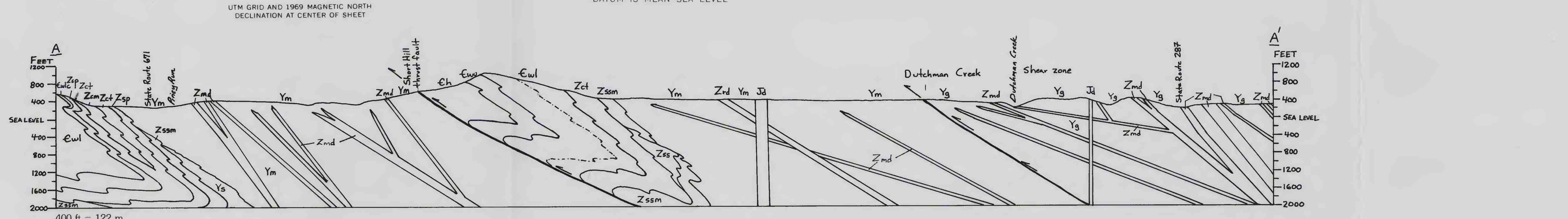
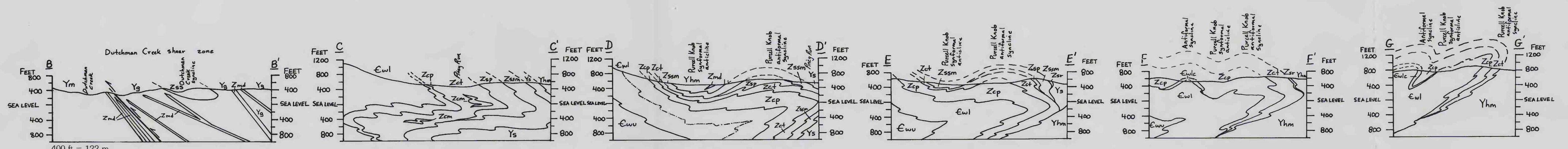
Prepared in cooperation with the
LOUDOUN COUNTY DEPARTMENT OF ENVIRONMENTAL RESOURCES

Base from U.S. Geological Survey, Harpers Ferry, 1969
Polyconic projection

Geology mapped in 1989–90
Manuscript approved for publication June 18, 1991



400 ft = 122 m
Surficial deposits are not shown



400 ft = 122 m
Surficial deposits are not shown

CORRELATION OF MAP UNITS

Unit	Age	Period
Qal, Qc	Holocene	QUATERNARY
Unconformity		
Jd	Early Jurassic	JURASSIC
Intrusive contact		
Chilhowee Group: Ꞓh, Ꞓwu, Ꞓwl / Ꞓwlc	Lower Cambrian	CAMBRIAN
Zcp, Zct, Zcm, Zrd, Zmd, Zsm, Zsp, Zss, Zssm, Zsr		LATE PROTEROZOIC
Unconformity		
Ys, Ym, Yg, Yhm		MIDDLE PROTEROZOIC

DESCRIPTION OF MAP UNITS

Qal **Alluvium and fine colluvial debris, undifferentiated (Holocene)**—Mixtures of clay, sand, pebbles, gravel, cobbles, and some boulders underlying sinuous flood plains along drainages of Piney Run, Dutchman Creek, Milltown Creek, and the Potomac and Shenandoah Rivers. Alluvium includes alluvial terraces as much as 6 m (20 ft) above stream channels. Fine colluvial debris from side slopes is transitional with alluvium. Sediments are well sorted and are found in fining-upward sequences as much as 6 m (20 ft) thick

Qc **Colluvium (Quaternary)**—Coarse cobbles, boulders, and blocks of quartzite, metabasalt, and some granitoid rocks that were transported by gravity, debris flow, and freeze/thaw. Abundant on mountain slopes. Includes boulder streams, boulder fields, and talus. Coarse colluvium is concentrated in hillslope depressions and hollows. Downslope extent of colluvium of quartzite on mountain slopes is delineated by heavy dotted line

Jd **Diabase dikes (Early Jurassic)**—Dark-gray (N3), fine-grained, to porphyritic diabase composed of quartz, olivine, augite, and plagioclase. Weathers to moderate yellowish-brown (10YR 5/4). Includes three geochemical types: high-titanium quartz normative, low-titanium quartz normative, and olivine normative. Found as sub-vertical linear bodies that are discontinuous and en echelon. On map, location of dikes approximate and width exaggerated. Residual cobbles and boulders are mapped as solid dots where trend of dike is unknown. Resistant to weathering and forms barrier to ground water. Expressed topographically as resistant knobs or shallow depressions. Four chemical analyses shown on table 1

Ꞓh **Harpers Formation (Lower Cambrian)**—Predominantly dark-greenish-gray (5G 4/1) to brownish-gray (5YR 4/1), very fine grained, laminated to massively bedded, phyllitic metasiltstone. Meta-arkose, sandy metasiltstone, fine pebble conglomerate, magnetite-rich metasiltstone, and calcareous metasiltstone are found locally from base to middle part of unit. Fine-grained, thin-bedded metasandstone is interbedded with metasiltstone near top of unit. Base of unit is locally sharp but transitional with underlying quartz-pebble conglomeratic quartzite of upper member of the Weverton Formation. Top is gradational with overlying Antietam Quartzite but not exposed in map area. Metasiltstone is highly cleaved and bedding is obscure; weathers along cleavage and joint planes to form thin slabs of colluvium that lie parallel to slope. Thickness ranges from 183 to 274 m (600 to 900 ft) on Short Hill Mountain to 762 m (2,500 ft) on Blue Ridge

WEVERTON FORMATION (LOWER CAMBRIAN)

Ꞓwu Upper member—Dark-greenish-gray (5GY 4/1) phyllitic metasiltstone, dusky-blue (5PB 3/2) to dark-gray (N3) quartz-pebble conglomerate and greenish-gray (5G 6/1) quartz-pebble conglomeratic quartzite. Poorly sorted, thick bedded, graded, and crossbedded. Contains local accumulations of magnetite, heavy minerals, red jasper, red quartz, and phyllite clasts. Pebbles commonly are 1 cm (0.4 in.) in diameter. Top of unit is sharp contact at top of quartz-pebble conglomeratic quartzite; bottom of unit is base of phyllitic metasiltstone overlying quartzite of the lower member. Thickness is 32 m (105 ft) on Short Hill Mountain and 183 to 244 m (600 to 800 ft) on the Blue Ridge

Ꞓwl Lower member—Light-gray (N7) to medium-light-gray (N6) medium- to fine-grained, well-sorted, graded and crossbedded quartzite. Massive to thick bedded at base and top. Middle part is thin bedded and contains light-gray (N7) phyllitic metasiltstone. Quartzite beds have detached from metasiltstone beds and form numerous ledges and intervening topographic swales; rounded to subangular cobbles, boulders, and blocks have floated more than 1 km (0.6 mi) into valleys by a combination of debris flow and colluvial-alluvial transport. Lower part of unit is locally arkosic and contains a distinctive basal conglomerate. Overlies phyllite and metabasalt of the Catoctin Formation or, locally, basement rock. Quartz veins, cataclastic quartz breccia, and mylonite related to thrust faults are abundant and locally constitute more than 80 percent of an outcrop. Thickness ranges from 86 to 122 m (282 to 400 ft) on Short Hill Mountain and 122 to 305 m (400 to 1,000 ft) on Blue Ridge. Locally contains:

Ꞓwlc Basal conglomerate—Small cobble to very coarse pebble conglomerate of rounded to subrounded white, blue, and red quartz, gneiss, red jasper, and variegated phyllite in grayish-black (N2) iron-rich siltstone matrix. Pebbles commonly are 1 to 2 cm (0.4 to 0.8 in.) in diameter but are as large as 6 cm (2 in.). Contains local interbeds of fine pebble conglomerate and graded and crossbedded quartzite. At most places is in sharp contact with phyllite of the Catoctin Formation (Zcp); at other places, contact is gradational. Unit is podiform and discontinuous and may represent local channel fill in the Catoctin. Unit has a maximum thickness of 5 m (16 ft) and is restricted to Blue Ridge

CATOCTIN FORMATION (LATE PROTEROZOIC)

Zcp Phyllite—Gray-black (N2), light-olive-gray (5Y 6/1) to light-gray (N7), fine-grained phyllite containing tuffaceous clasts and elongated amygdules. Top can be a sharp, possibly unconformable contact with overlying basal conglomerate of the lower member of the Weverton. Base is transitional with tuffaceous metasediments unit. Unit contains very fine pebbles of quartz that increase in number upward. Ranges in thickness from 0 to 122 m (400 ft) but commonly is less than 61 m (200 ft) and is restricted to Blue Ridge

Zct Tuffaceous metasedimentary rocks—Pink-gray (5YR 8/1), medium-light-gray (N6), light-brownish-gray (5YR 6/1), and medium-black-gray (N4) tuffaceous phyllite and schist, mud-lump breccia, and dark-greenish-gray (5G 4/1) thin-bedded metabasalt. Light-greenish-gray (5GY 8/1) metarhyolite tuff is also locally present. Base of unit is transitional contact with underlying metasedimentary rocks (Zss and Zsp) of the Swift Run Formation. Unit contains and is locally interlayered with the metabasalt unit (Zcm). Top grades into the overlying phyllite unit (Zcp). Unit is generally covered but is well exposed adjacent to massive metabasalt. Outcrop width suggests a maximum thickness of 366 m (1,200 ft) on Short Hill Mountain and 152 m (499 ft) on Blue Ridge. More than 34 m (112 ft) crops out in and along the Potomac River at Short Hill Mountain

Zcm Metabasalt—Dark-greenish-gray (5G 4/1) to medium-bluish-gray (5B 5/1), fine-grained to aphanitic, massive to schistose metabasalt (greenstone) composed of actinolite, chlorite, epidote, quartz, and albite. Includes amygdaloidal metabasalt and agglomeratic metabasalt breccia that contains epidosite. Epidosite bodies as much as 1 m (3 ft) in diameter are present locally. Contained within and locally interlayered with tuffaceous metasedimentary rocks unit (Zct). Interpreted as flows; individual flows range from 6 to 21 m (20 to 68 ft), but unit ranges from 0 to 50 m (164 ft) on Short Hill Mountain to 0 to 61 (200 ft) on Blue Ridge. Unit is resistant to weathering and forms numerous outcrops and colluvial boulders. Five chemical analyses are shown in table 1 and figure 3

Zrd Metarhyolite dikes (Late Proterozoic)—Light-gray (N7) to medium-light-gray (N6), aphanitic to fine-grained metarhyolite that contains grayish-yellow (5Y 8/4) potassium feldspar phenocrysts. A 50-m- (164-ft-) wide dike intrudes basement rocks and the Swift Run Formation. Dike widths are exaggerated on map. Medium-gray (N5) to medium-dark-gray (N4) tuffaceous metarhyolite, which contains potassium feldspar phenocrysts and quartz-filled amygdules as much as 3 mm (0.1 in.) in diameter and light-gray (N7) clasts of metarhyolite as much as 5 cm (2 in.) long, is found as float adjacent to dike along Potomac River. One chemical analysis is shown in table 1 and figure 3

Zmd Metabasalt dikes and sills (Late Proterozoic)—Dark-greenish-gray (5G 4/1), aphanitic to medium-grained metabasalt composed of actinolite, chlorite, epidote, and albite. Dikes and sills range in thickness from 1 cm (0.4 in.) to 50 m (164 ft). Some rock is coarse grained to porphyritic and has common masses of epidosite. Common in basement rocks and less abundant in the Swift Run Formation. Compositionally, unit is similar to the metabasalt of the Catoctin Formation (Zcm); however, unit never observed in contact with flow rocks. On map, location of dikes and sills is approximate and width is exaggerated; shown with slaty cleavage symbols. Ten chemical analyses are shown in table 1 and figure 3

SWIFT RUN FORMATION (LATE PROTEROZOIC)

Zsm Marble—Pinkish-gray (5YR 8/1) and yellowish-gray (5Y 8/1) to light-brownish-gray (5YR 6/1), fine-grained, dolomitic marble is found as a 2-m- (7-ft-) thick pod at top of formation on Short Hill Mountain near Potomac River. Size of outcrop exaggerated on map. Locally quarried in historic time for agricultural lime

Zsp Sericitic phyllite and arkose—Variegated, sericite-rich phyllite interbedded with thin, discontinuous beds of dark-gray (N3) to light-olive-gray (5Y 6/1) arkosic sandstone. Restricted to Purcell Knob antiformal syncline where intense deformation has tectonically mixed the sericitic phyllite and arkosic sandstone with metamorphic quartz veins and some metabasalt dikes and sills. Base of unit is sericitic metasandstone. Top of unit is transitional with overlying tuffaceous metasedimentary rocks (Zct) of the Catoctin Formation. Thickness ranges from 0 to 122 m (400 ft)

Zss Quartz sericite schist—Light-gray (N7), pale-olive (10Y 6/2), and dusky-yellow (5Y 6/4) to moderate yellowish-brown (10YR 5/4) quartz sericite schist and pale-olive (10Y 6/2) fine pebble conglomerate that contains rounded to subrounded white and blue quartz pebbles, abundant sericite, and sparse chlorite. Quartz sericite schist may be either a fining-upward sequence or a product of deformation at basement-to-cover contact. Bedding was not recognized. Thickness ranges from 0 to 91 m (298 ft) on Blue Ridge to more than 213 m (699 ft) in synclines east of Short Hill Mountain

Zssm Sericitic metasandstone—Pinkish-gray (5YR 8/1), yellowish-gray (5Y 8/1), light-greenish-gray (5GY 8/1), medium-gray (N5), and light-olive-gray (5Y 6/10) to greenish-gray (6GY 6/1) sericite-rich, very coarse to medium-grained metasandstone that contains rounded quartz cobbles as much as 11 cm (4 in.) in diameter. Also includes sericite-rich, matrix-supported or clast-supported coarse pebble conglomerate of rounded quartz pebbles. Elongate phyllite clasts as much as 8 cm (3 in.) in length are common locally. Graded beds and crossbeds are also common. Unit unconformably overlies Middle Proterozoic basement rocks and grades laterally into paleoregolith unit (Zsr). Thickness of unit ranges from 0 to 122 m (400 ft), but most outcrops are 10 m (33 ft) wide

Zsr Paleoregolith—Weathered basement rocks formed in the Late Proterozoic that constitute basement-to-cover transition zone found in two locations. Retains mineralogic composition of parent quartz syenite (Ys), but feldspars are subrounded and are in unsorted matrix that includes phyllite clasts. Texture suggests little transport. Unit is not thought to be a tectonite. Maximum thickness is 15 m (49 ft)

Ys **Quartz syenite (Middle Proterozoic)**—Moderate-pink (5R 7/4) to white (N9) quartz syenite that contains potassium feldspar megacrysts, 1 to 3 cm (0.4 to 1 in.) in length, in dusky-yellow-green (5GY 5/2) chlorite- and sericite-rich matrix. Unit has distinctive pinkish-green and, locally, grayish-red purple (5RP 4/2) hue. Converted to protomylonite where involved in Paleozoic folds. Consists of perthite, microperthite, microcline, albite (An_5), oligoclase (An_{15}), andesine (An_{30-40}), quartz, and minor amounts of sericite, chlorite, epidote, zircon, and opaque minerals. Modal composition ranges from 15 to 20 percent quartz, 60 to 63 percent potassium feldspar, and 17 to 25 percent plagioclase feldspar

Ym **Garnet monzogranite (Middle Proterozoic)**—Very coarse to medium-grained equigranular to granoblastic, garnet-bearing leucocratic monzogranite. Typically massive, but locally is mylonitized. Some phases are gneissic. Contains very light gray (N8) to light-gray (N7) feldspar with medium-gray (N5) quartz as much as 0.5 cm (0.2 in.) in diameter, and dusky-red (5R 3/4) euhedral to anhedral almandine garnet as much as 0.5 cm (0.2 in.) in diameter. Garnet can be highly fractured and includes lineated blebs of chlorite and sericite. Composed of quartz, microperthite, microcline, myrmekite, albite (An_{10}), oligoclase (An_{20-30}), andesine (An_{40-50}), and symplectite biotite, and minor amounts of chlorite, ilmenite, zircon, sphene, epidote, leucoxene, and clinozoisite. Modal composition ranges from 28 to 29 percent quartz, 35 to 40 percent potassium feldspar, and 28 to 32 percent plagioclase feldspar; almandine garnet makes up 2 to 5 percent of unit. Two chemical analyses are shown in table 1. Amphibolite-facies metamorphic minerals were retrograded to greenschist-facies assemblages during Paleozoic deformation

Yg **Biotite granodiorite gneiss (Middle Proterozoic)**—Medium-light-gray (N6) to light-olive-gray (5Y 6/1), equigranular, biotite-bearing granodiorite gneiss that contains light-brown (5YR 6/4), porphyroblastic to porphyroclastic, feldspar augen as much as 5 cm (2 in.) long. Augen gneiss is mylonitized in Dutchman Creek shear zone. Unit contains about 30 percent quartz, 20 to 30 percent potassium feldspar, 41 to 50 percent plagioclase, and as much as 10 percent biotite and sparse garnet. One chemical analysis is in table 1

Yhm **Hornblende quartz monzonite (Middle Proterozoic)**—Medium-light-gray (N6) to medium-gray (N5), equigranular to granoblastic, hornblende-bearing quartz monzonite. Also includes some compositionally layered augen gneiss. Unit usually massive but well foliated locally. Composed of 36 to 49 percent perthite and microperthite; 27 to 45 percent saussuritized plagioclase (oligoclase, An_{15-30}); 18 to 27 percent quartz; 10 to 20 percent hornblende in crystals 0.5 to 1 cm (0.2 to 0.4 in.) long; less than 5 percent orthopyroxene (possibly hypersthene) and biotite; and minor amounts of epidote, sericite, titanite and opaque minerals. Unit may correlate with the Pedlar Formation of the Blue Ridge province

EXPLANATION OF MAP SYMBOLS

Cataclastic quartz breccia in sole of thrust fault

Contact—Dashed where inferred or projected in cross section; dotted where concealed. Distribution and concentration of structural symbols indicates degree of reliability

Thrust fault—Dashed where approximately located or projected in cross section; dotted where concealed. Sawteeth on upper plate. In cross section, half arrow shows direction of relative movement

Normal fault—Ball and bar on downthrown block

Phyllitic metasiltstone in lower member of the Weverton Formation

Downslope extent of quartzite colluvium and debris on mountains

Drainage divide

Mylonite zone—Showing strike of zone. May be shown with schistosity

FOLDS

Overturned anticline—Dashed where approximately located; dotted where concealed. Showing trace of axial surface and direction of dip of limbs

Synformal anticline—Dotted where concealed. Showing trace of axial surface and direction of plunge

Overturned syncline—Dashed where approximately located; dotted where concealed. Showing trace of axial surface and direction of dip of limbs

Antiformal syncline—Dotted where concealed. Showing trace of axial surface and direction of plunge

MINOR FOLDS

20 Minor anticline—Showing bearing and plunge of axis and rotation sense as viewed down plunge

PLANAR FEATURES

(May be combined with each other or with linear features)

Strike and dip of bed—Ball indicates top of bed known from sedimentary structures

72 Inclined

30 Overturned

10 Rotated more than 180°

Vertical

Horizontal

Horizontal and inverted

30 Strike and dip of Middle Proterozoic foliation and (or) compositional layering in Middle Proterozoic rocks

A 20 Strike and dip of Paleozoic schistosity in Middle Proterozoic rocks—A, feldspar augen

Strike and dip of Paleozoic slaty cleavage in Late Proterozoic and Paleozoic rocks

10 Inclined

Vertical

Horizontal

12 Strike and dip of crenulation cleavage

10 25 Strike and dip of slaty cleavage cut by crenulation cleavage

Strike and dip of joint

30 Inclined

Vertical

10 Metabasalt dikes and sills (Zmd)—Dashed where inferred; dotted where concealed. Showing associated slaty cleavage. Approximately located and width exaggerated

Bedrock landslide—Hachures on escarpment; arrow shows direction of transport

Sackung (gravitational sag)

Rock block slump

LINEAR FEATURES

(May be combined with planar features)

30 Bearing and plunge of mineral lineation

OTHER FEATURES

S Quarry—S, sandstone or quartzite; M, marble; F, hematite; A, gold

Jurassic diabase boulder

Spring

3 Geochemical sample locality—Number refers to table 1

6 Reference locality—See text for discussion

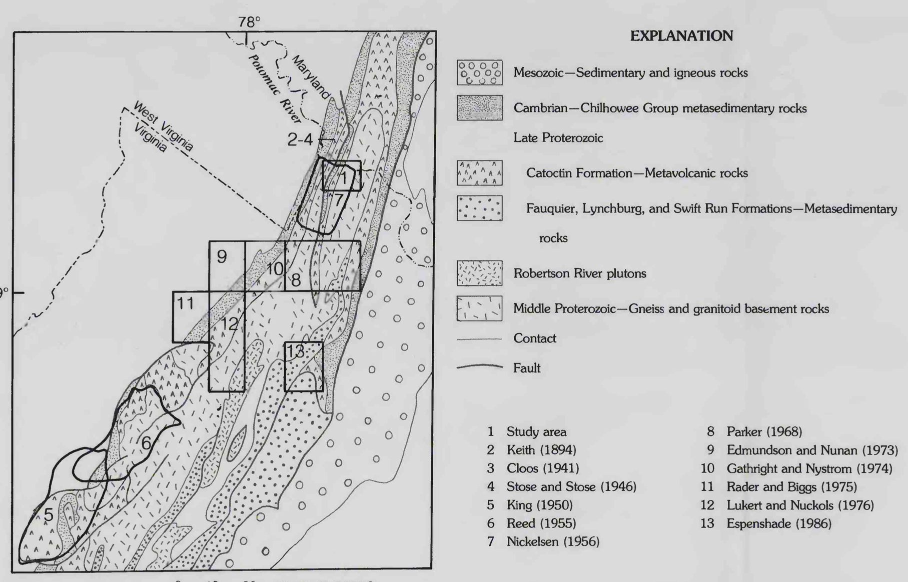


Figure 1.—Index map showing generalized geology of Blue Ridge-South Mountain anticlinorium and locations of study area and reports discussed in text (modified from Rankin and others, 1988).

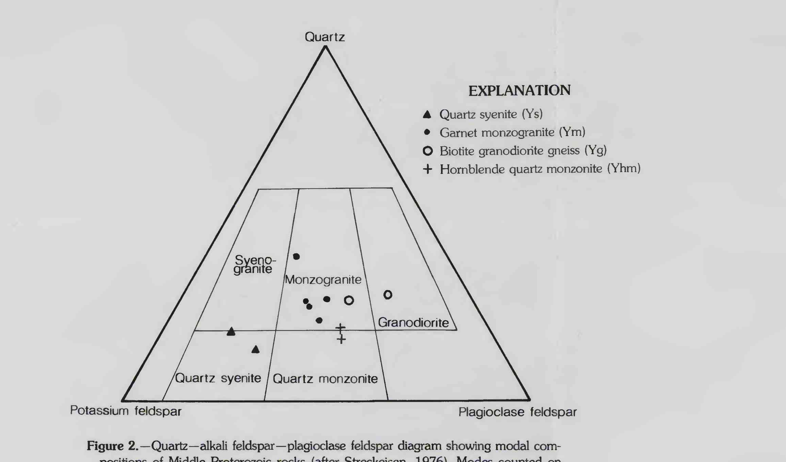


Figure 2.—Quartz—alkali feldspar—plagioclase feldspar diagram showing modal compositions of Middle Proterozoic rocks (after Streckeisen, 1976). Modes counted on Na-cobaltinitrate-stained rock slabs and thin sections.

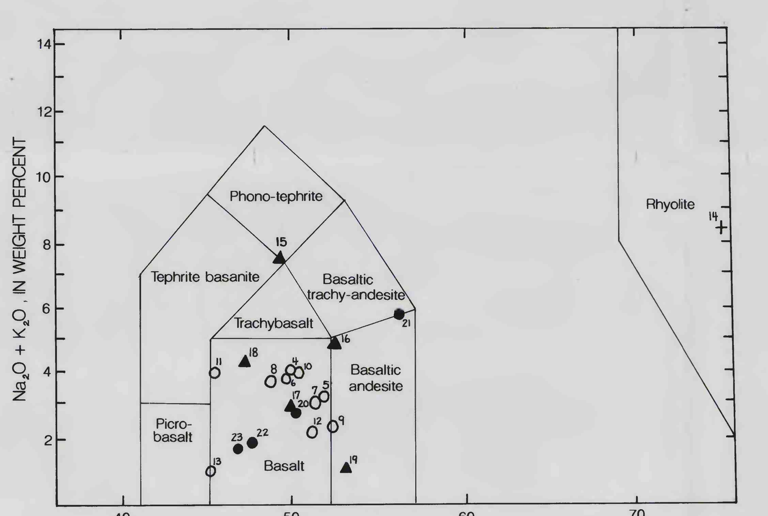


Figure 3.—Classification of Early Jurassic igneous and Late Proterozoic metavolcanic rocks (after LeBas and others, 1986).

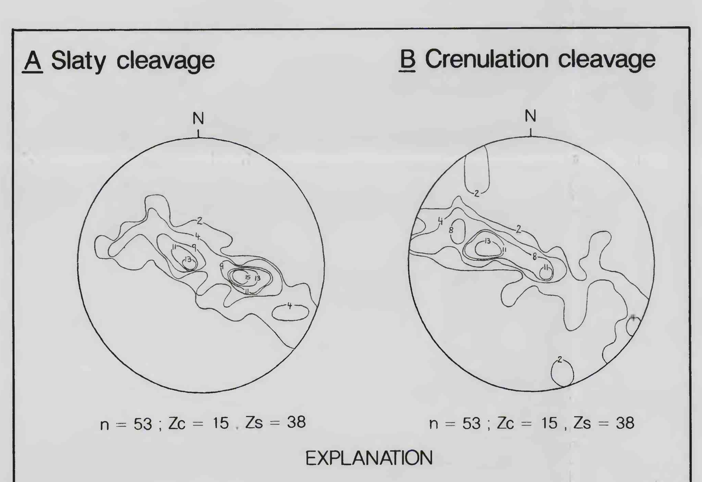


Figure 5.—Lower hemisphere equal-area projections of structural data from Purcell Knob inverted folds area of Blue Ridge terrane. Contours are percent per 1-percent area. *A*, Poles to slaty cleavage. *B*, Poles to crenulation cleavage.

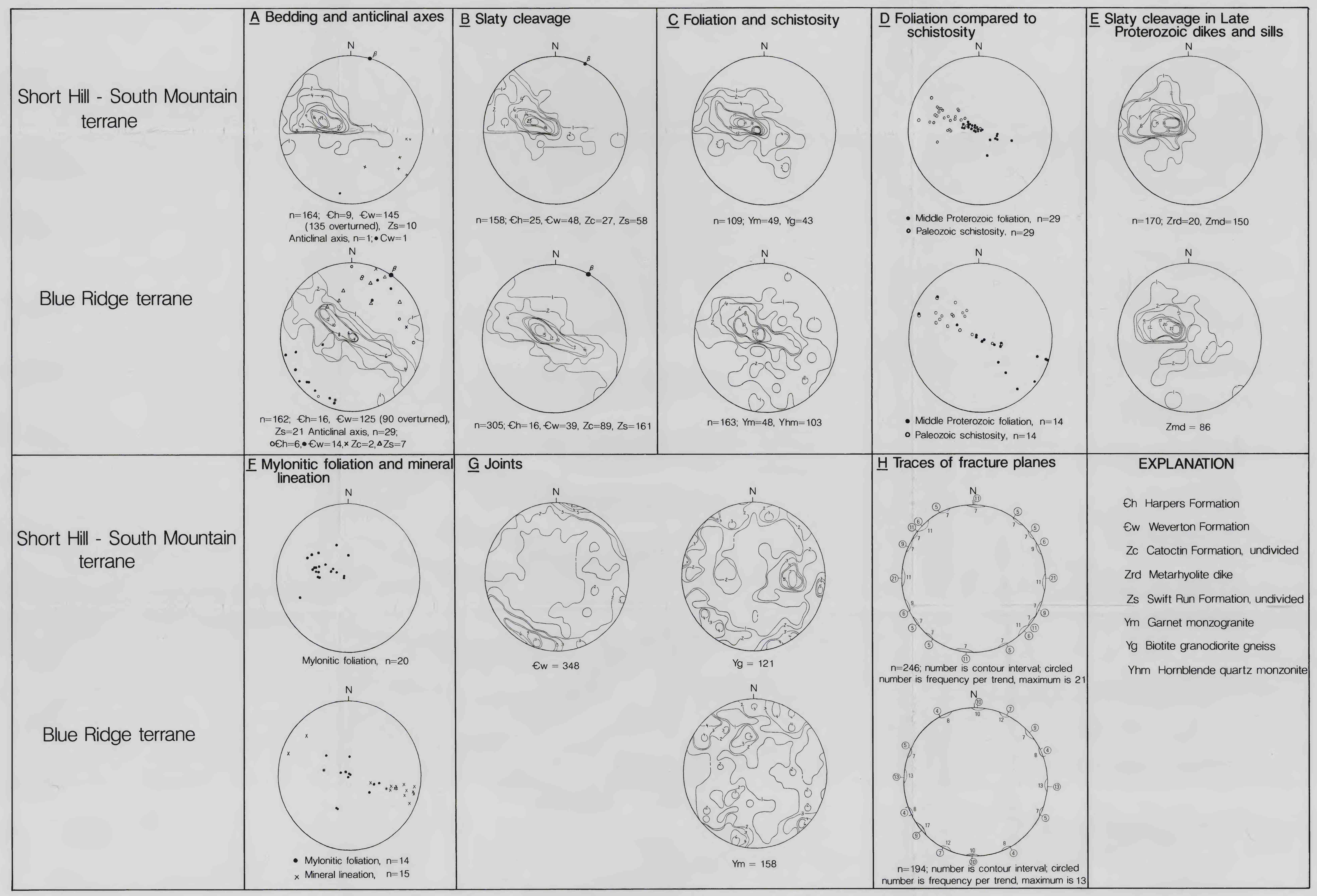


Figure 4.—Lower hemisphere equal-area projections of structural data from Short Hill-South Mountain and Blue Ridge terranes. Contours are percent per 1-percent area. β is a beta fold axis. *A*, Poles to bedding and anticlinal axes. *B*, Poles to slaty cleavage. *C*, Poles to foliation and schistosity. *D*, Poles to foliation compared to poles to schistosity. *E*, Poles to slaty cleavage of Late Proterozoic dikes and sills. *F*, Poles to mylonitic foliation and mineral lineation. *G*, Poles to joints. *H*, Poles to traces of fracture planes, two or more of parallel trend and assumed to be vertical.

Table 1.—*Chemical analyses of rocks from the Loudoun County part of the Harpers Ferry, Va.-Md.-W.Va. quadrangle*

[All analyses done in laboratories of U.S. Geological Survey. Major elements determined by x-ray spectroscopy by D.F. Sims and J.E. Taggart. Minor elements and rare-earth elements determined by instrumental neutron-activation analysis by G.A. Wandless and Jeff Grossman; --, no data; %, weight percent; ppb, parts per billion]

	Middle Proterozoic garnet monzo- --granite (Ym)--		Middle Proterozoic biotite granodiorite gneiss ---(Yg)---	Late Proterozoic metabasalt dikes --and sills (Zmd)--							
Map No.	1	2	3	4	5	6	7	8	9	10	11
Field No.	340 Cut	340 Dike	287	3-26-N55E	3-26-N15E	3-26-2-N15E	3-26-2-N55E	5	7	9	13
Lab No.	W-251091	W-251092	W-251094	W-251083	W-251084	W-251085	W-251086	W-250414	W-250416	W-250418	W-250422
	Oxides, in weight percent										
SiO_2	70.8	69.8	71.7	48.8	50.5	47.6	50.1	48.4	50.5	49.3	45.8
Al_2O_3	15.1	15.2	13.9	13.3	12.6	13.7	13.5	13.5	13.1	13.7	12.6
Fe_2O_3	.61	2.12	.96	3.44	4.86	3.76	2.6	2.86	3.23	3.77	3.84
FeO	1.8	1.1	1.4	9.6	9.4	9.4	10.0	10.4	9.7	8.3	11.5
MgO	.63	.39	.71	5.83	4.36	6.29	6.14	6.38*	4.16	6.18	5.67
CaO	1.35	3.32	1.79	9.59	8.73	9.54	8.80	9.54	9.39	9.58	9.56
Na_2O	3.56	4.40	3.00	2.44	2.24	3.13	2.39	2.99	1.74	3.47	2.63
K_2O	4.45	1.60	4.61	1.42	.83	.44	.45	.64	.49	.39	1.30
H_2O^+	.60	.55	.63	2.3	2.6	2.5	2.8	2.5	2.9	2.1	1.9
H_2O^-	.07	.18	.16	.20	.35	.29	.24	.14	.10	.25	.13
TiO_2	.26	.30	.35	2.47	2.80	2.29	2.30	2.23	2.74	1.92	3.99
P_2O_5	.10	.06	.16	.30	.35	.26	.28	.23	.52	.30	.53
MnO	.04	.05	.03	.20	.22	.19	.21	.22	.20	.20	.24
CO_2	<.01	<.01	.01	<.01	<.01	<.01	.07	<.01	.70	<.01	<.01
Total	99.38	99.08	99.41	99.9	99.85	99.4	99.88	100.04	99.47	99.47	99.7
	Elements, in parts per million unless otherwise noted										
Na(%)	--	--	--	1.86	1.72	2.39	1.84	2.22	1.28	2.57	1.99
Ca(%)	--	--	--	7.1	6.4	6.9	5.9	7.5	7.3	8.5	7.4
Sc	--	--	--	33	31.2	33.9	33.9	39.7	28.4	38.8	32.0
Ti(%)	--	--	--	1.8	1.66	2.1	1.38	1.7	2.0	<2	2.5
Cr	--	--	--	78.6	28.7	151	90.9	90.6	32.8	124	91.1
Fe(%)	--	--	--	10.05	10.94	10.00	9.79	10.26	9.99	9.30	12.06
Co	--	--	--	41.8	40.0	42.0	39.7	47.7	37.0	42.3	51.8
Ni	8	11	10	53	<50	63	<80	83	27	103	<150
Zn	69	20	41	126	148	106	138	116	147	108	142
As	--	--	--	<.5	<.6	<1	<.6	<1	<1	<1	<2
Rb	114	67	114	88	43.9	24.2	11.7	24.7	15.8	15.1	48
Sr	271	807	356	454	535	377	420	290	510	330	420
Zr	104	142	169	150	250	290	280	210	270	210	290
Mo	--	--	--	3.1	3.6	3.4	<4	<7	<6	<7	<5
Sb	--	--	--	<.2	<.07	<.09	<.08	<.1	.16	<.1	.21
Cs	--	--	--	1.30	1.00	.43	<.2	<.2	<.02	<.2	.40
Ba	842	348	762	298	290	416	374	237	572	163	429
La	20	28	36	17.4	24.1	17.6	14.4	13.8	28.4	16.0	29.7
Ce	54	71	92	37.3	51.2	34.1	33.7	30.0	59.8	35.1	63.7
Nd	--	--	--	26.0	29.4	22.0	21.6	18.1	34.4	18.1	35.1
Sm	--	--	--	6.33	7.49	6.24	6.02	5.24	8.81	5.18	8.81
Eu	--	--	--	1.98	2.15	1.93	1.69	1.66	2.46	1.65	2.71
Tb	--	--	--	1.02	1.14	1.047	1.048	.96	1.33	.89	1.27
Yb	--	--	--	3.21	3.77	2.96	3.19	2.93	3.87	2.85	3.02
Lu	--	--	--	.434	.52	.407	.430	.404	.530	.386	.404
Hf	--	--	--	4.50	5.54	3.94	4.39	3.78	6.45	3.93	5.49
Ta	--	--	--	1.07	1.32	1.02	.94	.95	1.30	.99	2.24
Au(ppb)	--	--	--	<6	<6	<7	<2	<5	<4	<5	<7
Th	--	--	--	1.46	2.06	1.31	1.04	1.26	1.83	2.09	3.17
U	--	--	--	.41	.73	.41	.27	.48	.66	.73	1.10

	Late Proterozoic metabasalt dikes --and sills (Zmd)--	Late Proterozoic metarhyolite dike ---(Zrd)---	Late Proterozoic Catoctin Formation ---metabasalt (Zcm)---						-------Jurassic diabase dikes (Jd)-------		
Map No.	12	13	14	15	16	17	18	19	20	21	22	23
Field No.	FG-89-VA-1	3-16-1	RT	6	8	10	11	3-23-1	12	FG-89-VA-2	VA-89-317A	VA-89-317B
Lab No.	W-249272	W-251088	W-251087	W-250415	W-250417	W-250419	W-250420	W-251089	W-250421	W-249273	W-249276	W-249277
	Oxides, in weight percent											
SiO_2	49.5	44.6	72.7	47.9	49.7	47.0	46.2	50.8	50.2	53.3	48.1	47.6
Al_2O_3	13.3	16.9	13.4	18.3	14.3	14.4	16.0	15.1	15.3	17.0	15.6	14.6
Fe_2O_3	14.9	6.1	1.18	10.42	9.13	4.52	8.09	9.42	2.45	11.7	11.2	11.4
FeO	--	5.0	1.3	4.4	5.2	7.1	6.5	4.4	7.7	--	--	--
MgO	3.96	4.96	.38	5.97	4.37	12.4	5.34	5.36	8.32	5.76	10.9	13.3
CaO	9.48	18.4	<.02	.87	3.92	2.28	6.25	6.64	11.5	1.95	12.0	11.3
Na_2O	1.83	.84	.75	5.99	1.92	2.60	4.02	1.22	1.86	5.09	1.60	1.46
K_2O	.38	.14	7.35	1.04	2.62	.04	<.02	<.02	.72	.13	.32	.31
H_2O^+	--	1.1	1.4	3.2	3.5	5.9	3.5	3.4	.92	--	--	--
H_2O^-	--	.19	.30	.21	.12	.31	.12	.25	.48	--	--	--
TiO_2	2.85	1.20	.36	.97	3.10	2.23	3.17	2.53	.68	1.10	.29	.27
P_2O_5	.54	.17	.06	.09	.40	.25	.60	.28	.10	.23	.07	.06
MnO	.20	.16	<.02	.28	.21	.34	.22	.20	.18	.15	.17	.18
CO_2	--	<.01	<.01	<.01	1.2	.19	<.01	<.01	.02	--	--	--
Total	96.94	99.7	99.23	99.65	99 69	99.56	100.04	99.63	100.43	96.41	100.25	100.48
	Elements, in parts per million unless otherwise noted											
Na(%)	1.33	1.99	.59	4.46	1.43	1.90	2.90	1.33	1.38	3.81	1.16	1.024
Ca(%)	7.5	7.4	<1.0	<.2	3.4	2.3	5.8	7.5	8.6	1.86	8.9	8.4
Sc	28.5	32.0	3.06	33.7	28.1	37.5	24.8	28.5	42.1	20.9	39.3	37.7
Ti(%)	1.6	2.5	<.7	<1	2.2	2.0	3.4	1.6	<1	<1	<1	<1
Cr	27.5	91.1	8.6	35.2	19.8	567	74.3	27.5	268	329	700	925
Fe(%)	10.35	12.06	1.88	10.51	10.63	8.68	11.01	10.3	7.94	7.93	7.71	7.97
Co	31.1	51.8	2.02	61.4	37.3	56.1	55.4	31.1	47.7	40.3	56.0	65.3
Ni	<40	<150	<15	134	<60	209	84	<40	75	191	322	446
Zn	179	142	53.1	199	81	132	155	179	92	118	88	80
As	<.7	<2	<.6	<1	<1	<2	<1	<.7	<2	<.8	<.9	<.9
Rb	26.5	48	180	27.4	52.3	<6	<6	26.5	38.6	7.7	16.9	12.5
Sr	470	420	<40	<140	130	<120	700	470	160	96	<170	<130
Zr	250	290	543	160	300	220	240	250	<120	130	<160	<120
Mo	<5	<5	4.0	3.0	<7	<7	<4	<5	<10	<5	<5	<6
Sb	.15	.21	.127	<.09	.14	.13	<.09	.15	<.1	<.1	<.09	<.09
Cs	.66	.40	.30	.43	.71	<.02	<.2	.66	.45	<.3	.37	<.7
Ba	282	429	648	209	476	<40	<100	282	134	69	115	91
La	29.2	29.7	137	4.61	37.9	21.7	25.8	29.2	4.9	8.0	4.54	4.2
Ce	62.7	63.7	113	10.1	73.7	41.2	53.8	62.7	10.7	18.0	10.2	9.9
Nd	37.3	35.1	119	6.5	35.9	22.7	30.2	37.3	6.6	9.5	4.2	5.3
Sm	9.13	8.81	25.4	2.33	8.58	5.91	7.73	9.13	1.95	2.38	1.20	1.15
Eu	2.55	2.71	2.20	.985	2.50	1.76	2.53	2.55	.692	.610	.302	.288
Tb	1.34	1.27	3.80	.67	1.31	.92	1.17	1.34	.530	.435	.266	.258
Yb	4.09	3.02	11.2	2.88	3.17	2.35	2.93	4.09	2.06	2.23	1.85	1.79
Lu	.552	.404	1.42	.420	.439	.327	.401	.552	.30	.290	.294	.277
Hf	6.71	5.49	16.5	1.10	6.16	3.69	4.62	6.71	1.36	2.54	.93	.80
Ta	1.40	2.24	5.45	.200	2.68	1.14	1.92	1.40	.231	.71	.162	.127
Au(ppb)	<5	<7	<4	16.6	<8	<7	<6	<5	<10	<3	6.0	26.1
Th	1.78	3.17	11.30	.26	4.16	2.50	2.03	1.78	1.09	.87	.94	.86
U	1.09	1.10	3.49	<.4	1.06	<.4	.57	1.09	.44	<.3	<.3	<.3

GEOLOGIC MAP OF THE LOUDOUN COUNTY, VIRGINIA, PART OF THE HARPERS FERRY QUADRANGLE

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1991

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