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GEOLOGY OF THE KEEN MOUNTAIN QUADRANGLE, VIRGINIA

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EXPLANATION

QUATERNARY

al — Alluvium

PENNSYLVANIAN

Norton Formation

Pn₁ , interbedded siltstones and sandstones

ns , sandstone

Pnm , McClure Sandstone Member

Pnc , Council Sandstone Member

n , Norton coal bed

h , Hagy coal bed

sd , Splash Dam coal bed

ub , Upper Banner coal bed

lb , Lower Banner coal bed

bf , Big Fork coal bed

k , Kennedy coal bed

a , Ally coal bed

r2 , Raven No. 2 coal bed

r1 , Raven No. 1 coal bed

j , Jawbone coal bed

t , Tiller coal bed

Pn — Norton Formation, undivided

MISSISSIPPIAN

Pp — Pocahontas Formation

Pp₁ , interbedded siltstones and sandstones

Pbm , Middlesboro Member of the Lee Formation

p4 , Pocahontas No. 8 coal bed

p3 , Pocahontas No. 3 coal bed

Mb — Bluestone Formation

in cross-section only

KEY

CONTACTS

Contact
Solid where exposed; dashed where approximately located or covered

Coal bed
Solid where exposed; dashed where approximately located or covered

FOLDS

Anticline showing trace of axial surface, direction of plunge shown by arrow

FAULTS

Solid where exposed; dashed where approximate; U, upthrown side, D, downthrown side; arrows indicate direction of relative movement

In cross section:
T—relative movement towards observer
A—relative movement away from observer

ATTITUDE OF ROCKS

Strike and dip of beds

Horizontal beds

MODIFIED LAND

Mine dump, valley fill, or areas of extensive reclamation

COAL MINES

Mine adit

Adit of abandoned mine

Surface mine; hachures toward highwall

Area of extensive surface mining (e.g. mountain-top removal), where the bounding coal bed and all units above have been removed

Coal outcrop or prospect

TEST WELLS FOR OIL AND GAS

Gas well

Gas well; shut in

Abandoned gas well

REPOSITORY NUMBERS

R, repository number of surface coal sample and analysis on file at Virginia Division of Mineral Resources

R, repository number of underground coal sample and analysis on file at Virginia Division of Mineral Resources

CROSS SECTION DESIGN

1. No vertical exaggeration.
2. Subsurface units interpreted from surface and drill-hole data.
3. Coal bed thickness is diagrammatic.
4. Thin surficial deposits not shown.

Base map from U.S. Geological Survey, 1958, PR 1975
Keen Mountain quadrangle, 7½ minute series.
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INTRODUCTION

The Keen Mountain quadrangle encompasses an area of approximately 60.2 square miles in eastern Buchanan County, northwest Russell County, and western Tazewell County. The quadrangle lies entirely within the Appalachian Plateaus physiographic province.

Refinements of previous geologic mapping by Hinds (1918) and Nolde and Mitchell (1984) include: 1) the reinterpretation of the stratigraphic position and areal extent of the Gladeville Sandstone; 2) the identification of the Dorchester (Glamorgan) coal as the Norton coal bed; 3) the recognition and mapping of the Keen Mountain fault; 4) the recognition of a widespread "marine" zone (Eagle Shale of White, 1891) as a key bed for stratigraphic correlation; and 5) the recognition of the Pocahontas No. 8 coal bed and its relationship to the Lee and Pocahontas Formations. Generally, the coal names used in this report are the same names used in Wise County (Nolde and Diffenbach, 1988; Nolde and others, 1988). Local usage, where it differs from the Wise County terminology, is shown in parentheses after the Wise County name.

STRATIGRAPHY

There are 2700 to 2800 feet of Pennsylvanian-age strata overlying the Mississippian-age Bluestone Formation in the Keen Mountain quadrangle. The Pennsylvanian rock sequence is divided from oldest to youngest into the Pocahontas, Lee, and Norton Formations and is comprised of sandstone, conglomeratic quartzarenite, siltstone, shale, coal, underclay, and minor limestone.

The subsurface Pennsylvanian rock units examined in Keen Mountain quadrangle are, in ascending order, the Pocahontas Formation, the Lee Formation, and the lower portion of the Norton Formation. Well samples and related stratigraphic data from these rock units are in the repository at the Virginia Division of Mineral Resources in Charlottesville. Strata assigned to the Pocahontas, Lee, and Norton Formations in the Prater and Varnant quadrangles (Nolde and Mitchell, 1984), which lie to the west of Keen Mountain quadrangle, have been included in the Pocahontas, New River, and Kanawha Formations in the Jewell Ridge quadrangle (England, 1981) and the Honaker quadrangle (Meissner and Miller, 1981) which lie to the east and south respectively.

Quaternary surficial deposits including alluvium, talus, and landslide debris are common but generally thin, rarely approaching 50 feet in thickness.

PENNSYLVANIAN SYSTEM

The Pocahontas Formation as defined by Campbell (1896) extended from the top of the red shale of the Mississippian-age Bluestone Formation up to the top of the Pocahontas No. 3 coal bed. Later workers included the Pocahontas No. 4 through No. 7 coal beds and an uppermost sandstone member, the Flattop Mountain Sandstone, in the Pocahontas Formation (White, 1908; Hennen and Gawthrop, 1915).

In the Keen Mountain quadrangle, the Pocahontas Formation averages 650 feet in thickness and is dominantly shale and sandstone, and coal bed sandstones are prominent locally and have maximum individual thicknesses of up to 100 feet. The sandstones are typically light gray, fine- to medium-grained, feldspathic, and micaceous with low quartz content. Siltstones and shales are medium- to dark-gray, thin- to medium-laminated, and contain plant material. Two coals, the Pocahontas No. 3 and No. 7, are present in the subsurface. The top of the formation in the quadrangle area is marked by the Flattop Mountain Sandstone Member of the Pocahontas Formation, which is above the Pocahontas No. 7 coal bed. Correlation of coal exploratory-hole logs in eastern Buchanan County confirmed the presence of the Flattop Mountain Sandstone Member of the Pocahontas Formation and the Pocahontas No. 8 coal bed of the overlying Norton (New River) Formation.

Where present the lower tongue of the Middlesboro Member of the Lee Formation ranges in thickness up to 140 feet, thinning from northwest to southeast. The member consists of very-light-gray to white, fine- to medium-grained, quartzarenite that interrupts with light- to medium-gray, fine- to medium-grained, feldspathic sandstone, siltstone, and coal of the Pocahontas Formation. The quartzarenite commonly contains a few well rounded and dispersed quartz pebbles. Correlation of coal exploratoral-hole logs and geophysical logs from gas wells in Virginia and West Virginia shows that the lower quartzarenite beds extend into the Pocahontas Formation below the Flattop Mountain Sandstone Member (White, 1908) and above the Pocahontas No. 6 coal bed.

The Pocahontas Formation is conformably overlain by the Norton Formation (New River Formation east of the Middlesboro Member of the Lee Formation termination). The subsurface portion of the Norton Formation, the interval below the Tiller coal bed, averages 1000 feet in thickness. The coal beds indicated from drill-hole data for this interval are the Pocahontas No. 8, Little Fire Creek, Lower Hovargen, Beckley, War Creek, Middle and Upper Horsepen, and the Lower Seaboard.

Approximately 1300 feet of siltstone, sandstone, shale, and coal are present above stream level in the Keen Mountain quadrangle. These rocks comprise part of the lower and most of the upper Norton Formation. In the map area, the interval below the Kennedy coal bed is informally termed the lower Norton Formation.

About 300 feet of the lower Norton Formation are exposed in the quadrangle. The Tiller, Jawbone, Raven Marker, Raven No. 1, Raven No. 2, and Ally coal beds are generally present in this interval. The lowest exposed rock unit is a medium-gray siltstone in the 70-foot interval beneath the Tiller coal bed. Where the coal crops out along Dismal and Grassy creeks, two extensive sandstone units are differentiated on the map. They are the Council Sandstone Member, which is present below the Jawbone coal bed, and a prominent unnamed sandstone below the Raven No. 1 coal bed. A sandstone below the Ally coal that is probably equivalent to the Dismal sandstone of England (1981) and the McClure Sandstone Member of the Norton Formation are also differentiated on the map.

The upper Norton Formation ranges in thickness from about 850 to 950 feet and contains seven named coals: Kennedy, Big Fork, Lower Banner, Upper Banner, Splash Dam, Hagy, and Norton. The Kennedy, Lower Banner, and Splash Dam are the major coal beds in the Norton Formation. The upper Norton includes three coarsening-upwards hay-fill sequences of clay shale grading upward into siltstone. The three hay-fill sequences are located above the Lower Banner coal, above the Splash Dam coal, and about 50 feet above the Hagy coal. The hay-fill sequence above the Hagy coal appears to be the Eagle Shale of White (1891) and the sequence above the Splash Dam appears to be the Oceana Limestone of Hennen and Gawthrop (1915). These correlations are based on position and character of the units as interpreted from geophysical logs from dirty gas wells in Virginia and West Virginia. A laterally extensive sandstone below the Lower Banner coal bed that appears to be equivalent to the Bearwallow Sandstone Member of the Kanawha Formation of England (1981) is differentiated on the map.

A stratigraphic problem involving the identity of the Gladeville Sandstone in part of Buchanan County was resolved during mapping of the Keen Mountain quadrangle. During the mapping of the Varnant quadrangle, to the west, Nolde and Mitchell (1984) questioned the presence of the Gladeville Sandstone. Hinds (1918) identified, as the Gladeville Sandstone, a 50- to 100-foot-thick sandstone that lies 10 to 20 feet below the Glamorgan coal. Subsequent mapping by the Division of Mineral Resources staff between the town of Wise, the type area of the Gladeville Sandstone, and Keen Mountain quadrangle demonstrated that the Gladeville is very thin or absent in Buchanan County and that the Gladeville of Hinds (1918) is the sandstone below the Norton coal bed. As a result, all of the Gladeville mapped by Hinds along Mill Branch Ridge, Fork Ridge, and Henry Ridge is the sandstone below the Norton coal. Therefore, in Keen Mountain quadrangle, the entire stratigraphic sequence above drainage is assigned to the Norton Formation.

QUATERNARY SYSTEM

Surficial deposits of Quaternary age occur as flood-plain alluvium and various slope deposits. The alluvial deposits are composed of fine- to coarse-grained sand and gravel and are found only in stream valleys. Landslide, rockfall, colluvium, debris flow, and avalanche deposits are present on or at the base of slopes over most of the area. These deposits, which may be subject to mass movement, are shown on a map that was prepared by Quatrefoil (1984). Man-made deposits (gob piles, spoil, and valley fills), present in mined areas, are composed of an unsorted mixture of coal, shale, siltstone, and sandstone. Only the alluvial and man-made surficial deposits are shown on the geologic map.

STRUCTURE

In general, strata in the Keen Mountain area have a homoclinal dip of approximately 1.5° to the northwest. Two subtle but extensive structures in the map area are the Dry Fork anticline and the Keen Mountain fault. The Dry Fork anticline in the extreme southeastern corner of the map area is a slightly asymmetrical, low relief, open-fold whose axis trends northeastward. The asymmetry is defined by dips of 1° to 6° on the northwest limb and dips on the southeast limb of 2° to 8°. The fold plunges to the southwest at approximately 2°.

The Keen Mountain fault was first described in the field by Jonas (1968) and mapped and named by Elder and others (1974). It is a northwest-trending, steeply inclined (60° southwest) to near-vertical, down-to-the-west fault with local variations in vertical displacement and an apparent right-lateral, strike-slip component. Vertical displacement observed along the fault ranges up to 18 feet. Slickensides are parallel to bedding, suggesting that major movement was horizontal rather than vertical. The maximum amount of lateral movement along the fault, as suggested by the subsurface data, may range between 500 and 1000 feet but may be much less.

Joints, present in sandstone and siltstone, and cleat in coal beds are extension fractures. However, some joints dip at angles as low as 45°, a characteristic more common to shear joints where beds are nearly horizontal. A compilation of the strike trends of joints and cleat indicate these fractures occur in orthogonal sets. The systematic set of this joint system strikes about N35°W; the non-systematic set strikes about N55°E. Regional jointing is essentially parallel to the strike of the Keen Mountain fault (Elder and others, 1974). The coal cleat system on the northeast-side of the fault is rotated within a 1000-foot-wide zone parallel to the fault. Cleat measurements in the zone show face cleat trending N30°E and butt cleat trending N75°E. These trends contrast with the face cleat in undeformed coal which strikes roughly N18°W; and the butt cleat which strikes about N67°E. The rotation of the cleat on the northeast side of the fault, indicates this side acted as a buttress against which the southwest block moved (McCulloch and others, 1975).

MINERAL RESOURCES

COAL

Coal is the primary mineral/energy resource in the area. At present, coal is produced by drift and surface mines in the Norton Formation, and deep shaft mines in the Pocahontas Formation. The Pocahontas No. 3 coal, a low-volatile bituminous coal, lies at depths of approximately 1350 feet and is produced from three shaft mines. The deep mines are owned by Island Creek and the Consolidation Coal companies. The Pocahontas No. 3 bed ranges from 20 to 70 inches in thickness and averages 56 inches.

The stratigraphically lowest coal exposed in Keen Mountain quadrangle is the Tiller coal bed which is commonly 18 to 42 inches thick, but may be locally thinner or absent. The Tiller crops out along Dismal and Grassy creeks.

The Jawbone coal bed occurs above the Council Sandstone Member where it is present and is generally 50 to 100 feet above the Tiller. The coal is commonly good quality ranging between 10 and 60 inches in thickness. The overlying Jawbone rider coal bed lies 20 to 40 feet above the Jawbone and ranges between 6 and 21 inches in thickness. Sandstone commonly separates the Jawbone rider from the Jawbone.

The Raven No. 1 (Jewell, Middle Raven, Red Ash) coal bed lies about 140 feet above the Jawbone. The coal is extensively mined underground north of Contrary Creek, where it ranges between 24 and 48 inches in thickness. A Raven marker coal bed lies 25 feet below the Raven No. 1. The marker bed varies between 4 and 31 inches in thickness and is not shown on the map.

The Raven No. 2 coal bed is from about 30 to 50 feet above the Raven No. 1. The Raven No. 2 coal averages 13 inches in thickness and is not shown on the map.

The Ally coal bed, which lies 80 to 150 feet above the Raven No. 1, is very thin in most places but may be as much as 23 inches thick locally. Stratigraphically, the Ally lies above the sandstone thought to be equivalent to the Dismal Sandstone Member of the New River Formation (England, 1981) and below the McClure Sandstone Member of the Norton Formation.

The Kennedy coal bed is 230 to 260 feet above the Raven No. 1. It occurs in or closely above the McClure Sandstone Member. Where present it can be up to 38 inches in thickness and is bright and clean with rare shale partings. Where the coal is exposed, many antitetic and synthetic thrusts may be seen within the bed. The coal may be overlain by several feet of sandstone, above which is a thick sequence of medium-gray siltstone. Though it is generally absent, there may be a rider coal bed up to 15 inches thick, 15 to 25 feet above the Kennedy. The Kennedy rider bed is commonly argillaceous, contains several shale partings, and was not differentiated on the map.

The Big Fork coal bed lies 140 to 170 feet above the Kennedy coal and within 10 feet of the base of a persistent sandstone (the Bearwallow Sandstone Member of England, 1981). This coal is present throughout the area, locally attaining a maximum thickness of 25 inches.

The Lower Banner (Cary) coal bed crops out 180 to 210 feet above the Kennedy coal. The coal has been surface mined extensively and can be up to 54 inches in thickness.

The Upper Banner coal bed is 70 to 100 feet above the Lower Banner and has not been mined. The coal was observed in only a few scattered outcrops in the area. A maximum exposed thickness of 15 inches was seen along the road beside Bill Young Branch. Elsewhere in the area the coal is very thin or absent.

The Splash Dam coal zone is 140 to 180 feet above the Lower Banner coal and is above a prominent sandstone unit. Throughout most of the area the Splash Dam consists of a lower coal bed that is 10 to 23 inches thick and an upper coal bed that is 5 to 24 inches thick that are separated by 5 to 20 feet of siltstone. A Splash Dam marker coal bed is approximately 30 feet below the lower bed and within the underlying sandstone. The marker bed is generally less than 10 inches in thickness. The Splash Dam has been surface mined along Radliff Ridge, where the coal thickness averaged 24 inches.

The Hagy coal bed is 110 to 140 feet above the Splash Dam coal and also is above a prominent sandstone unit. It ranges from 6 to 27 inches in thickness and averages 16 inches. The Hagy has not been mined in the area.

The Norton (Glamorgan) coal bed lies 110 to 140 feet above the Hagy coal and is the uppermost coal bed preserved in the quadrangle. Where it is present it is usually thin. The coal can be seen as a bloom on the ridge to the west of Antioch Church.

NATURAL GAS

Drilling in the quadrangle began in 1947. The first gas well, completed on January 30, 1948 to a total depth of 2301 feet, was the United Producing Company, Inc., W. M. Ritter Lumber Company Unit No. 1-V-1461 (now owned by Ashland Oil Company). Initial open flow was 17,196 Mcf/g/d (thousand cubic feet of gas per day). The well was subsequently plugged and abandoned on August 29, 1958. Production was from the "Ravencliff" sand of the Mississippian-age Hinton Formation.

As of November 1, 1988, twenty-six wells have been drilled for natural gas in the Keen Mountain area. As of this date four are producing, one is shut-in, and twenty-one are plugged and abandoned. All the wells were stimulated by hydraulic fracturing, acidizing, or both. Current production is from the "Ravencliff" sand, "Big Lime " (Greenbrier Limestone), and Devonian shale. Average initial open flow ranges from a low to 200 Mcf/g/d. After stimulation, the wells flow between 230 and 15,000 Mcf/g/d.

Natural gas in the area is also associated with several coal beds. The most notable is the Pocahontas No. 3 coal which is present throughout the quadrangle. The potential in-place methane resource for the Keen Mountain area has been calculated from available gas content values from Diamond and Levine (1981). The average coal reserve estimate is 1.5 billion tons. By use of an estimated low of 339 ft³/ton and a high of 564 ft³/ton, the in-place methane resources [tons mined areas] ranges from a minimum of 106 billion cubic feet to a high of 175 billion cubic feet. This estimate is based on in-place gas within the coal bed and does not consider the gas influx from strata other than coal.

SHALE AND SILTSTONE

Beds of shale and siltstone of sufficient thickness and areal extent to be mined commercially occur in the Norton Formation at several horizons. Tests of the shale and siltstone from the Norton Formation (Johnson and others, 1966) indicate that some of these materials are suitable for the manufacture of lightweight aggregate.

SANDSTONE

Sandstone comprises about 50 percent of the total rock sequence exposed. The lithologies of the various sandstones are described in the stratigraphic column. In general, sandstones are highly variable in thickness, composition, and texture. Usually they are most competent and of best quality where thickest. Iron-staining is a common flaw in the stone. Some sandstone has been quarried, but little has been used as facing stone for buildings. This is because of the irregular shape of the cross-bedding of the sandstone and the fact that individual beds are generally too thin to use. Because a uniform texture is essential in a building stone it is evident that the aforementioned characteristics preclude the possibility of these sandstones ever attaining wide use. Most sandstone quarried has been used as rough foundation work and road metal. Small quantities have been used as flagstone and for other decorative purposes.

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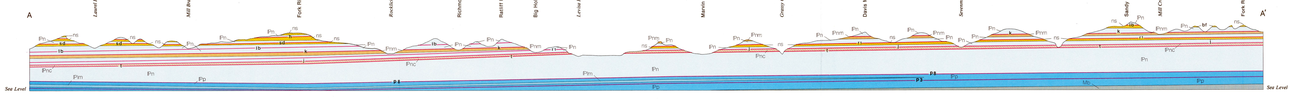
SERIES	FORMATION, MEMBER, AND BED	GAMMA-RAY LOG	LITHOLOGY	COAL THICKNESS, IN INCHES	DESCRIPTION
QUATERNARY	ALLUVIUM				Stratified, moderately to well sorted deposits of clay, silt, sand, pebbles, and some cobbles and boulders. Thickness: 0-20 feet.
PENNSYLVANIAN, MIDDLE, NORTON FORMATION	Norton coal			12	Sandstone, siltstone, and coal. Sandstone, light- to medium-gray, fine- to medium-grained, thin- to thick-bedded, cross-bedded, moderately indurated. Siltstone, light- to medium-gray, medium-laminated to medium-bedded, platy, weathers pale brown. Coal, mostly bright attritus with minor amounts of vitrain and dull attritus, finely cleated, and brittle. Thickness: 120-140 feet.
	Eagle Shale				Siltstone, shale, sandstone, and coal. Siltstone, medium-gray to gray-ish-black, weathers medium-light-gray to dark-yellowish-brown, with minor black, laminated to thin-bedded shale, fissile to platy; siltstone, may contain siderite nodules and lenses, sparse plant fragments; interbedded with sandstone at top of intervals. A shale, medium- to dark-gray, medium-laminated which contains brachiopods and bivalves is about 20 feet above the Splash Dam coal bed. The Eagle Shale (White, 1891), about 50 feet above the Hagy coal bed, is medium-gray to gray-ish-black, even- to ripple-laminated; linguloid brachiopods occur locally, especially near bottom. Sandstone, medium- to light-gray, weathers pale-yellowish-brown, fine- to coarse-grained, thin-bedded, cross-bedded, moderately indurated. Coal, mostly bright attritus with minor amounts of vitrain and dull attritus, finely cleated, and brittle. Thickness: 250-280 feet.
	Hagy coals			6-27	
	Splash Dam coals			6-24 10-23	
	Splash Dam Marker coals			10	Siltstone, sandstone, shale, and coal. Siltstone, light-olive-gray to medium-gray, medium-laminated to medium-bedded, platy; weathers light-olive-gray to dark-yellowish-brown, sparse siderite nodules, and ripple marks. Sandstone, medium-gray, weathers moderate-yellowish-brown to light-olive-gray, very-fine- to fine-grained, thin- to medium-bedded regionally extensive sandstone; and massive, cross-bedded, lenticular sandstone; sparse plant fragments, silty zones, and hummocky-beds. Shale, grayish-black, thinly-laminated containing bivalve and brachiopod fossils; occurs 40 feet above the Lower Banner coal. Coal, mostly bright attritus with minor amounts of vitrain and dull attritus, finely cleated, and brittle. Thickness: 140-180 feet.
	Upper Banner coal			15	
	Lower Banner coal			0-54	
	Big Fork coal			0-25	Siltstone, sandstone, and coal. Siltstone, light- to medium-gray, medium-laminated to medium-bedded, platy, weathers pale-brown. Sandstone member (20-45 feet thick) at top of interval is medium-gray, fine- to medium-grained, thick-bedded, cross-bedded; contains considerable feldspar, mica flakes, and dark minerals. Coal, mostly bright attritus with minor amounts of vitrain and dull attritus, finely cleated, and brittle. Thickness: 160-220 feet.
	Kennedy Rider coal			0-15	
	Kennedy coal			1-38	
	McClure Sandstone Member				Sandstone, siltstone, and coal. McClure Sandstone Member (60-120 feet thick) at top of interval, light- to medium-gray, weathers medium-gray, fine- to medium-grained, thick- to very-thick-bedded, cross- and planar-bedded; contains feldspar, mica flakes, and dark minerals; contains few scattered quartz and lithic pebbles and local conglomerate lenses near base. Sandstone member below the Ally coal bed (60-110 feet thick), light- to medium-gray, very-fine- to coarse-grained, contains few scattered quartz pebbles, micaceous, feldspathic, with dark mineral grains and coal laminations. Interbedded shale and siltstone, medium- to dark-gray, contains sandstone and coal laminations. Coal, mostly bright attritus with thin to thick vitrain bands, fine to medium cleated. Thickness: 255-285 feet.
	Ally coal			0-23	
	Raven No. 2 coal			13	
	Raven No. 1 coal			21-48	
	Raven Marker coal			4-31	
	Jawbone Rider coal			6-21	Siltstone, shale, sandstone, and coal. Siltstone, medium- to light-gray, even- to ripple-bedded. Shale, medium-gray to black, evenly laminated, few beds are carbonaceous; siderite concretions and well preserved plant fossils locally. Sandstone, light- to medium-light-gray, very-fine- to coarse-grained, thick-bedded to massive, cross-bedded, and locally ripple-bedded. Coal, mostly bright attritus with thin vitrain bands, finely cleated. Thickness: 120-160 feet.
	Jawbone coal			10-60	
	Council Sandstone Member				Sandstone, siltstone, and coal. Council Sandstone Member (50-100 feet thick) at top of interval, light- to medium-gray, medium- to coarse-grained, medium- to thick-bedded, cross-bedded, and quartzose to feldspathic, locally contains quartz pebbles. Siltstones, light- to medium-gray, contains sandstone and coal laminations. Coal, mostly bright attritus with thin vitrain bands, finely cleated. Thickness: 160 feet exposed above stream level.
	Tiller coal			18-42