Prepared in cooperation with the U.S. GEOLOGICAL SURVEY NATIONAL GEOLOGIC MAPPING PROGRAM

The Ramsey quadrangle is located in Passaic and Bergen Counties, New Jersey and also part of Rockland County, New York. Large tracts of land in the central and western parts of the quadrangle remain undeveloped either through management by the Bergen County Department of Parks, the New Jersey Department of Environmental Protection, or private non-profit organizations. The quadrangle is in the Ramapo River drainage basin, and the Ramapo and Mahwah Rivers form the dominant drainages. The upland areas along the eastern flank of Ramapo Mountain are drained by a series of southeast-flowing streams, but farther west the uplands are also dissected by numerous smaller variably-oriented streams.

The quadrangle straddles the Highlands and Piedmont Physiographic Provinces but is primarily in the latter. The Ramapo fault traverses the quadrangle northeastward from Oakland and provides a structural and physiographic boundary between the two provinces. Mesoproterozoic and Neoproterozoic rocks of the Highlands underlie the upland areas in the northwestern part of the area and they provide the maximum relief in the map area. Mesozoic rocks of the Piedmont underlie the remainder of the quadrangle. Basalt formations support the moderate relief east of the Ramapo and Mahwah Rivers, along Campgaw Mountain and at Oakland and Franklin Lakes. Areas east of Campgaw Mountain are underlain by sedimentary rocks that form a muted topography largely covered by glacial sediments (Stanford, 2002). Small areas of Paleozoic-age rocks are locally preserved along the Ramapo River.

STRATIGRAPHY

The youngest bedrock in the Ramsey quadrangle is Mesozoic in age and constitutes part of the Newark basin, a northeast-trending half-graben in northern and central New Jersey that contains approximately 24,600 ft. of interbedded Upper Triassic to Lower Jurassic sedimentary and igneous rocks. These consist of conglomerate, sandstone, siltstone, and shale of fluvial and lacustrine origin and three

tholeiitic basalt flows. However, only the upper part of this succession occurs in the quadrangle.

The general stratigraphic order of the Mesozoic units is one of progressively younger beds from east to west. Sedimentary units from oldest to youngest are the Passaic, Feltville, and Towaco Formations of Lower Jurassic age. Conglomeratic facies of the Passaic and Feltville Formations crop out near the top of the formations and represent sediment coarsening due to uplift that preceded eruption of the directly overlying basalt formations. The Towaco Formation does not crop out in the map area but it is known to be present from drill-hole data. It crops out to the southwest in the Pompton Plains quadrangle where it coarsens upward into a conglomeratic facies directly beneath the Hook Mountain Basalt (Volkert, 2010). Mesozoic igneous units from oldest to youngest include Orange Mountain Basalt, Preakness Basalt, and diabase of Lower Jurassic age. The Orange Mountain Basalt is well exposed along the ridge east of Fyfe Brook at Darlington and in Oakland and Franklin Lakes. The Preakness Basalt crops out along Campgaw Mountain where nearly its entire thickness is exposed. Basalt that is interpreted to be correlative with the Preakness Basalt based on geochemistry (Geiger, 1984) (Fig. 1) and stratigraphic relationships (this study) crops out to the north at Suffern in the quarry at Union Hill. Geochemical analyses of Preakness Basalt from Union Hill are given in Table 1. Regionally, Preakness Basalt contains conformable coarse-grained to locally pegmatitic layers mapped as gabbroid that occur at several stratigraphic intervals. These are well exposed on Campgaw Mountain. Gabbroid and pegmatite layers within Preakness Basalt are interpreted by Puffer and Volkert (2001) to have formed through fractionation from finer-grained basalt.

Two small bodies of Lower Jurassic diabase crop out along the hanging wall of the Ramapo fault. The northern body, known informally as the Turtle Hill diabase, is west of the Ramapo River at Darlington. Stratigraphically, it intrudes the Passaic Formation directly beneath the contact with Orange Mountain Basalt. Major and trace element geochemistry of the Turtle Hill diabase is given in Table 1. A second, previously unrecognized diabase body that intrudes the Towaco Formation, here named the Deerhaven diabase, is about 2 miles southwest of the Turtle Hill body. The Deerhaven diabase is not exposed and was mapped based on drill-hole data. No samples of Deerhaven diabase are available for geochemical

thin, interbedded siltstone beds occur as tectonic lenses on the footwall and hanging wall of the Ramapo fault and are also known from drill-hole data at Darlington and Mahwah. Similar highly deformed dark-gray phyllonitic shale and siltstone are exposed to the southwest, along the Pequannock River at Riverdale, in the Pompton Plains quadrangle, where they are preserved on the footwall of the Ramapo fault (Volkert, 2010).

Mesoproterozoic rocks in the quadrangle are intruded by thin diabase dikes of Neoproterozoic age (Volkert and Puffer, 1995) that strike toward the east or northeast. The dikes are as much as 25 ft. wide and have sharp contacts and chilled margins against enclosing Mesoproterozoic rocks. Neoproterozoic diabase dikes in the New Jersey Highlands are interpreted to have an age of about 600 Ma and were emplaced during breakup of the supercontinent Rodinia (Volkert and Puffer, 1995).

The oldest rocks in the quadrangle are Mesoproterozoic in age and are part of the New Jersey Highlands. They include various granites and gneisses metamorphosed under conditions of granulite facies at about 1050 Ma (Volkert, 2004) during the Grenville orogeny. Temperature estimates for this high-grade metamorphism from calcite-graphite thermometry are 769°C (Peck et al., 2006) and from biotite thermometry are 754°C (Volkert, 2006). Calc-alkaline rocks of the Losee Suite are interpreted as a sequence of metamorphosed volcanic and plutonic rocks formed in a continental-margin magmatic arc (Volkert, 2004). They include quartz-oligoclase gneiss, biotite-quartz-oligoclase gneiss, and hypersthene-quartz-plagioclase gneiss that have the geochemical composition of dacite, andesite, and rhyolite (Volkert and Drake, 1999). These rocks are well exposed northwest of Ramapo Mountain in the area of Ringwood and along the crest of Ramapo Mountain. Rocks of the Losee Suite are spatially associated with a succession of supracrustal rocks interpreted as formed in a back-arc basin inboard of the Losee magmatic arc (Volkert, 2004). They include potassic feldspar gneiss, clinopyroxene-quartz-feldspar gneiss, pyroxene gneiss, biotite-quartz-feldspar gneiss, hornblende-quartz-feldspar gneiss, and amphibolite. Rocks of the Losee Suite and the supracrustal rocks yielded similar U-Pb (SHRIMP) zircon ages that range from about 1300 to 1250 Ma (Volkert et al., 2010). These Mesoproterozoic rocks are intruded by hornblende granite of the Byram Intrusive Suite (Drake et al., 1991) that constitutes part of the Vernon Supersuite (Volkert and Drake, 1998). Byram granite has an A-type geochemical composition (Volkert et al., 2000) and has yielded U-Pb (SHRIMP) zircon ages of about 1185 Ma (Volkert et al., 2010). Other hornblende granite that crops out in a large body along the prominent ridge east of the Ramapo River at Suffern, New York is not continuous with the Byram granite on Ramapo Mountain and the two bodies are separated by a fault. Hornblende granite at Suffern is here correlated with the Storm King Granite that has been dated at 1174 Ma (Ratcliffe and Aleinikoff, 2001) and, thus, is slightly younger than the Byram granite. The

The youngest Mesoproterozoic rocks in the quadrangle are small, irregular bodies of granite pegmatite that are undeformed and have discordantly intruded most other Mesoproterozoic rocks. None of the pegmatites are large enough to be shown on the map. Pegmatites regionally have yielded ages of 1004 to 987 Ma by U-Pb (TIMS) dating of zircon (Volkert et al., 2005).

Storm King Granite is abundantly exposed in the Hudson Highlands of New York, north of the Ramsey

Mesozoic bedding

Bedding in the Mesozoic rocks is somewhat variable in orientation and is influenced by the location of the outcrops in relation to folds that extend throughout the map area. The orientation of bedding is more uniform in the central and northeastern parts of the map area where it strikes north or northeast. All beds dip toward the west or northwest at 11° to14° and average12°.

Proterozoic foliation

Crystallization foliation (the parallel alignment of mineral grains) in the Mesoproterozoic rocks is an inherited feature resulting from compressional stresses during high-grade metamorphism that deformed Mesoproterozoic rocks in the Grenville orogeny. Foliation is fairly uniform throughout most of the map area, but locally is somewhat variable due to deformation by regional folds. Foliation strikes mainly northeast and averages N.35°E. (Fig. 2). It dips toward the southeast, and less commonly toward the northwest, at 6° to 90° and averages 60°. Locally, in the hinge areas of major folds, foliation strikes northwest and dips gently to moderately toward the northeast.

Mesozoic rocks are deformed into a broad, upright syncline and anticline pair that plunges northwest and dominates the structural geology of the Piedmont part of the map area. In general, Mesozoic units thicken in the cores of the folds. The Mesoproterozoic rocks have been deformed by at least two phases of folding. Characteristic fold styles of antiforms and synforms are predominantly northeast-plunging, northwest overturned to northeast-plunging and upright. Mineral lineations plunge parallel to the axes of major and minor folds. The predominant fold axes and mineral lineations plunge 4° and 35° toward N.38°E. Two additional, but smaller, populations plunge 5° to 30° toward N.60°E. and 8° to 39° toward N.25°E. Variation in the plunge azimuth of mineral lineations likely resulted from changing compressional stress orientations during formation of the folds.

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calcite, directly above scoriaceous flow contacts. Dark-gray, coarse- to very-coarse-grained gabbroid (Jpg) composed of clinopyroxene grains up to 0.5 in. long and plagioclase grains up to 1.0 in. long occurs at several stratigraphic intervals in the unit but is most abundant in the lowest flow. Gabbroid has sharp upper contacts and gradational lower contacts with basalt. Unit consists of at least three major flows, the tops of which are marked by prominant vesicular zones as much as 8 ft. thick. Radiating slender columns 2 to 24 in. wide, due to shrinkage during cooling, are abundant near the base of the lowest flow. Maximum thickness

is about 1,040 ft. Levels of natural radioactivity range from 5 to 8 (mean=6) Micro R/Hr.

Feltville Formation (Lower Jurassic) (Olsen, 1980) – Reddish-brown or light-grayish-red, fineto coarse-grained sandstone, siltstone, shaly siltstone, and shale, and light- to dark-gray or black, locally calcareous siltstone, shale, and carbonaceous limestone. Upper part of unit is predominantly thin- to medium-bedded, reddish-brown siltstone and locally cross-bedded sandstone. Reddish-brown sandstone and siltstone are moderately well sorted, commonly cross-laminated, and interbedded with reddish-brown, planar-laminated shale. Conglomeratic sandstone with subangular to subrounded clasts of Mesoproterozoic lithologies, Paleozoic quartzite and quartz, dolomite, and shale in matrix of brown, coarse sand to silt interfinger with sandstone beds near base of unit. As much as 2 ft. of unit have been metamorphosed along the contact with Preakness Basalt. Maximum thickness of unit is about 510 ft. Levels of natural radioactivity range from 11 to 14 (mean=12.5) Micro R/Hr in reddish-brown sandstone and siltstone and 9 to 13 (mean=11) Micro R/Hr in conglomerate.

Orange Mountain Basalt (Lower Jurassic) (Olsen, 1980) – Dark-greenish-gray to black, fine-grained, dense, hard basalt composed mostly of calcic plagioclase and clinopyroxene. Locally contains small spherical to tubular gas-escape vesicles, some filled by zeolite minerals or calcite, just above scoriaceous flow contacts. Unit consists of three major flows that are separated in places by a weathered zone, a bed of thin reddish-brown siltstone, or by volcaniclastic rock. Tops of flows are characterized by vesicular zones as much as 8 ft. thick. Lower part of upper flow is locally pillowed; upper part has pahoehoe flow structures. Middle flow is massive to columnar jointed. Lower flow is generally massive with widely spaced curvilinear joints and is pillowed near the top. Thickness of unit is about 590 ft. Levels of natural radioactivity range from 5 to 9 (mean=6) Micro R/Hr.

sequence of reddish-brown, medium- to coarse-grained sandstone and pebbly sandstone, pebble to cobble conglomerate, siltstone, shaly siltstone, and shale. Reddish-brown sandstone, pebbly sandstone, and pebble-to-cobble conglomerate are thin- to medium-bedded and locally massive-bedded, planar to cross-bedded in rhythmically fining-upward cycles. Locally coarsens to pebble-to-cobble conglomerate (JTrpc) beneath contact with Orange Mountain Basalt (Jo). Clasts are matrix-supported and consist mainly of reddish-brown and olive-gray sandstone and siltstone, light-gray dolomite, quartzite, and quartz. Elsewhere, unit contains beds of shaly siltstone and shale that are fine-grained, very thin- to thin-bedded, planar to ripple cross-laminated, locally fissile, bioturbated, and contain evaporite minerals, root casts and load casts. As much as 2 ft. of unit have been metamorphosed along the contact with Orange Mountain Basalt. Maximum thickness regionally is about 11,500 ft but an incomplete thickness of about 2,500 ft. occurs in the map area. Levels of natural radioactivity range from 11 to 14 (mean=12.5) Micro R/Hr in reddish-brown sandstone and siltstone and 9 to 13 (mean=10) Micro R/Hr in pebbly sandstone and conglomerate.

JUTLAND KLIPPE SEQUENCE

Passaic Formation (Lower Jurassic and Upper Triassic) (Olsen, 1980) - Interbedded

Jutland klippe sequence undivided (Middle Ordovician to Upper Cambrian?) (Perissoratis et al., 1979) - Gray-weathering, dark-gray phyllonitic shale containing thin, discontinuous siltstone lenses. Crops out along the Ramapo River near Oakland, but otherwise is known from water-well records and drill-hole data. Unit is in fault contact with Mesoproterozoic rocks on the west and Mesozoic rocks on the east. Thickness of unit is unknown. Levels of natural radioactivity range from 11 to 15 (mean=14) Micro R/Hr.

NEW JERSEY HIGHLANDS

Diabase dikes (Neoproterozoic) (Volkert and Puffer, 1995) - Light gray- or brownish-gray-weathering, dark-greenish-gray, aphanitic to fine-grained rocks. Composed principally of plagioclase (labradorite to andesine), augite, ilmenite and (or) magnetite. Pyrite blebs are common. Contacts are typically chilled and sharp against enclosing Mesoproterozoic rocks. Dikes are as much as 25 ft. thick.

Vernon Supersuite (Volkert and Drake, 1998)

Byram Intrusive Suite (Drake et al., 1991) Hornblende granite (Mesoproterozoic) - Pinkish-gray or buff-weathering, pinkish-white or

light-pinkish-gray, medium- to coarse-grained, massive, foliated granite composed of mesoperthite, microcline microperthite, quartz, oligoclase, and hornblende. Unit includes small bodies of pegmatite too small to be shown on map.

Metasedimentary Rocks

Biotite-quartz-feldspar gneiss (Mesoproterozoic) - Pinkish-white to pinkish-gray and locally

rusty-weathering, gray, tan, or greenish-gray, medium- to coarse-grained, layered and

composed of microcline, quartz, oligoclase, clinopyroxene, and trace amounts of titanite and

Potassic feldspar gneiss (Mesoproterozoic) - Light-gray or pinkish-buff-weathering, pinkish-white or light-pinkish-gray, medium-grained, massive, foliated gneiss composed of quartz, microcline microperthite, oligoclase, and biotite. Garnet, sillimanite, and magnetite occur locally.

foliated gneiss containing microcline microperthite, oligoclase, quartz, biotite, garnet, sillimanite, graphite and pyrrhotite. Hornblende-quartz-feldspar gneiss (Mesoproterozoic) - Pinkish-gray to buff- weathering, pinkish-white to pinkish-gray, medium-grained, layered and foliated gneiss composed of microcline, quartz, oligoclase, hornblende, and magnetite. Some outcrops contain both

hornblende and biotite in near equal amounts and are mapped as hornblende-biotite-quartz-feldspar gneiss (Yhb). Both types of gneiss contain local garnet. linopyroxene-quartz-feldspar gneiss (Mesoproterozoic) - Pinkish-gray or pinkish-buff-weathering, white to pale-pinkish-white, medium-grained, foliated gneiss

Pyroxene gneiss (Mesoproterozoic) - White-weathering, greenish-gray, medium-grained, ayered and foliated gneiss containing oligoclase, clinopyroxene, variable amounts of quartz, and trace amounts of titanite and opaque minerals. Unit is commonly spatially associated

with rusty biotite-quartz-feldspar gneiss (Yb) and amphibolite (Ya).

Losee Metamorphic Suite (Drake, 1984; Volkert and Drake, 1999)

Quartz-oligoclase gneiss (Mesoproterozoic) – White-weathering, light-greenish-gray, medium- to coarse-grained, massive, foliated gneiss composed of oligoclase or andesine, quartz, and variable amounts of clinopyroxene, hornblende and (or) biotite. Locally contains layers of amphibolite not shown on map.

Albite-oligoclase granite (Mesoproterozoic) - White-weathering, light-greenish-gray, pink mottled, medium- to coarse-grained, massive granite and local alaskite composed of pink and white albite or oligoclase, quartz, and variable amounts of clinopyroxene and magnetite. Unit appears to be spatially related to quartz-oligoclase gneiss from which it may have formed through sodium metasomatism.

Biotite-quartz-oligoclase gneiss (Mesoproterozoic) - White or light-gray-weathering, medium-gray or light greenish-gray, medium- to coarse-grained, foliated and locally layered gneiss composed of oligoclase or andesine, quartz, biotite, and garnet. Some outcrops contain hornblende. Unit grades into quartz-oligoclase gneiss (Ylo) with decrease in biotite. Locally contains thin, conformable layers of biotite-bearing amphibolite not shown on map.

Hypersthene-quartz-plagioclase gneiss (Mesoproterozoic) - Light gray or tan-weathering, greenish-gray or greenish-brown, medium-grained, layered and foliated gneiss composed of andesine or oligoclase, quartz, clinopyroxene, hornblende, and hypersthene. Commonly contains conformable layers of amphibolite and mafic-rich quartz-plagioclase gneiss not shown on map.

Amphibolite (Mesoproterozoic) - Gray to grayish-black, medium-grained, foliated gneiss composed of hornblende and andesine. Some variants contain biotite or clinopyroxene. Amphibolite associated with the Losee Metamorphic Suite is metavolcanic in origin. Other amphibolite associated with metasedimentary rocks may be metavolcanic or metasedimentary in origin. Both types are shown undifferentiated on the map.

Hornblende granite of uncertain affinity (Mesoproterozoic) - Tan to buff-weathering, pinkish-gray or greenish-gray, medium- to coarse-grained, locally pegmatitic, weakly foliated Sample TH 1 TH 2 RA3 UH 1 UH 2 UH 3 UH 5 UH 7 to gneissoid granite. Composed of mesoperthite, microcline microperthite, oligoclase, hornblende, magnetite, and local biotite. Contains abundant xenoliths of well-foliated gneiss. Unit may correlate to the Storm King Granite in the New York Hudson Highlands.

Al₂O₃ 13.52 13.29 13.50 14.80 14.17 14.26 14.33 13.74 Mesoproterozoic rocks undivided – Mesoproterozoic rocks of unknown affinity confined to an area along the Ramapo River that are known from water-well records and drill-hole data.

CORRELATION OF MAP UNITS NEWARK BASIN

FAULT CONTACT JUTLAND KLIPPE SEQUENCE

NEW JERSEY HIGHLANDS INTRUSIVE CONTACTS Vernon Supersuite Byram Intrusive Suite

FAULT CONTACT

INTRUSIVE CONTACTS

Other Rocks

Contact - Dotted where concealed.

Faults - Dotted where concealed

Overturned Synforn

Strike and dip of crystallization foliation

Strike and dip of mylonitic foliation

LINEAR FEATURES

OTHER FEATURES

Abandoned mine – M, magnetite; S, sulfide

Form lines showing foliation in Proterozoic rocks.

1,000

-1,000

SEA LEVEL

Bearing and plunge of mineral lineation in Proterozoic rocks

Strike and dip of inclined beds

Drill hole bottoming in bedrock

Shown in cross section

Bedrock outcrop or float

Active rock quarry

EXPLANATION OF MAP SYMBOLS

Normal fault - U, upthrown side; D, downthrown side.

Reverse fault - U, upthrown side; D, downthrown side.

Fault – Arrows show relative horizontal movement

Faults of indeterminate dip direction and attitude

Folds in Proterozoic rocks showing trace of axial surface

Folds in Mesozoic rocks showing trace of axial surface,

direction of dip of limbs, and direction of plunge.

PLANAR FEATURES

direction of dip of limbs, and direction of plunge.

Bar and ball show dip of fault plane.

Bar and ball show dip of fault plane.

Metasedimentary Rocks Yb Ymh/Yhb Ymp Losee Metamorphic Suite Ylo Yla Ylb Yh

--, Not determined

MESOPROTEROZOIO

Union Hill quarry (Geiger, 1984).

Table 1. Geochemical analyses of diabase and basalt from the Ramsey quadrangle

SiO₂ 51.92 51.88 52.20 50.82 51.49 52.32 51.85 50.66

TiO₂ 1.48 1.41 1.34 0.98 1.01 1.12 1.08 1.04

Fe₂O₃ -- -- 3.82 2.13 2.05 2.25 2.21 2.47

FeO* 10.79 11.14 -- -- -- -- -- --

MgO 5.76 4.32 5.90 6.84 6.52 6.06 6.57 6.21

MnO 0.18 0.17 0.20 0.15 0.15 0.13 0.12 0.11

CaO 10.75 11.18 10.30 9.85 10.04 9.65 10.18 9.72

Na₂O 1.98 2.18 2.10 2.14 2.30 2.42 2.63 2.85

K₂O 0.93 0.45 0.45 0.54 0.60 0.55 0.51 0.49

P₂O₅ 0.18 0.15 0.17 0.19 0.20 0.21 0.20 0.20

LOI -- -- 1.85 1.11 0.97 0.90 0.92 1.19

Total 97.39 96.17 99.73 98.89 98.87 99.58 99.53 97.83

Nb -- -- 20 -- -- -- --

Y -- -- 30 34 35 39 36 36

Zr -- -- 130 -- -- -- --

Co -- -- 61 -- -- -- --

Cr 120 92 100 -- -- -- -- --

Ni 48 35 68 -- -- -- -- --

La -- -- 14.20 -- -- -- --

Sm -- -- 3.73 -- -- -- --

Eu -- -- 1.36 -- -- -- --

Yb -- -- 2.30 -- -- -- -- --

TH 1 and TH 2, Turtle Hill diabase (data source unknown); RA 3, Turtle Hill diabase (New

Jersey Geological Survey, unpublished data); UH 1, 2, 3, 5, and 7, Preakness Basalt from

Table 2. Geochemical analyses of host rock

0.07

0.10

141

Sample 458, metagabbro host rock; sample

Total Fe as Fe₂O₃

--, Not determined

458-P, pyrrhotite.

100.01

and pyrrhotite from Ramapo Mountain sulfide

Cu -- -- 155 35 79 89 87 76

FeO -- -- 7.90 9.34 9.37 9.71 8.93 9.15

49.40 America Special Paper 268, p. 95-118. 0.07 0.25 1.44 21.69 35.75 9.09 Ratcliffe, N.M., and Aleinikoff, J.N., 2001, New insights into the tectonic history of the Mesoproterozoic basement of 17.44 14.57 0.29 0.18

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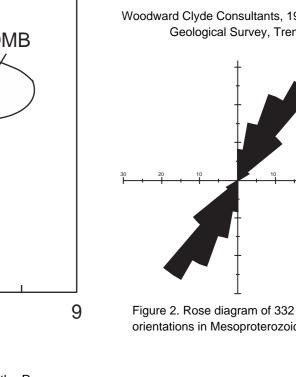


Figure 1. TiO₂ versus MgO plot of Mesozoic igneous rocks of the Ramsey quadrangle. TH1 and RA3, Turtle Hill diabase (this study). UH 1-3, 5,7, Preakness Basalt from Union Hill quarry (Geiger, 1984). Fields for Orange Mountain Basalt (OMB), Preakness Basalt (PB), and Hook Mountain Basalt (HMB), and average compositions (asterisks) of Preakness flows 1 through 3 and Hook Mountain flows 1 and 2 from Puffer (1992)

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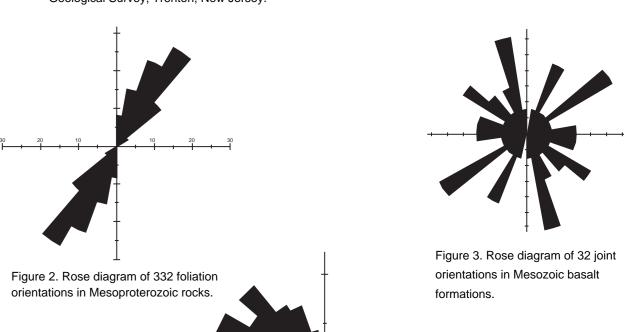
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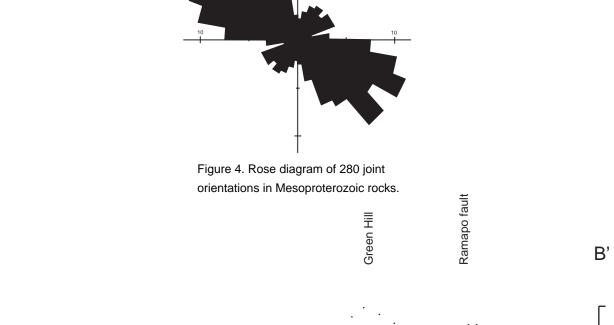
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Small brittle faults of Mesozoic age deform the Passaic Formation through the Preakness Basalt in the southwestern part of the map area. These faults range in width from <1 ft. to about 20 ft., and the wider faults commonly consist of zones of multiple thin faults. All faults are characterized by very close-spaced jointing, thin zones of breccia and (or) clayey gouge, slickensides locally coated with chlorite or calcite, and eroded gaps in basalt outcrops. The faults strike N.02°W. to N.14°W. and dip 75° to 90°. Kinematic indicators that consist of subhorizontal to gently north-plunging slip lineations constrain the predominant movement to right-lateral strike-slip.

Mesoproterozoic rocks throughout the map area are deformed by northeast-trending and, less commonly, by northwest-trending faults. The fault just west of, and subparallel to, the Ramapo fault is characterized by a pervasive, steeply southeast-dipping mylonitic fabric. The rest of the faults cutting Mesoproterozoic rocks are characterized by brittle fabric that includes retrogression of mafic mineral phases, chlorite or epidote-coated fractures or slickensides, and close-spaced fracture cleavage. Widths of the fault zones typically are on the order of tens of feet but locally they may be as much as several hundred feet wide. Some of the wider fault zones are possibly due to the interaction of several smaller parallel or anastomosing faults, rather than consisting of a single, discrete fault. A northwest-trending fault at Hillburn and Suffern in New York underlies the Ramapo River Valley. This fault is not recognized in outcrop, but is inferred from the apparent offset of lithologic units. The movement sense is interpreted to be right-lateral strike-slip.

The Ramapo fault is the dominant structural feature in the region, extending northeastward from the Peapack-Gladstone area (Houghton and Volkert, 1990; Drake et al., 1996) into New York State. The fault has a complex and protracted history of movement that began in the Proterozoic. Multiple episodes of subsequent reactivation have left overprinting brittle and ductile fabrics that record kinematic indicators consistent with normal, reverse, and strike-slip movement. In the Ramsey quadrangle the Ramapo fault trends about N.40°E. The fault dips about 50° to 55° toward the southeast as indicated by borings drilled to the southwest at Bernardsville (Ratcliffe and others, 1990) and by a series of borings drilled for Route 287 between Montville and Riverdale (Woodward-Clyde Consultants, 1983). However, outcrops of ductilely deformed Mesoproterozoic rocks on the footwall of the fault, especially to the south in the Pompton Plains quadrangle, consistently record mylonitic foliation of probable Proterozoic and Paleozoic

Joints are a ubiquitous feature in all of the bedrock units in the quadrangle. Insufficient outcrops of Mesozoic sedimentary rock occur in the quadrangle to determine a dominant trend. The few joints measured are oriented N.60°W. and dip about 80° toward the northeast. These joints are characteristically planar, moderately well formed, and are unmineralized, except near faults where they may contain sparse calcite. Joint surfaces typically are smooth and less commonly irregular. Joints are variably spaced from <1 ft. to several feet. Those in sandstone tend to be more penetrative than joints developed in the finer-grained lithologies such as siltstone and shale. Joints in shale are commonly less well developed and

are continuous over short distances in outcrop. All joints formed near faults are spaced much closer and

age that dips steeply toward the southeast at 60° to 85°.

N.64° E. to N. 86°E., dipping 75° to 84° toward the southeast.

typically are on the order of <1 ft.

southwest at an average of 74°.

Joints in the Mesozoic igneous rocks consist of two predominant types, columnar (cooling) and tectonic. Columnar joints are present in all of the basalt formations and diabase in the map area. They are characteristically polygonal, arrayed radially and are variable in height and spacing. A comprehensive study of cooling joints in the basalts was performed by Faust (1978). Tectonic joints occur in all of the basalt formations and diabase but are commonly obscured by the more pervasive cooling joints. Tectonic joints are planar, moderately to well formed, smooth to slightly irregular, steeply dipping, unmineralized, and variably spaced from a few ft. to tens of ft. However, near faults, joint spacing is typically 1 ft. or less. Two principal joint trends are developed, one striking northwest and the other northeast. Northwest joints trend N.30° W. to N. 70°W. (Fig. 3) and dip 73° to 87° toward the southwest and much less commonly toward the northeast. A second, smaller population trends N.06° W. to N. 10°W. and dips 60° to 80° toward the northeast. Northeast joints occur equally among three separate trends: N.03° E. to N. 21°E., dipping 65° to 81° toward the southeast; N.35° E., to N. 50°E., dipping >80° toward the southeast and northwest;

Joints developed in Mesoproterozoic rocks are characteristically planar, moderately well formed. Sedimentary rocks of probable Ordovician to Cambrian age are tentatively correlated with rocks of the moderately to widely spaced, and moderately to steeply dipping. Surfaces of joints are unmineralized, except near faults, and are smooth and less commonly slightly irregular. Joints are variably spaced from ft. to tens of ft. Those developed in massive rocks such as granite tend to be more widely spaced, irregular and discontinuous than joints developed in the layered gneisses. Joints formed near faults are spaced more closely, typically 2 ft. or less.

> The dominant joint orientation within the Mesoproterozoic rocks is nearly orthogonal to the strike of crystallization foliation, and this orthogonal relationship of the principal joint set to foliation is a consistent feature in Mesoproterozoic rocks throughout the Highlands (Volkert, 1996). The dominant joint set strikes N.40°W. to N.80°W. (Fig. 4) and dips steeply toward the northeast and, less commonly, toward the

ECONOMIC RESOURCES

Mesoproterozoic rocks in the quadrangle were mined for magnetite at two locations and sulfide was mined at one location. Magnetite was mined from sometime before 1868 until 1880 at the Butler mine northwest of Bear Swamp Lake (Bayley, 1910). A second prospect east of Bear Swamp, the Pierson exploration, is about 0.5 mile northeast of the Butler mine. The ore here is apparently very lean and the mine was not developed (Bayley, 1910). The dates of this working are not given, but probably overlap those of the Butler

A small mine along the western side of Monroe Ridge was worked for a sulfide mineral, reported to be "iron pyrite" containing nickel (Cook, 1868). However, the sulfide phase was identified by X-ray diffraction analysis as pyrrhotite (J. Dooley and L. Mueller, oral communication, 2002). No dates of operation or other information regarding this mine are known. A historical note (New Jersey Geological Survey, 1879) mentions nickel and cobalt as constituents of pyrite in Precambrian rocks in Warren and Hunterdon Counties. However, the geochemical composition of pyrrhotite from the map area (Table 2), obtained during the current mapping, shows nickel and cobalt to be present in only minor amounts and insufficient

Lower Jurassic basalt was formerly quarried for use as aggregate and for dimension stone at Union Hill in Suffern until 2002 when the quarry was shut down and sold. It is now under new ownership but was not

Small deposits of sand and gravel were mined at several locations in the quadrangle (Stanford, 2002), mainly in the Ramapo River Valley.

NATURALLY OCCURRING RADIATION

Background levels of naturally occurring radioactivity were measured in Mesozoic bedrock outcrops using a hand-held Micro R meter and the results are given under the individual rock unit descriptions. In general, basalt and diabase yield consistently low readings of about 6 Micro R/Hr regardless of stratigraphic position, texture, or composition. Sedimentary units yield higher and somewhat more variable readings ranging from 9 to 21 Micro R/Hr that appear to be influenced mainly by grain size. Values recorded from sandstone and pebbly sandstone are lower than those from finer-grained siltstone and shale, suggesting that clay minerals are principal hosts of the radiogenic mineral phases. This relationship applies on a regional basis as well, based on measurements of various lithofacies of the Mesozoic sedimentary formations from quadrangles in the Newark basin from New Brunswick north to Pompton Plains (R.A.

NEWARK BASIN

Diabase (Lower Jurassic) Dark greenish-gray to black, fine- to medium-grained diabase composed of plagioclase (An_{50.70}), clinopyroxene (mainly augite), and magnetite \pm ilmenite. Olivine is rare. Diabase is dense, hard, and is massive to columnar jointed. Levels of natural radioactivity range from 5 to 7 (mean=6) Micro R/Hr.

commonly hummocky and trough cross-laminated, and siltstone is commonly planar laminated or bioturbated and indistinctly laminated to massive. Maximum thickness regionally is about 1,250 ft. However, unit does not crop out in the quadrangle and is known only from water-well records and drill-hole data. Levels of natural radioactivity range from 12 to 21 (mean=15) Micro R/Hr in reddish-brown lithologies and 13 to 20 (mean=16) Micro R/Hr in

dense, hard basalt composed mainly of intergrown calcic plagioclase and clinopyroxene.

DESCRIPTION OF MAP UNITS

Towaco Formation (Lower Jurassic) (Olsen, 1980) - Reddish-brown to brownish-purple, buff, olive-tan, or light-olive-gray, fine- to medium-grained, micaceous sandstone, siltstone, and shale in fining-upward sequences 3 to 10 ft. thick. Unit consists of at least eight sequences of gray, greenish-gray, or brownish-gray, fine-grained sandstone, siltstone, and calcareous siltstone, and black microlaminated calcareous siltstone and shale with diagnostic pollen, fish, and dinosaur tracks. Gray fine-grained sandstone has carbonized plant remains. Irregular mud cracks and symmetrical ripple marks are present locally. Sandstone is

Preakness Basalt (Lower Jurassic) (Olsen, 1980) - Dark-greenish-gray to black, fine-grained,

Contains small spherical to tubular gas-escape vesicles, some filled by zeolite minerals or

Bedrock geology mapped by R.A. Volkert in 1988, 2002, and 2003 Digital cartography by M.W. Girard Research supported by the U. S. Geological Survey, National Cooperative Geological Mapping Program, under USGS award number 99HQAG0141 The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U. S. Government.

SEA LEVE

BEDROCK GEOLOGIC MAP OF THE RAMSEY QUADRANGLE PASSAIC AND BERGEN COUNTIES, NEW JERSEY AND **ROCKLAND COUNTY, NEW YORK**

Richard A. Volkert

SCALE 1:24 000

Base map U.S. Geological Survey, 1995

LOCATION IN **NEW JERSEY**

2011