain. Shoaling of interdistributary bays by overbank flooding (Elliot, 1974) provided stable low-lying platforms for the development of laterally extensive (although not very thick) coal seams. Sulfur content in these coal is dependent on the depositional environment of the roof rock. Marine rocks above the coals allow saline waters to leach down into the seams, increasing their sulfur content (Caruccio and Ferm, 1975).

The upper delta plain was the area of greatest stability. It was dominated by meandering streams and the stratigraphy of these areas reflects the fluvial processes of meandering, levee-building and overbank flooding. Coal swamps lay between major distributaries. The swamps were not as areally extensive as transitional lower delta plain; however, peat deposits of the upper delta plain could develop great thickness. Upper delta plain coal is usually low in sulfur, and contains numerous partings due to flooding of nearby distributaries. Seams split and merge, and are channeled by meandering distributaries.

Cyclic Sedimentation

The geometry of high constructive, elongate deltas and the process of delta-lobe switching are conducive to production of cyclic sequences of rock. Many discussions of Pennsylvanian cycles and cyclothems have been written (for example see: Weller, 1930; Beerbower, 1964; Swann, 1964; Elliot, 1976; Broadhurst, Simpson and Hardy, 1980). Because of the abundant literature, cyclothems are considered classic Carboniferous stratigraphy.

A simple statistical analysis (Selley, 1970) was performed on the collective stratigraphic sections for the Price coal measures in Pulaski County and the core section from Price Mountain in order to identify any cyclic arrangement of rock types. The results revealed no cyclicity in the coal measures. This result is significant; it implies the Merrimac seam was not deposited in an environment similar to the Langhorne seam.

Depositional Model for Price Formation Coals

In Cloyd time, a large amount of hydrothermal quartz material entered the foreland basin from a source north of the study area. Longshore currents transported this material south. Offshore barrier bars formed (Kreisa and Bambach, 1973). Data from field mapping supports this interpretation of the lowest Price member, because: 1) the Cloyd pinches out to the south; in Pulaski and Long Spur quadrangles the unit was thinner and finer grained than elsewhere, 2) the Cloyd was mapped as lenses, and 3) trough cross bedding and wave ripples were noted. The elongate-blade grain shape of the Cloyd pebbles is also characteristic of high energy beach environments (Read, oral communication, May, 1981).

Observations of the Cloyd in other outcrop belts has led some investigators (Walker, 1964; Whitehead, 1979) to suggest a base-of-prodelta-slope environment with slump or turbidity current transport mechanism. No evidence for this explanation was found in the Little Walker-Cloyd-Brush Mountain outcrop belt.

Behind the Cloyd bars, lagoons filled with silt and very fine sand. Sandy quartz-pebble conglomerates in the Lower Price unit are interpreted by Kreisa (1972) as storm washovers from the bars.

From the outcrop belt across Montgomery and Pulaski Counties it is difficult to determine how long Cloyd-type bars existed offshore. The Lower Price unit was deposited in a situation of increasing energy up-section; its sands become slightly coarser and highly cross bedded in the "marker bed" subunit.

The "marker bed" may represent a unique stage of Price depositon. Kreisa (1972) included this unit with the non-marine sandstones of the Upper Price unit, as part of a transition zone between marine and non-marine deposits. He described the transition zone as a brackish or fresh water environment which may have supported plant life. No marine fossils have been noted in the "marker bed" sandstones. Kreisa believed the presence of vertical burrows suggestive of a tidal flat; however, no other tidal flat features, such as mudcracks, were noted. Schmidt (1973) interpreted cross bedding in the "marker bed" as point bar deposits.

Mapping across the field area has led the writer to believe parts of the "marker bed" subunit were under marine influence when deposited, and may be representative of a reworked distal distributary mouth bar facies. Sands were reworked by wave and tidal action, possibly from a northern source, and deposited as a delta front beach. Tidal channels and subsequent distributary channels dissected this facies to produce the mixture of marine and non-marine features. This hypothesis is based on: 1) lateral extent, 2) petrography, and 3) sedimentary structures.

1) The "marker bed" extends across the entire study area at a consistent stratigraphic horizon. This lateral extent suggests a marine origin.

2) A petrographic comparison of Lower Price marine, "marker bed" and Upper Price non-marine sandstone provides evidence for the reworked nature of the "marker bed"; however, because point-count data (Kreisa, 1972) is not available for all three types at one section the results may be coincidental. From the data in Table 4, it is shown that the "marker bed" has a low matrix percent, compared to the non-marine sandstone point-count from the same section and marine sandstone point-count from Route 781. It is important to note the lowest matrix percent belongs to a non-marine sandstone from U.S. Route 460.

3) Trough cross bedding and wave ripples are the dominant sedimentary features of the "marker bed". The trough cross bedding is best developed in eastern Newport and western McDonalds Mill quadrangles. Bartlett (Bartlett and Webb, 1972, p. 27) expressed surprise in results of his paleocurrent studies of the "marker bed" sandstone:

> " Northwestward flowing currents were anticipated from the eastward thickening isopach and eastern increase in clastic ratio. Oddly, it was found that a preponderance of cross bedding is inclined to the southeast..."

Bartlett proposed the "preponderance" was due to tidal influences or washover fans from shallow marine bars.

Table 3. Point-count analyses of marine, non-marine and "marker bed" sandstones.

Section	Sample no.*	Quartz				chert	k-spar	plag.	Rock Fragments		matrix
		common	hydro.	ortho.	meta.				meta.	sed.	
Non-marine sandstones											
H	15	42	3	-	5	-	-	-	13	tr.	17
L	24	47	4	-	15	-	-	4	10	-	9
K	72	No recorded data									
"Marker bed" sandstones											
H	14	33	1	-	11	tr.	-	-	28	-	10
K	44	No recorded data									
Marine sandstones											
H	72	No recorded data									
L	44	No recorded data									
K	30	54	2	-	5	-	-	2	5	1	24

* See Kreisa (1972) for exact sample locations.

Kreisa (1972), Bartlett (1974) and Bartholomew (personal communication, 1980) report thin coal below the "marker bed" on Virginia Route 100, County Route 781, and Price Mountain, respectively. Field mapping proved these coals are discontinuous. These seams possibly formed in lower delta plain-type coal swamps. The morphology of the swamps may have been modified from an elongate form by wave and tidal action. Plant material could also have accumulated along the shore due to rafting (Spackman, Riegel and Dolsen, 1969). The presence of the "marker bed" over these coals represents shifting of distributary channels and continued reworking of the distributary mouth bars.

A point source of the " marker bed" sheet sand is not known. If a large fluvial-deltaic system existed to the north of the field area in Cloyd time (Kreisa and Bambach, 1973), it may also have been available later to supply "marker bed" sediments. A thickening of the "marker bed" was noted in western McDonalds Mill quadrangle. Cutting of the Pulaski thrust into the Lower Price section prevents further investigation to the northeast within Montgomery County.

The depositional environment of the Upper Price unit can be deduced by applying the previously described coal model to the Langhorne and Merrimac seams.

The Langhorne was described by Campbell (1925) as 1.5 to 3 feet thick and as having rare clay partings. Analyses of the coal show it to be very low in sulfur. This seam is usually located a few feet above the "marker bed" and separated from it by very thin bedded micaceous siltstone. The Langhorne represents accumulation of peat on shoaled-bay fill over a delta front sheet sand and may be compared to the Pennsylvanian transitional lower delta plain coals.

Roof rock of the Langhorne seam is not cross bedded sandstones. Overlying rocks are silty shales or very fine-grained, flaggy sandstones. As the Price shoreline prograded, the Langhorne swamps were filled by overbank flooding. On Virginia Route 100, 45 feet of highly bioturbated claystone, siltstone and very fine-grained sandstone lie between the Langhorne and Merrimac seams. Plant fossils are abundant throughout this interval.

Campbell (1925) described the Merrimac coal as being variable in thickness, even within a single mine. It is thinnest at the Slusser mines (C14-15, Plate 2) and thickens generally to the southwest. At the Empire Mine (C43-44, Plate 1), the coal is 20 feet thick, with many partings in the central 8 feet. This interval of partings becomes a clastic wedge, splitting the Merrimac seam, in Wythe County, southwest of the study area. Within the field area, multiple seam traces above the Langhorne horizon are considered local splays off the Merrimac seam.

Features such as 1) variable thickness, 2) abundant partings, and 3) splitting of the seam identify the Merrimac coal as upper delta plain in origin. The roof rock types also support this conclusion. Merrimac mines have sandstone roof rocks. Recent reopening of the Keister Mine (Section K, Plate 2) has exposed thick low angle cross beds of fine sandstone. These are interpreted as point bar deposits. On Brookmont Road in Pulaski County (Section C, Plate 2), sandstone rock included upright Lepidodendropsis trunks. The upright trees indicate rapid burial, and the sandstone is interpreted as crevasse splay deposits.

As the alluvial plain prograded across the delta plain, red beds became more common; thus, the Price grades into the red Maccrady Formation. It is beyond the scope of this paper to discuss the Maccrady depositional environments; however red beds with nodular dolomite and dolomite lenses traced in the Maccrady during mapping suggest a drying trend in the climate.

The conclusion of this investigation is the Price Formation coals of Montgomery and Pulaski County were deposited on a high-energy shoreline. Sediments for the shoreline were initially transported from a northern deltaic source (Cloyd and Lower Price times) and later, from fluvial systems flowing across the coastal plain.

BIBLIOGRAPHY

Bartlett, C. S., Jr., 1974, Anatomy of the Lower Mississippian Delta in Southwestern Virginia: Ph.D. dissertation, University of Tennessee, Knoxville, Tennessee, 373 p.

-----, and H. W. Webb (Field trip leaders), 1972, Geologic Features of the Bristol and Wallace Quadrangles, Washington County, Virginia and Anatomy of the Lower Mississippian Delta in Southwestern Virginia; Field Guide No. 1, Department of Geology, Emery and Henry Colloge, Emory, Virginia, 45 p.

Bambach, R. K., E. J. Deemer and S. J. Lewis, 1974, Community paleo-ecology of a turbulent environment: the basal Cloyd Conglomerate (Lower Miss.), in Montgomery and Pulaski Counties, Virginia (abs.): A.A.P.G. Abstr. with Programs, v. 6, p. 330-331.

Bartholomew, M. J. and W. D. Lowry, 1979, Geology of the Blacksburg quadrangle, Virginia: Virginia Division of Mineral Resources Publication 14 (GM81B), text and 1:24,000 scale map.

Bartholomew, M. J., R. C. Millici and A. P. Schultz, 1980, Geologic structure and hydrocarbon potential along the Saltville and Pulaski thrusts in southwestern Virginia and northeastern Tennessee; Virginia Division of Mineral Resources Publication 24, sheets 1-4.

Beerbower, J. R., 1964, Cyclothems and cyclic depositional mechanisms in alluvial plain sedimentation; Kansas Geol. Survey Bull. no. 169, p. 31-42.

Branson, E. B., 1912, A Mississippian delta: Geol. Soc. America Bull., v. 23, p. 447-456.

Broadhurst, F. M., I. M. Simpson and P. G. Hardy, 1980, Seasonal sed-imenation in the Upper Carboniferous of England: Jour. Geol., v. 88, p. 639-651.

Butts, C., 1940, Geology of the Appalachian Valley in Virginia: Virginia Geol. Survey Bull. 52, part 1, 568 p.

Campbell, M. R., 1894, Paleozoic overlaps in Montgomery and Pulaski Counties, Virginia: Geol. Soc. America Bull., v. 5, p. 171-190.

-----, and Others, 1925, The Valley Coal Fields of Virginia: Virginia Geol. Survey Bull. 25, 322 p.

Caruccia, F. T. and J. T. Ferm, 1975, Paleoenvironment reconstructions and aid in predicting acid mine drainage problems, <u>in</u> P. H. Given and A. D. Cohen (eds.), Interdisciplinary Studies of Peat and Coal Origins (microfiche).

Colton, G. W., 1970, The Appalachian Basin: its depositional sequences and their geologic relationships, in Fisher et al. (eds.), Studies in Appalachian Geology: Central and Southern, p. 5-47.

Cooper, B. N., 1937, The Price Formation in the Draper Mountain area, Virginia: Jour. Geol., v. 45, p. 414-431.

----- 1961, Guidebook of the Grand Appalachian Excursion: V. P. I., Dept. of Geol. Sciences Gdbk. no. 1, 240 p.

Darrah, W. C., 1960, Priciples of Paleobotany, 2d ed., The Ronald Press Company: New York, 295 p.

Eby, J. B. and Staff, 1926, Analyses of Virginia Coals: U.S. Bureau of Mines Tech. Paper no. 365, 75 p.

----- 1944, Analyses of Virginia Coals: U.S. Bureau of Mines Tech. Paper no. 656, 159 p.

Elliot, T., 1974, Interdistributary bay sequences and their genesis: Sedimentology, v. 21, p. 611-622.

----- 1976, Upper Carboniferous sedimentary cycles produced by river-dominated, elongate deltas; Jour. Geol. Soc. London, v. 132, p. 199-208.

Fish, F. H., 1935, The agglutinating value of some lower volitile Virginia coals: V. P. I. Eng. Exper. Station Series Bull. no 20, 14 p.

----- and J. L. Porter, 1933, The gases liberated from Virginia coals by thermal decomposition at various temperatures: V. P. I. Eng. Exper. Station Series Bull. no. 16, 15 p.

Fisher, W. L., L. F. Brown, A. S. Scott and J. H. McGowen, 1969, Delta systems in the exploration for oil and gas: Bur. Econ. Geol., University of Texas, Austin, 78 p.

Glover, L., III, 1953, The stratigraphy of the Devonian-Mississippian boundary in southwestern Virginia: unpublished M.S. thesis, Virginia Polytech. Inst., 39 p.

Hatcher, R. D., Jr. and A. L. Odom, 1980, Timing of thrusting in the southern Appalachians, U.S.A.: model for orogeny?: Jour. Geol. Soc. London, v. 137, p. 321-327.

Horne, J. C. and J. C. Ferm, 1978, Carboniferous depositional environments in eastern Kentucky and southern West Virginia: Dept. of Geology, University of South Carolina, Columbia, 151 p.

-----, F. T. Caruccio and B. P. Baganz, 1978, Depositional model in coal exploration and mine planning in the Appalachian region: A.A.P.G. Bull., v. 62, p. 2379-2411.

Ingram, R. L., 1954, Terminology for the thickness of stratification and parting units in sedimentary rocks: Geol. Soc. America Bull., v. 65, p. 937-938.

Kreisa, R. D., 1972, The origin of the Price Formation in the type area, Montgomery and Pulaski Counties, Virginia: unpublished M.S. thesis, Virginia Polytech. Inst., 155 p.

----- and R. K. Bambach, 1973, Environments of deposition of the Price Formation (Lower Mississippian) in its type area, southwestern Virginia: Am. Jour. Sci., B. N. Cooper Mem. Volume 273-A, p. 326-342.

Lesquereux, L., 1884, Description of the coal flora of the Carboniferous formations in Pennsylvania and throughout the United States: Pa. 2d Geol. Survey Report, v. 3, p. 850-851.

Lowry, W. D., 1971, Appalachian overthrust belt, Montgomery County, southwestern Virginia, in Lowry (ed.), Guidebook to Appalachian Tectonics and Sulfide Mineralization of southwestern Virginia: V. P. I., Dept. Geol. Sciences Gdbk. no. 5, p. 143-178.

----- (ed.), 1979, Nature of Thrusting along the Allegheny Front near Pearisburg and of Overthrusting in the Blacksburg-Radford area of Virginia: V. P. I., Dept. Geol. Sciences Gdbk. no 8, 66 p.

Markello, J. R., C. G. Tillman and J. F. Read, 1979, Lithofacies and biostratigraphy of Cambrian and Ordovician platform and basin facies carbonates and clastics, southwestern Virginia, in Glover and Read (eds.), Guides to Field Trips 1-3 for Southeastern Section meeting, Geol. Soc. America, Blacksburg, Virginia, p. 42-85.

Pettijohn, F. J., 1957, Sedimentary Rocks, Harper and Row: New York, 628 p.

Read, C. B., 1955, Floras of the Pocono Formantion and Price Sandstone in parts of Pennsylvania, Maryland, West Virginia and Virginia: U.S. Geol. Survey P.P. no. 263, 30 p.

----- and S. H. Mamay, 1964, Paleozoic floral zones and floral provinces of the Unites States: U.S. Geol. Survey P.P. no. 454K, p. 1-35.

Reading, H. G., (ed.), 1980 Sedimentary Environments and Facies, Elsevier: New York, p. 121-125.

Rogers, H. D. and W. B. Rogers, 1858, The Geology of Pennsylvania, v.1, Penn. Geol. Survey, 586 p.

Rogers, W. B., 1884, A reprint of annual reports and other papers on the geology of the Virginias, A. Appleton and Company: New York, 832 p.

Scheckler, S. E. (ed.), 1978, Outcrops of the Price Formation (Lower Mississippian): Fieldtrip Guidebook for the Paleobotany Section of the Botanical Soc. Am. Plant Sciences Conference, V. P. I., Blacksburg, Virginia, 10 p.

Schmidt, G. L., 1973, The Price Formation, southwestern Virginia and southeastern West Virginia: unpublished M.S. thesis, University of North Carolina, Chapel Hill, 44 p.

Schultz, A. P., 1979, Deformation associated with Pulaski overthrusting in the Price Mountain and East Radford windows, Montgomery County, southwest Virginia: unpublished M.S. thesis, Virginia Polytech. Inst., 135 p.

Selley, R. C., 1970, Studies of sequence on sediments using a simple mathematical device: Jour. Geol. Soc. London., v. 125, p. 557-581.

----- 1976, An Introduction to Sedimentology, Academic Press: New York, 408 p.

Spackman, W., W. L. Riegel and C. P. Dolsen, 1969, Geological and biological interactions on the swamp-marsh complex of southern Florida, in Dapples and Hopkin (eds.), Environments of Coal Deposition: Geol. Soc. America S. P. 114, p. 1-36.

Stevens, D. W., 1959, A survey of factors which affect mining of the Lower Mississippian coals in Montgomery County, Virginia: unpublished M.S. thesis, Virginia Polytech. Inst., 74 p.

Swann, D. H., 1964, Late Mississippian rhythmic sediments of the Mississippi Valley, in Ancient Deltas: A.A.P.G. Reprint Series no. 19, p. 87-107.

Weller, J. M., 1930, Cyclical sedimentation of the Pennsylvanian period and its significance: Jour. Geology, v. 38, p. 97-135.

Whitehead, N. H., III, 1979, Lithostratigraphy of the Grainger-Price Formation, northeastern Tennessee and southwestern Virginia, and the depositional history of the east central United States: Ph.D. dissertation, University of North Carolina, Chapel Hill, 209 p.

APPENDIX A

Section H, the Reference Section.

Price Formation section is adapted from Bartlett (1974, p. 63-65). The lower Price unit is solely Bartlett's work. The coal measures portion was measured by the writer.

Location--Section located on Virginia State Highway 100, six miles north of Dublin, Virginia, from the crest of Cloyds Mountain to the 2120 foot elevation. Bedding dips 58° S36°E.

Unit No.	(Total Thickness) ft./m.	Unit Thickness ft./m.	Cumulative Thickness ft./m.
PRICE FORMATION (1630.8 ft/497.1 m.)			
Upper Price Unit (376.9 ft./115.0 m.)			
40	Sandstone, light olive-gray to gray, fine- to medium-grained, thin- to medium-bedded, argillaceous and arkosic (?); contains some light gray clay pebbles.	41.0/12.5	1630.8/497.1
39	Mostly covered except basal 20.0 ft./6.1 m. of carbonaceous shale, light brownish gray, containing carbonized plant stems.	206.0/62.8	1589.8/484.6
38	Sandstone, light olive-gray to pale red, very fine to medium-grained, medium- to thick-bedded, cross-bedded.	33.3/10.2	1383.8/421.8
37	Sandstone, weathers yellowish brown, very fine grained, argillaceous, interbedded with siltstone, light gray, carbonaceous.	12.2/ 3.7	1350.5/411.6
36	Siltstone, very light gray to yellowish gray, carbonaceous.	10.7/ 3.2	1338.3/407.9
35	Coal, with claystone partings. Abrupt basal contact with unit 34.	15.0/ 4.6	1327.6/404.7
34	Sandstone, dark gray, very fine grained to siltstone, thin-bedded,		

	thinly laminated, fissile, bioturbated. Upper surface contains some small coalified roots (?).	4.3/ 1.3	1312.6/400.1
33	Mudstone, light gray, grades up into unit 34, thin-bedded, highly bioturbated, abundant Chlidanophyton dublinensis fragments.	3.0/ 0.9	1308.3/398.8
32	Sandstone, very fine grained, interlaminated with siltstone, medium gray, thin-bedded, bioturbated.	4.3/ 1.3	1305.3/397.9
31	Sandstone, light gray, fine- to medium grained, with small plant fragments, interbedded with thin beds of siltstone.	6.0/ 1.8	1301.0/396.5
30	Claystone interbedded with siltstone, light maroonish gray, thin-bedded.	6.6/ 2.0	1295.0/394.7
29	Mudstone, light beige, interlaminated with claystone, light to medium gray, with claystone increasing upsection, claystone concretions (3.0-4.0 in./7.6-10.1 cm.) in upper 1 ft./0.3 m.	11.5/ 3.5	1288.4/392.7
28	Siltstone, light maroonish gray, thin-bedded, with coaly plant fragments.	1.3/ 0.4	1276.9/389.2
27	Claystone, dark brownish gray to black, thin-bedded, highly carbonaceous to coaly.	6.6/2.0	1275.6/388.8
26	Coal, black, highly sheared, grading from and into highly carbonaceous claystone.	10.5/ 3.2	1269.0/386.8
25	Siltstone, light gray to yellowish gray, very thinly laminated, with coaly plant fragments.	4.6/ 1.4	1258.5/383.6

Lower Price Unit (1168.0 ft./356.0 m.)

24	Sandstone, light to medium gray, fine- to coarse-grained, medium- to thick-bedded, silicic, partly		

	carbonaceous and contains lycopod trunk imprints in upper part.	21.0/ 6.4	1253.9/382.2
23	Sandstone, light gray, fine- to medium-grained, thin- to medium-bedded, argillaceous, partly very carbonaceous with plant imprints; some interbedded mudstone and siltstone in middle part, micaceous and carbonaceous.	41.8/12.7	1231.9/375.8
22	Sandstone, fine- to medium-grained, very light gray to light brown, grains subrounded, partly argillaceous, thin- to thick-bedded; some ripplemarked surfaces, trough S30°W.	16.3/ 5.0	1191.1/363.0
21	Carbonaceous shale, partly sandy and coaly in upper part, medium dark gray to dark gray; contains trunk segments of lycopods.	26.2/ 8.0	1174.8/358.1
20	Sandstone, friable, fine- to medium-grained, subrounded grains, light gray to grayish-orange-pink, medium- to thick-bedded; some beds contain large clay pebbles. Rare ripplemarked layer with trough trend S65°W. Changes to shaly, very thin bedded in upper half with shale partings. Few feet of sandy, carbonaceous shale 25.0 ft./7.6 m. below top.	58.0/17.7	1148.6/350.1
19	Argillaceous sandstone, fine- to medium-grained, yellowish gray to grayish orange, thin-bedded and with some interbedded silty shale.	20.6/ 6.3	1090.6/332.4
18	Covered interval, at turnout.	28.0/8.5	1070.0/326.1
17	Clay shale, pinkish gray and medium light gray, some vertical worm tubes.	4.8/ 1.5	1042.0/317.6
16	Sandstone, partly argillaceous, friable, fine- to very fine grained, very light gray, partly weathered pink, medium- to thick-bedded, cross-bedded;		

	contains very fine muscovite flakes and minor partings of very light gray clay shale.	45.0/13.7	1037.2/316.1
15	Interbedded silty shale, yellowish gray, sandy siltstone, olive-gray and argillaceous sandstones, very fine-grained, very thin bedded, weathered pink, contains rare crinoid columnals. Sandstone-siltstone vs. shale ratio estimated 1/5. At 13 ft./3.9 m. above base is 3 in./7.6 cm. streak of conglomeratic sandstone with pebbles to 8 mm.	327.7/20.1	992.2/302.4
14	Interbedded shale, sandstone and conglomerate. Shale or mudstone is medium light gray and weathers hackly; silty shale is medium light gray; sandstone partly fine- to very fine grained, yellowish gray and partly argillaceous, medium gray, very thin to medium bedded. Ratio is 2/1; some bedding planes very micaceous. At 27.0 ft./8.2 m. above base is a 4.0 ft./1.2 m. bed of ferruginous quartz-pebble conglomerate with rounded pebbles to 17 mm. diameter. Just above this bed is a fossil-bearing sandstone with abundant _Chonetes_ sp. brachiopods and ostracods. At 60.0 ft./18.3 m. above unit base is another ferruginous fossiliferous sandstone, thinly laminated and spheroidally weathered, containing _Chonetes_ sp., _Camarotechia mutata_ Hall and abundant ostracods.	71.0/21.6	664.5/202.5
13	Sandstone, fine- to medium-grained, light gray, micaceous, thick- to massive-bedded; at top is 0.5-foot ferruginous quartz-pebble conglomerate with pebbles to 12 mm. Ferruginous fossiliferous streak at base contains _Chonetes_ sp., crinoid columnals, and unidentified pelecypods and gastropods.	15.5/ 4.7	593.5/180.9

12	Interbedded sandstone, fine- to very fine grained, mostly very thin bedded but with few thin to medium beds, and silty shale, medium gray.	13.8/ 4.2	578.0/176.2
11	Shale and mudstone, medium light gray, containing rare imprints of *Chonetes* sp.; some interbedded siltstone, light olive-gray, micaceous, increasing upward. Ratio estimated 1/5.	380.5/116.0	564.2/172.0
10	Interbedded argillaceous sandy siltstone, light olive-gray, very thin bedded; dense sandstone, very fine grained, light gray, slightly carbonaceous, thin-laminated and cross laminated, medium bedding; and very silty shale, light olive-gray, blocky. Upper 28.0 ft./8.5 m. mostly sandstone.	63.0/ 19.2	183.7/ 56.0
9	Coarse siltstone, quartzitic, medium gray, and very fine grained sandstone, light olive-gray, thin- to medium-bedded.	9.0/ 2.7	120.7/ 36.8
8	Slightly silty mudstone, yellowish-gray and some coarse siltstone, light olive-gray, very thin to thin-bedded. Ratio 1/4.	25.8/ 7.9	111.7/ 34.1
Cloyd Conglomerate Member (85.9 ft./26.2 m.)			
7	Conglomeratic sandstone, quartzitic, containing pebbles to 45 mm., medium gray, thin- to thick-bedded and some orthoquartzite, very fine-grained, light gray.	9.5/ 2.7	85.9/ 26.2
6	Silty shale and mudstone, very light gray, slightly carbonaceous; poorly exposed.	15.1/ 4.6	76.4/ 23.3
5	Quartz-pebble conglomerate, quartzitic, partly ferruginous, thick- to very thick bedded; top surface studded with rounded quartz and quartzite pebbles to 70 mm., float pebbles to 95 mm.	10.0/ 3.0	61.3/ 18.7

4	Small thrust fault repeats units 5 and 6		
3	Shale and mudstone, soft, medium to dark gray, partly light brownish-gray, weathers fissile; contains rare imprints of ostracods, pelecypods and orbiculoid brachiopods.	26.0/ 7.9	51.3/ 15.6
2	Interlayered orthoquartizite, very fine to fine-grained, very light gray and quartz-pebble conglomerate, light gray, pebbles to 65 mm. at 2.0 feet above base. Partly ferruginous and contains some light gray clay-pebbles. Upper half has some inter-bedded soft sandy shale and mudstone, yellowish- gray.	25.3/ 7.7	25.3/ 7.7
	"Chemung" Sandstone (?) (104.0 ft./ 31.7 m., incomplete)		
1	Very silty shale, light olive-gray, hackly. At 17.0 feet above base is 8.5-foot thick dense fossiliferous sandstone, very fine to fine-grained brownish gray, containing some light gray clay-pebbles. Fossils include Chonetes sp., and Camarotoechia contracta Hall.	104.0/31.7	104.0/31.7

Plant List:

Chlidanophyton dublinensis
Lycopod trucks

APPENDIX B

Section A.

Coal measures portion of Price Formation section adapted from Bartlett (1974, p. 326).

Location - Section is located south of the town limits of Pulaski, on U.S. Highway 11, between Hermosa Dr. and Valley Street. Bedding dips 38 degrees N20°W.

Unit No.	(Total Thickness) ft./m.	Unit Thickness ft./m.	Cumulative Thickness ft./m.
PRICE FORMATION (818.3 ft./249.3 m., incomplete)			
Upper Price Unit (617.0 ft./100 m., incomplete)			
14	Coarse siltstone, olive-gray to light olive-gray, and shale, light olive-gray, hackly.	59.0/18.0	818.3/249.3
13	Silty shale, light olive-gray, hackly.	17.3/ 5.3	759.3/231.3
12	Very fine grained sandstone to coarse siltstone, light olive-gray, dense, medium- to thick-bedded.	31.0/ 9.4	742.0/226.0
11	Mostly covered. Arkosic sandstone, fine- to medium-grained, light gray, carbonaceous, thin- to medium-bedded and cross-bedded.	325.0/99.1	711.0/216.6
10	Mostly covered. Near top is 2.0-foot coal and 10 feet of shale, medium gray.	105.0/32.0	386.0/117.5
9	Silty shale, medium gray to yellowish gray, brittle, sub-fissile; some coaly streaks, crumpled near fault.	67.0/20.4	281.0/ 85.0
8	Upper part mostly covered. Shale, medium dark gray, brittle; plant imprints of <u>Rhodea</u> sp., contorted, contains one or two thin coal beds.	13.0/ 3.9	214.0/ 65.1
Lower Price Unit, upper tongue (44.0 ft./13.4 m.)			
7	Very argillaceous sandstone,		

	very fine to fine-grained, medium dark gray, carbonaceous, thin-bedded; weathers shaly; oscillation ripple marks with trough trending S50°E at 9.0 feet above base; some silty shale, dark gray, brittle, very thinly laminated.	16.0/ 4.9	201.0/ 61.2
6	Arkosic sandstone, fine- to coarse-grained, light gray, light olive-gray and medium gray, very carbonaceous in upper part, medium-bedded, cross-bedded.	28.0/ 8.5	185.0/ 56.3
Upper Price Unit (89.6 ft./27.3 m.)			
5	Partly silty clay shale, light gray, smooth waxy wrinkled surfaces; and sandy carbonaceous siltstone, medium gray; some plant fragments, mostly covered.	47.0/14.3	157.0/ 47.8
4	Covered interval.	37.6/11.4	110.0/ 33.5
3	Covered, coaly soil. Some fresh coal was dug out but exact thickness of coal uncertain.	5.0/ 1.5	72.4/ 22.1
Lower Price Unit, the "marker bed" (67.4 ft./20.5 m.)			
2	Arkosic sandstone, fine- to medium-grained, light gray; some dark gray, very carbonaceous at top, thin- to medium-bedded.	39.4/12.0	67.4/ 20.5
1	Covered interval.	28.0/ 8.5	28.0/ 8.5

Plant List (from Read, 1955):

Rhodea blacksburgensis
Triphyllopteris lescuriana

Section B.

Measured by Ingram and Brown.

Location - Section is located 2.05 miles N64^{o}W bearing from the Pulaski High School. The section is accessible by hiking in from the north along an unimproved jeep trail. The jeep trail intersects Route 640, 1.5 miles south of the intersection of County Route 738 (Robinson Tract Road) and County Route 640 (Brookmont Road).

Unit No.	(Total Thickness) ft./m.	Unit Thickness ft./m.	Cumulative Thickness ft./m.
	PRICE FORMATION (51.3 ft./ 15.5 m., incomplete)		
	Upper Price Unit (51.3 ft./ 15.5 m., incomplete)		
13	Claystone, light to medium gray and light maroonish gray, thin- to medium-bedded, some portions highly phytoturbated with abundant plant imprints.	10.0/ 3.0	51.3/15.5
12	Silty claystone, medium gray, highly phytoturbated.	3.0/ 0.9	41.3/12.5
11	Coal, black, very sheared.	1.0/ 0.3	38.3/11.6
10	Siltstone, medium gray, thin-bedded; grades upward into claystone, light buff-gray, dense.	4.0/ 1.2	37.3/11.6
9	siltstone, dark gray, thin-bedded,fissile.	6.0/1.8	33.3/10.1
8	Coal, black, very sheared.	0.7/ 0.3	27.3/ 8.3
7	Claystone, dark gray, thin-bedded; grades upward into siltstone, carbonaceous, fissile, with iron-stained surfaces.	3.0/ 0.9	26.6/ 8.0
6	Siltstone, medium gray, weathering olive-gray, thin-bedded, slightly calcareous, with small clayey (1 in.) concretions.	5.0/ 1.5	23.6/ 7.1
5	Impure limestone, dark to		

	medium gray, weathering orangish buff, blocky or subspheriodal, persistent across cliff face.	0.2/ 0.06	18.6/ 5.6
4	Siltstone, dark gray, very thin-bedded, becoming sandy upward; middle interval interbedded mudstone and medium-bedded sandstone, fine-grained.	6.0/ 1.9	18.4/ 5.6
3	Sandstone, medium gray, fine-grained, thin-bedded, highly carbonaceous with coaly surfaces along shears, contorted.	7.5/ 2.3	12.4/ 3.7
2	Claystone, medium gray, thinly laminated, lightly carbonaceous, highly fossiliferous; log imprints parallel and perpendicular to bedding.	1.0/ 0.3	4.9/ 1.4
1	Coal, measured in drift (within the mine).	3.9/ 1.1	3.9/ 1.1

Plant List:

Triphyllopteris rarinervis
T. lescureuiana
Rhodea vespertina
Lepidodendropsis vandergrachtii
Sphenopteris elegans
Cardiopteridium fragments
Gnetopsis hispida

Section C.

Measured by Ingram and Brown.

Location - Section is located in a road cut, slightly less than one mile south of the intersection of County Route 738 (Robinson Tract Road) and County Route 640 (Brookmont Road), on Route 640.

Unit No.	(Total Thickness) ft./m.	Unit Thickness ft./m.	Cumulative Thickness ft./m.
PRICE FORMATION Upper Price Unit (13.2 ft./ 4.0 m.)			
9	Sandstone, light gray, weathering buff, very fine to fine-grained, thin-bedded with distinct 1- to 2-inch layers of clay-galls; tree stump casts perpendicular to bedding, 6- to 8-inch diameters; plant fossil imprints on bedding planes.	2.0/0.6	13.1/4.0
8	Siltstone, medium gray to light gray, with thin irregular laminations, carbonaceous, distinct clay-gall layers.	3.5/1.0	11.1/3.4
7	Siltstone, dark gray, thin-bedded and cross-bedded, abundant fine-grained carbonized plant fragments.	0.2/0.006	7.6/2.3
6	Coal, with bright and dull laminations.	0.2/0.06	7.4/2.3
5	Siltstone, dark gray to black, very fine grained sandstone, phytoturbated, abundant fine-grained carbonized plant fragments, coaly streaks, iron-stained.	1.1/0.3	7.2/2.2
4	Claystone, dark gray to black, fossiliferous, with <u>Lepidodendropsis</u> sp. imprints.	2.5/0.8	6.1/1.9
3	Coal, with clay partings.	1.8/0.5	3.6/1.1
2	Claystone, medium dark gray, phytoturbated with root casts.	1.0/0.3	1.8/0.5
1	Claystone, light gray, small		

roots or burrows, dense.	0.8/0.2	0.8/0.2

Plant List (from Scheckler, 1978):

Lepidodendropsis vandergrachtii
L. scobiniformis
Triphyllopteris rarinervis
Neuropteris (?)
Gneotpsis hispida or Carpolithers
sporangial aggregations, affinity unknown

Section D.

Coal measures portion of Price Formation section, adapted from Bartlett (1974, p. 302-303).

Location - Section is 5 miles north of Pulaski on Pulaski County Route 738. The section begins 0.3 mile west of the crest of Little Walker Mountain and continues to the 2200-foot contour line.

Unit No.	(Total Thickness) ft./m.	Unit Thickness ft./m.	Cumulative Thickness ft./m.
PRICE FORMATION (187.4 ft./ 57.1 m., incomplete)			
Upper Price Unit (120.2 ft./ 36.6 m., incomplete)			
6	Carbonaceous shale, medium to dark gray with 0.5-foot coal seam at base and 0.9-foot coal seam near top.	11.0/ 3.4	187.4/57.1
5	Silty sandstone, very fine grained, light olive-gray, thin-bedded, and interbedded silty shale, light gray, hackly; plant fossil imprints common.	30.8/ 9.4	176.4/53.7
4	Clay shale, light gray, sub-fissile, with abundant fossil plant imprints; some silty shale, dark gray, fissile.	28.0/ 8.5	145.6/44.3
3	Clay shale, medium gray to medium light gray, carbonaceous, fissle and interbedded argillaceous sandstone, weathering light orange-pink, feldspathic, very fine grained, ratio of 2/1. One vertebra-like imprint found.	16.8/ 5.1	117.6/35.8
2	Mostly covered.	33.6/10.3	100.8/30.7
Lower Price Unit (67.2 ft./ 20.4 m.)			
1	Sandstone, medium dark gray to medium light gray, weathering yellowish gray, feldspathic, medium- to fine- grained with streaks on lower half, medium		

to very coarse-grained with scattered subrounded quartz pebbles up to 0.2 inch, thick- to very thick bedded.	67.2/20.4	67.2/ 20.4

Plant List (from Scheckler, 1978):

Triphylopteris rarinervis
T. biloba
Rhodea vespertina
Lagenospermum imparirameum
Gnetopsis hispida

Section E.

Measured by the writer.

Location - Section measured at an elevation of 2385' above sea level, 500 feet S75W from the most northern part of County Route 642 (Empire Mine Road), in the northern part of Pulaski 7.5-minute quadrangle.

Unit No.	(Total Thickness) ft./m.	Unit Thickness ft./m.	Cumulative Thickness ft./m.
	PRICE FORMATION (57.4 ft./17.4 m.,incomplete) Upper Price Unit (52.5 ft./16.0 m., incomplete)		
15	Sandstone, maroonish gray, fine-grained, thin-bedded, with fine-grained carbonized plant fragments.	2.0/0.6	57.4/17.4
14	Mudstone, dark medium gray, thin-bedded.	1.0/0.3	55.4/16.8
13	Mudstone, maroonish gray, thin-bedded.	3.9/1.2	54.4/16.5
12	Mudstone, dark to medium gray, highly bioturbated.	5.9/1.7	50.5/15.3
11	Covered interval; upper portion correlates with horizon containing mine adit.	15.0/4.6	44.6/13.6
10	Covered interval; soil is dark gray to black, possible weathered coal seam.	4.9/1.5	29.6/ 9.0
9	Mudstone, dark to medium gray, thin-bedded.	3.0/0.9	24.7/7.5
8	Coal.	2.0/0.6	21.7/ 6.6
7	Mudstone, medium gray, thin-bedded, abundant plant fossils (fragments); thin coal seam (0.3-foot) at the bottom.	2.3/0.7	19.7/ 6.0
6	Mudstone, mottled maroonish gray and medium gray, bioturbated.	2.6/0.8	17.4/ 5.3

5	Sandy siltstone, maroonish gray, thin-bedded.	2.0/0.6	14.8/ 4.5
4	Mudstone, dark to medium gray, bioturbated.	1.0/0.3	12.8/ 3.9
3	Sandstone, medium gray, fine-grained, carbonaceous, with abundant carbonized plant fragments, cross-bedded.	2.0/0.6	11.8/ 3.6
2	Covered interval. Adit located within this interval.	4.9/1.5	9.8/ 3.0
Lower Price Unit (?) (4.9 ft./ 1.5 m.)			
1	Sandstone, mostly covered, weathered buff, fine- to medium-grained, friable.	4.9/1.5	4.9/1.5

Section F.

Measured by Bartholomew and the writer.

Location - Section is located 300 feet north of the most northern point of the Empire Mine Road, on an unimproved jeep trail, in the northern part of the Pulaski 7.5 minute quadrangle.

Unit No.	(Total Thickness) ft./m.	Unit Thickness ft./m.	Cumulative Thickness ft./m.
PRICE FORMATION (73.7 ft./ 22.3 m., incomplete)			
Upper Price Unit (48.8 ft./ 14.7 m., incomplete)			
13	Partly covered interval, dark gray to black soil and highly weathered coal.	20.0/ 6.0	73.7/22.3
12	Siltstone, medium gray, thin-bedded, partly cross-laminated, few plant fragments; upper surface with distinct root-traces (?) evenly spaced.	3.9/ 1.2	53.7/16.3
11	Mudstone, dark to medium gray, thin-bedded.	3.0/ 0.9	49.8/15.1
10	Mudstone, medium grey, thin-bedded with frequent fossil plant fragments.	3.0/ 0.9	46.8/14.2
9	Mudstone, maroonish gray.	1.0/ 0.3	43.8/13.3
8	Siltstone, medium gray, thin-bedded and cross-laminated.	1.0/ 0.3	42.8/13.0
7	Sandstone, partly covered, light gray, medium-grained.	3.0/ 0.9	41.8/12.7
6	Covered interval, black to medium gray soil.	3.0/ 0.9	38.8/11.8
5	Sandstone, medium gray, fine-grained, thin-bedded, cross-laminated.	2.0/ 0.6	35.8/10.9
4	Covered interval, dark gray to black soil.	4.9/ 1.5	33.8/10.3

3	Sandstone, light gray and maroonish gray, medium-grained.	3.0/ 0.9	28.9/ 8.8
2	Claystone, maroonish gray.	1.0/ 0.3	25.9/ 7.9

Lower Price Unit (24.9 ft./ 7.6 m., incomplete)

1	Sandstone, light gray, weathering light buff, medium-grained, argillaceous, medium-bedded.	24.9/ 7.6	24.9/ 7.6

Section G.

Coal measures portion of Price Formation section adapted from Bartlett (1974, p. 306).

Location - Section is located about 7 miles north of Pulaski on Pulaski County Route 643, beginning about 200 yards north of Little Walker Mountain summit, and measured down the south slope to elevation 2260 feet.

Unit No.	(Total Thickness)	Unit Thickness ft./m.	Cumulative Thickness ft./m.
PRICE FORMATION (355.9 ft./ 108.4 m., incomplete)			
Upper Price Unit (273.4 ft./ 83.3 m., incomplete)			
6	Argillaceous sandstone, light brownish gray, very fine to fine-grained, arkosic, thin-bedded, grades upward to sandy argillaceous siltstone, grayish orange and light olive-gray.	54.0/ 16.4	355.9/ 108.4
5	Silty shale, dark gray, trace carbonaceous matter, brittle and fissile.	7.4/ 2.3	301.9/ 92.0
4	Silty mudstone, yellowish gray to pinkish gray, laminated, very thinly bedded.	92.0/ 28.1	294.5/ 89.7
3	Black coal and clay shale, light brownish gray with abundant plant fragments.	5.0/ 1.6	202.5/ 61.6
2	Slightly silty mudstone, very light gray; and argillaceous sandy siltstone, weathers yellowish gray.	79.0/ 24.0	197.5/ 60.1
Lower Price Unit (118.5 ft./ 36.1 m., incomplete)			
1	Sandstone, medium to light gray, fine- to medium-grained, medium- to thick-bedded.	118.5/ 36.1	118.5/ 36.1

Section I.

Measured by Ingram and Brown.

Location - Section is located at an elevation 2080 feet, at the head of the fifth tributary to Back Creek, in the northwestern part of Staffordsville 7.5 minute quadrangle. The section is accessible by hiking in from the south on an unimproved jeep trail which intersects County Route 612 at 1.14 miles WSW of the intersection of County Route 612 and County Route 600, near the New River.

Unit No.	(Total Thickness)	Unit Thickness ft./m.	Cumulative Thickness ft./m.
PRICE FORMATION (99.6 ft./ 30.0 m., incomplete)			
Upper Price Unit (96.6 ft./ 29.4 m., incomplete)			
8	Sandstone, light gray, fine- to medium-grained, with large (greater than 2 feet) log impressions.	9.8/ 3.0	99.6/ 30.3
7	Claystone, light gray, highly burrowed, with occasional plant fossils.	2.6/ 0.8	89.8/ 27.3
6	Clayey siltstone, medium gray, thin-bedded, highly carbonaceous with coaly streaks, abundant plant fossils.	0.7/ 0.2	87.2/ 26.5
5	Coal, black, occasionally banded, sheared; interbedded with claystone, dark gray to black, thin-bedded.	6.6/ 2.0	86.5/ 26.3
4	Siltstone, and clayey siltstone, dark gray to black, coaly surfaces.	1.6/ 0.4	79.9/ 24.3
3	Claystone, light gray, burrowed, occasional fossil leaves and fragments.	0.3/ 0.09	78.3/ 23.9
2	Covered interval; may include part of Lower Price Unit.	75.0/ 22.9	78.0/ 23.8
Lower Price Unit (3.0 ft./ 0.9 m., incomplete)			
1	Sandstone, light to medium gray, medium-grained, thick- to medium-bedded.	3.0/ 0.9	3.0/ 0.9

Plant List:

Rhodea sp.
lycopod truncks

Section J.

Coal measures portion of Price Formation section adapted from Bartlett (1974, p. 309).

Location - Section measured on the west bank of the New River, along the Norfolk and Western Railway, between 0.5 and 1.5 miles north of Parrott. The complete section begins at the railroad signal lights 300 yards north of a prominent outcrop of Cloyd Conglomerate.

Unit No.	(Total Thickness) ft./m.	Unit Thickness ft./m.	Cumulative Thickness ft./m.
PRICE FORMATION (410.1 ft./ 124.9 m., incomplete)			
Upper Price Unit (394.5 ft./120.0 m., incomplete)			
17	Arkosic sandstone, medium to light gray, fine-grained, subangular, thin-bedded, cross-bedded; and shaly siltstone, medium to dark gray, carbonaceous, very thin bedded.	33.6/ 10.2	410.1/124.9
16	Clay shale; weathers dusky yellow, poorly exposed.	22.4/ 6.8	376.5/114.7
15	Interbedded clayey siltstone, light olive-gray and sandstone, light olive-gray, very fine-grained, thin- to medium-bedded.	28.0/ 8.5	354.1/107.8
14	Claystone, medium to dark gray and light olive-gray.	28.0/ 8.5	326.1/ 99.3
13	Very silty mudstone, light olive-gray, medium- to thick-bedded.	22.4/ 6.8	298.1/ 90.8
12	Claystone, slightly silty, medium to dark gray.	28.0/ 8.5	275.7/ 84.0
11	Covered interval,possible fault, steep dip in unit 10.	67.2/ 20.5	247.7/ 75.5
10	Argillaceous sandstone, light olive-gray, very fine to fine-grained, subangular, medium-bedded, weathers spheroidally.	10.0/ 3.0	180.5/ 55.0
9	Poorly exposed, shaly siltstone, light olive-gray; and silty clay-stone, medium gray. At 29.0 feet		

	above base some thin coaly shale streaks.	50.2/ 15.4	170.5/ 52.0
8	Sandstone, light gray, very fine-grained, thin-bedded, thinly laminated, interbedded with silty shale, medium gray, carbonaceous, poorly bedded.	16.8/ 5.1	120.3/ 36.6
7	Slightly silty clay shale, medium gray, hackly.	26.3/ 8.0	103.5/ 31.5
6	Coal, black.	8.0/ 2.4	77.2/ 23.5
5	Partly silty shale, medium to dark gray, carbonaceous, hackly; one thin bed of fine-grained sandstone, light gray.	25.2/ 7.7	69.2/ 21.1
4	Covered, probably contains coal.	14.2/ 4.4	44.0/ 13.4
3	Sandstone, light gray, very fine to fine-grained, carbonaceous, with fine mica flakes, thin-bedded with partings of silty shale, light gray, highly carbonaceous.	10.7/ 3.2	29.8/ 9.0
2	Coal and very carbonaceous, micaceous mudstone, dark yellowish brown.	3.5/ 1.1	19.1/ 5.8
Lower Price Unit (15.6 ft./ 4.7 m., incomplete)			
1	Sandstone, light olive-gray to medium gray, fine-grained, thin-bedded; upper part micaceous with large carbonized plant stems.	15.6/ 4.7	15.6/ 4.7

Section K.

Coal measures portion of Price Formation section abapted from Bartlett (1974, p. 314-315).

Location - Complete section is located on Montgomery County Route 781, seven to eight miles west of Blacksburg. The section begins 1.2 miles northwest of Sunnyside Church.

Unit No.	(Total Thickness) ft./m.	Unit Thickness ft./m.	Cumulative Thickness ft./m.
PRICE FORMATION (376.5 ft./ 114.7 m., incomplete)			
Upper Price Unit (336.3 ft./ 102.5 m., incomplete)			
11	Arkosic sandstone, light olive-gray, very fine to fine-grained, partly argillaceous with trace carbonaceous material, thin- to thick-bedded, cross-bedded; forms topographic ridge.	39.0/ 11.9	376.5/ 114.7
10	Covered interval.	60.0/ 18.2	337.5/ 102.8
9	Arkosic sandstone, medium gray, fine- to medium-bedded, argillaceous, thin-bedded, partly cross-bedded; interbedded with siltstone, light olive-gray; thin, dense ferruginous layer 30 feet from base.	67.5/ 20.6	277.5/ 84.6
8	Very arkosic sandstone, medium to light gray, fine- to medium-grained, finely micaceous and very carbonaceous on some bedding planes, thin- to thick-bedded, cross-bedded.	54.5/ 16.6	210.0/ 64.0
7	Covered interval.	32.0/ 9.8	155.5/ 47.4
6	Sandstone, medium to light gray, very fine to fine-grained, slightly carbonaceous; interbedded with silty shale, medium gray, subfissile.	9.0/ 2.7	123.5/ 37.6
5	Coal, black, sheared.	4.0/ 1.2	114.5/ 34.9
4	Siltstone, medium to dark gray, partly carbonaceous.	16.9/ 5.2	110.5/ 33.7

3	Covered interval.	15.8/ 4.8	93.6/ 28.5
2	Sandy siltstone, light olive-gray, thin-bedded; grades upward into silty mudstone, medium to dark gray, subfissile; partly covered.	37.6/ 11.5	77.8/ 23.7

Lower Price Unit (40.2 ft./ 12.2 m., incomplete)

1	Sandstone, medium gray to light olive-gray, very fine to medium-grained, thin- to medium-bedded, dominantly composed of quartz with some feldspar, and argillaceous; ripple marks with trough trends at S 60°W and due W.	40.2/ 12.2	40.2/ 12.2

Section L.

Coal measures portion of the Price Formation section measured by the author, and is recorded with descriptions by Bartlett (1974, p. 326).

Location - Section is located on and near U.S. Highway 460, close to the base of Brush Mountain. Section was measured from the stream culvert on Coal Bank Hollow Road where the road intersects the highway, south along U.S. Highway 460 to the intersection of County Route 648.

Unit No.	(Total Thickness) ft./m.	Unit Thickness ft./m.	Cumulative Thickness ft./m.
PRICE FORMATION (334.6 ft./ 102.0 m., incomplete)			
Upper Price Unit (281.4 ft./ 85.8 m., incomplete)			
9	Siltstone, light to medium gray, with some fine-grained sandstone beds, medium gray, thin- to medium-bedded.	33.6/ 10.3	334.6/ 102.0
8	Siltstone, dark gray, carbonaceous, thin-bedded, brittle; with minor very fine grained sandstone, light gray, very thin bedded. At top is 1.5-foot thick coal with some sulfur bloom.	50.4/ 15.4	301.0/ 91.7
7	Covered interval.	105.0/ 32.0	250.6/ 76.3
6	Sandstone, weathering pink and orange, fine- to medium-grained, thin- to medium-bedded, possibly including some feldspar, with argillaceous matrix.	11.2/ 3.4	145.6/ 44.3
Small normal fault repeats part of Unit 5.			
5	Claystone, medium gray to black, highly sheared, with bright coaly streaks.	14.0/ 4.2	134.4/ 40.9
4	Mudstone, medium gray to brownish gray, very thin bedded, carbonaceous, with small plant fossils.	33.6/ 10.3	120.4/ 36.7
3	Covered interval, dark gray to black soil, possible coal seam horizon.	22.4/ 6.8	86.8/ 26.4

2	Siltstone, medium gray to brownish gray, sandy, thin-bedded, fissile, with carbonized plant fossils, and mica flakes on bedding planes.	11.2/ 3.4	64.4/ 19.6

Lower Price Unit (53.2 ft./ 16.2 m., incomplete)

1	Sandstone, light gray, fine- to medium-grained, medium-bedded with cross-bedding; lower parts are interbedded with siltstone, with grain size and bedding thickening upward. Top of unit is marked by symmetrical ripple-marks.	53.2/ 16.2	53.2/ 16.2

Plant List (from Scheckler, 1978):

Lepidodendropsis scobiniformes
L. vandergrachtii
Lepidophylloides sp.
Protostigmaria essetiema
Rhodea sp. cf. *R. blacksburgensis*

APPENDIX C

Core 7.

Core drilling was done by the Orogenic Studies Laboratory, of the Department of Geological Sciences, V.P.I and S.U.

Location - Core hole located on the north side of Price Mountain, 2 miles WNW of the town of Merrimac, very near the Kinsor Mine (C33, Plate 2).

Unit No.	(Total Thickness) ft./m.	Unit Thickness ft./m.	Feet Below Surface
36	Elbrook Dolomite (?, 0.2 ft.) Limestone, light olive-gray, fine-grained.	0.2/ 0.06	16-24
35	Upper Maccrady Formation (?, 0.1 ft.) Quartz conglomerate, dark gray, with well rounded clasts, some shale rip-ups.	0.1/ 0.03	
	PRICE FORMATION (91.9 ft./28.0 m., recovered) Upper Price Unit		
34	Sandstone, light gray, fining upward from medium- and coarse-grained to fine- grained, argillaceous and micaceous, with coaly surfaces on fractures.	3.7/ 1.1	
33	Claystone, medium gray, with coaly surfaces on fractures.	0.3/ 0.09	
32	Sandstone, coarse-grained, light gray, argillaceous and micaceous, with some shale rip-ups; core is fractured and faulted at high angles with quartz growth in fractures.	12.3/ 3.7	24-34
31	Sandstone, coarse-grained, medium gray, argillaceous and carbonaceous, with fine-grained coaly flecks.	8.3/ 2.5	34-44
30	Shale clast conglomerate, claystone rip-ups in fine-grained sand matrix.	0.8/ 0.2	
29	Claystone, dark medium gray, highly carbonaceous, very thinly laminated.	2.3/ 0.7	44-54

28	Sandstone, fine-grained, fining upward to siltstone, dark medium gray, carbonaceous; shale clasts in lower sandstone.	3.0/ 0.9	
27	Siltstone rip-ups and thinly laminated, fine-grained sandstone.	7.2/ 2.2	
26	Core noted as missing by driller.	--------	
25	Sandstone, coarse-grained, light gray, argillaceous.	0.7/ 0.2	
24	Interlaminated coarse-grained sandstone and fine-grained sanstone; fines upward into interlaminated fine-grained sandstones and siltstones. Sharp deformed contact with unit 23.	1.0/ 0.3	54-64
23	Interlaminated medium sandstone (light gray) and siltstone (dark medium gray), carbonaceous, cross-laminated and bioturbated. Siltstone stringers extend up into unit 24, either through bioturbation orsoft-sediment deformation; fractures are filled with calcite and pyrite.		
22	Claystone, carbonaceous to coaly, friable, generally bioturbated, with some thin laminations of siltstone.	5.1/ 1.6	
21	Coal, black, no lamination, poor recovery.	0.3/ 0.1	
20	Siltstone, medium gray, interlaminated with medium- to fine-grained sandstone (fining upward), carbonaceous and bioturbated.	5.8/ 1.8	
19	Claystone, dark medium gray to dark gray, highly bioturbated, carbonaceous to coaly; fractures are filled with calcite.	3.2/ 1.0	74-84

18	Sandstone, fine- to coarse-grained, fining upward, light medium gray, with cross-laminations, partly bioturbated.	0.9/ 0.3	
17	Interlaminated siltstone and fine-grained sandstone, medium gray.	3.2/ 1.0	
16	Silty claystone, dark gray, carbonaceous, with minor fine-grained sandstone laminations.	1.0/ 0.3	
15	Coal, black, highly fractured.	1.6/ 0.5	
14	Claystone, dark gray, carbonaceous, fraible, bioturbated, lowest part very dense.	2.9/ 0.9	84-94
13	Coal and coaly claystone, dark gray to black, highly sheared.	2.7/ 0.8	
12	Siltstone, interbedded with fine-grained sandstone, medium gray, minor bioturbation; amount of sand increases upward.	4.8/ 1.5	
11	Sandstone, coarse-grained, fining upward to interbedded fine-grained sandstone and siltstone, total unit is carbonaceous.	3.5/ 1.1	94-104
10	Sandstone, medium gray, fine-grained, highly bioturbated, carbonaceous.	2.5/ 0.8	
9	Claystone, dark gray, with some siltstone laminations, gradational contact with unit 8.	1.2/ 0.4	
8	Sandstone, medium-grained, medium gray, with highly carbonaceous lamination.	1.0/ 0.3	
7	Sandstone, fine-grained, light gray, bioturbated; fractures filled with calcite.	2.0/ 0.6	104-114
6	Interlaminated very fine grained sandstone and siltstone, carbonaceous with coaly veins in fractures.	3.4/ 1.0	

5	Coal, bony, dark gray.	0.2/ 0.1
4	Core noted as missing by driller.	--------
3	Claystone, dark gray, highly carbonaceous to coaly with carbonized plant fossil imprints (*Lepidodendropsis* sp.).	2.2/ 0.4
2	Coal, black, fractured.	1.4/ 0.4
1	Claystone, dark gray, highly carbonaceous.	0.2/ 0.06

Plant list:

Lepidodendropsis sp.

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Stratigraphy and Deposition

of the

Price Formation Coals

in

Montgomery and Pulaski Counties, Virginia

by

K. Elizabeth Brown

(Abstract)

The conclusion of this investigation, based on field mapping and measured sections, is the Price Formation was deposited on a high-energy shoreline. Sediments for the shoreline were initially transported from a northern deltaic source. The Cloyd Conglomerate Member represents offshore barrior bars, while the Lower Price unit was deposited in a lagoon behind the bars. At the top of the Lower Price unit, the "marker bed" sandstone includes sedimentary features of marine and fluvial origin. This sandstone is interprered as a delta-front sand, reworked from distributary mouth bars. The Langhorn and Merrimac coal seams were deposited in swamps formed across the sandstone.

PLATE 1

MAP SCALE
0 4000 FT.

Identified coal mines, from Campbell (1925).

C 40 - Cloyd Mine
Sec. E, F - Empire Mine
C 47 - Altoona Mine
C 50 - Mine owned by local farmer
C 56 - Summit Coal and Iron Co. Mine

Lithologies

Mmc Mississippian Maccrady Formation
Mpu Mississippian upper Price unit
Mpl Mississippian lower Price unit
Mpc Mississippian Cloyd Conglomerate Member
Dch Devonian "Chemung" Sandstone
Cr-e Cambrian Rome Shale and Elbrook Dolomite

PLATE 2

MAP SCALE

0 4000 FT.

Identified coal mines, from Campbell (1925).

- C 10 - Slusser and Doss Mine
- C 14 - Slusser Mine
- Sec. L - Slusser Mine, drift exposed in drainage ditch.
- C 16 - Diamond Coal Co.
- C 18 - Plunkett and Wall mine
- C 19 - Seymore Price, College mine.
- C 20 - College mine, 2D adit
- C 21 - Linkous and Kipp Mine
- C 22 - Poverty Creek Gap, Virginia Anthracite Co.
- C 24 - Superior Mine, Superior Anthracite Co.
- C 25 - Big Vein Mine
- C 26 - Great Valley Mine
- C 27 - Lykens Hill Mine
- C 28 - Merrimac Mine
- C 29 - Brumfield Mine
- C 31 - Beachan Mine
- C 32 - Kipp Mine
- C 33 - Kinzor Mine
- C 34 - Price Mine
- Sec. K - J. H. Keister Mine

Lithologies

Mmc	Mississippian Maccrady Formation
Mpu	Mississippian upper Price unit
Mpl	Mississippian lower Price unit
Mpc	Mississippian Cloyd Conglomerate Member
Dch	Devonian "Chemung" Sandstone
Єr-e	Cambrian Rome Shale and Elbrook Dolomite