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Digital Geologic Map Data for the Ozark National Scenic Riverways and Adjacent Areas Along the Current River and Jacks Fork, Missouri

Data Series 1017

U.S. Department of the Interior
U.S. Geological Survey

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

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Abstract

The geology of the Ozark National Scenic Riverways (ONSR) in southern Missouri has been mapped at 1:24,000 scale. This endeavor was achieved through the combined efforts of U.S. Geological Survey and Missouri Geological Survey individual quadrangle mapping and additional fieldwork by the authors of this report. Geologic data covering the area of the ONSR and a 1-mile (1.6-kilometer) buffer zone surrounding the park, as well as geologic data from a few key adjoining areas, have been compiled into a single, seamless geographic information system database. The intent is to provide base geologic information for natural science research and land management in the park and surrounding areas. The data are served online at ScienceBase (https://www.sciencebase.gov/catalog/), where they are provided in Environmental Systems Research Institute (ESRI) file geodatabase format, and are accompanied by metadata files. These data can be accessed at: http://dx.doi.org/10.5066/F7CJ8BKB. Additional detailed geologic information about the ONSR and surrounding areas is available in the separate 1:24,000-scale quadrangle maps and in a 1:100,000-scale map and report on the regional geology.

Introduction

Purpose

Geologic map data were created and compiled to provide seamless 1:24,000-scale coverage for an area that contains the entire Ozark National Scenic Riverways (ONSR) and completes a geologic inventory sponsored by the National Park Service (NPS), Geologic Resources Division. These data are intended to provide geologic information to ONSR personnel and their scientific cooperators for use in various natural resource and land classification studies. This report includes a brief summary of the geology of the park area; refer to http://dx.doi.org/10.5066/F7CJ8BKB (Weary and others, 2016).

For more detailed and site-specific geologic descriptions and discussions, the reader should refer to the individual 1:24,000-scale quadrangle reports that are the basis for most of this report (fig. 1; table 1). In addition, Weary and others (2014) provide a comprehensive discussion of various geologic aspects of the entire region, and Lowell and others (2010) provide detailed descriptions of selected geologic and karst-related features in and around the ONSR area.

Scope of the Data

The spatial extent of these data covers the ONSR as well as areas extending 1 mile (mi) (1.6 kilometer [km]) beyond the exterior park boundaries. In addition, several other areas along the Current River and Jacks Fork are included for continuity of coverage along the rivers. These areas are (1) part of the headwaters area of the Current River in the vicinity of Montauk Springs and Montauk State Park; (2) the headwaters area of Jacks Fork; (3) the reach of Jacks Fork near the town of Eminence that is not within the ONSR; and (4) a reach of the Current River near the town of Van Buren that is not within the ONSR (fig. 1).

Geologic data include (1) polygons describing the extent and distribution of bedrock units, areas of overlying surficial deposits, and the location and extent of karst sinkholes; (2) lines marking the traces of mapped faults, mapped fold axes, and the contacts of both the bedrock and surficial map units; and (3) points marking the location and measurement values of bedding attitude in sedimentary rocks or foliation in igneous rocks.

Geographic information system (GIS) data representing the boundaries of the ONSR and the 1:24,000-scale U.S. Geological Survey (USGS) topographic quadrangles are also included for geographic reference.

Original Data Sources

Data in this report were compiled chiefly from geologic map databases generated by the USGS and the Missouri Geological Survey (fig. 1; table 1). For geologic coverage of the

ONSR and the surrounding area that lies outside of the completed quadrangle maps (fig. 1; table 1), data were compiled from the regional geologic map of the area (Weary and others, 2014) and augmented by additional fieldwork by the authors.

Sinkhole location data were derived from the published geologic maps and from the USGS 1:24,000-scale base topographic maps with 20-foot (ft) (6-meter [m]) contour intervals. Sinkholes less than 10 m (33 ft) in diameter are all represented as 10-m-diameter circular polygons.

Some surficial units were mapped in only one or two quadrangles. See the Description of Map Units for notes on the limited distribution of these units.

Geologic Description

The ONSR lies in the southeastern part of the Ozark Plateaus physiographic province of central and southern Missouri (fig. 1). The geology of the ONSR comprises a Mesoproterozoic (~1.4-Ga) (giga-annum)-age basement of intrusive and extrusive igneous rocks, discomformably overlain by relatively flat-lying Cambrian and Lower Ordovician (~500–470 Ma) (mega-annum) sedimentary rocks, on which various surficial and residual sedimentary units are superposed (fig. 2). Basement rocks of Mesoproterozoic age, chiefly granite and rhyolite, are exposed as erosional remnant hills in an uplifted area near the central part of the park (fig. 1). The overlying Paleozoic sedimentary rocks are chiefly dolomite that contains interlayers of quartz sandstone and chert (fig. 3). Only geologic units exposed at the land surface in the ONSR are described herein. For descriptions of subsurface units in the project area, see the individual quadrangle reports (table 1) or Weary and others (2014).

The bedrock in the ONSR area is cut by numerous faults having northwest-southeast and northeast-southwest trends. These are chiefly vertical strike-slip faults resulting from stresses associated with the late Paleozoic ancestral Rocky Mountain-Ouachita-Alleghenian orogenic systems, as the Ouachita front is only about 200 km to the south; see Cox (2009) and Hudson (2000) for analyses of late Paleozoic faulting in the Ozark region. The entire exposed Paleozoic section is pervasively karstified.

For a more complete discussion of the geology in the ONSR and surrounding area, see the individual quadrangle source publications (listed in table 1) as well as regional descriptions in Lowell and others (2010) and Weary and others (2014).

Table 1. List of quadrangle maps completed in the Ozark National Scenic Riverways and vicinity by the U.S. Geological Survey and the Missouri Geological Survey and used as sources for this compilation. See References Cited for full citations. Numbers correspond to quadrangle locations in figure 1.

Quadrangle number in figure 1	Quadrangle(s)	Author(s)	Year of publication
1	Montauk	Weary	2015
2	Cedargrove	Weary	2008
3	Round Spring	Orndorff and Weary	2009
4	Alley Spring	Weary and Orndorff	2012
5	Eminence	Orndorff and others	1999
6	Powder Mill Ferry	McDowell and Harrison	2000
7	Jam Up Cave and Pine Crest	Weary and others	2013
8	Stegall Mountain	Harrison and others	2002
9	Van Buren North	Weary and Weems	2004
10	Van Buren South	Weary and Schindler	2004
11	Big Spring	Weary and McDowell	2006
12	Grandin SW	Baker	1999a, 1999b

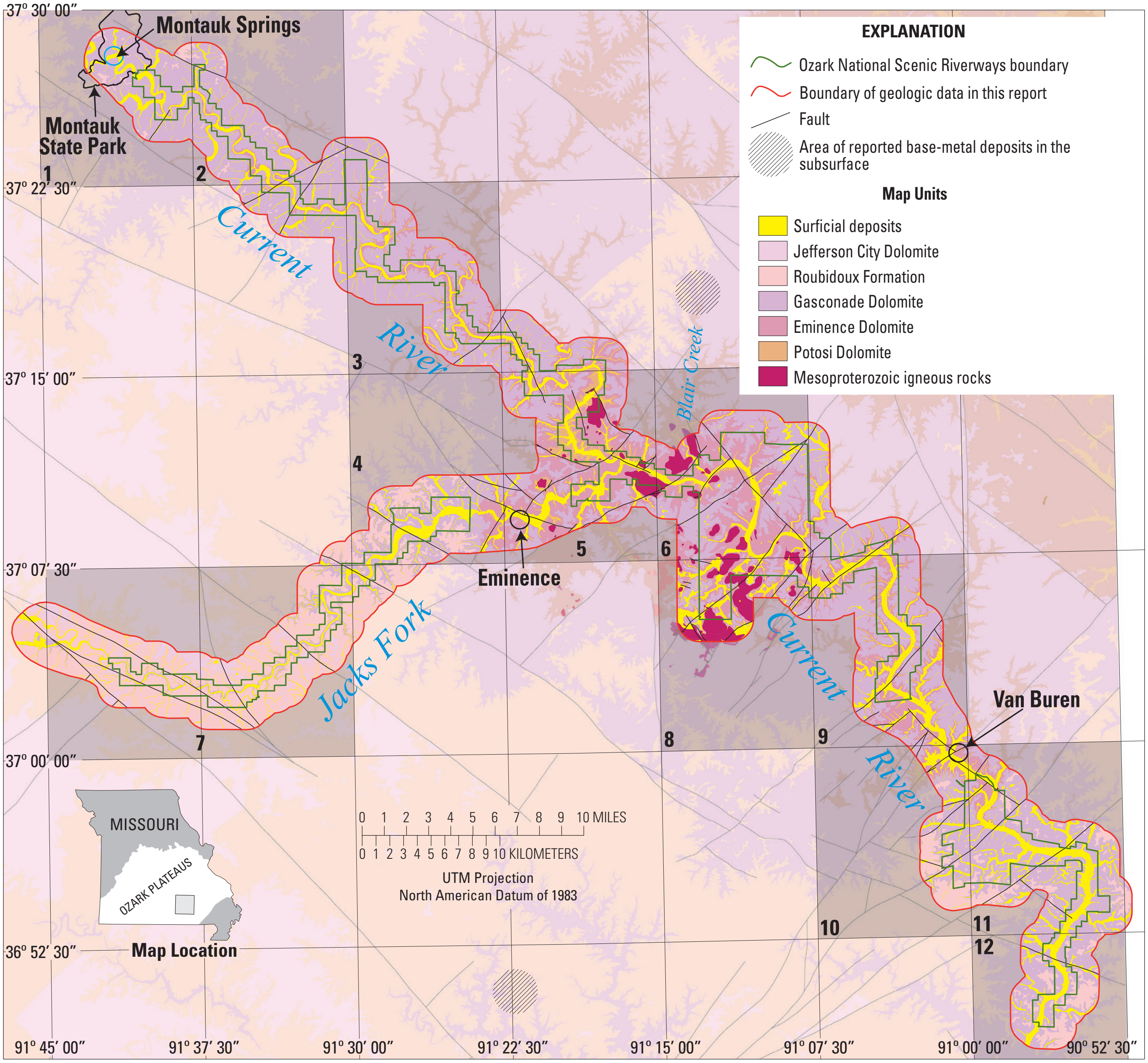

Figure 1. Simplified geologic map of the Ozark National Scenic Riverways area based on the 1:24,000-scale geographic information system (GIS) data provided in this report. The various Mesoproterozoic igneous rock and Cenozoic surficial map units identified in the GIS data are not differentiated. The geology in the subdued part of the figure, outside of the report area (that is, outside the boundary of geologic data in this report), is modified from Weary and others (2014; available online at: http://pubs.er.usgs.gov/publication/sim3280). Also shown are the locations of individual geologic maps (gray rectangles) published by the U.S. Geological Survey and the Missouri Geological Survey from 1999 to 2015. Bold numbers in the rectangles correspond to quadrangle maps listed in table 1. See References Cited for full citations.

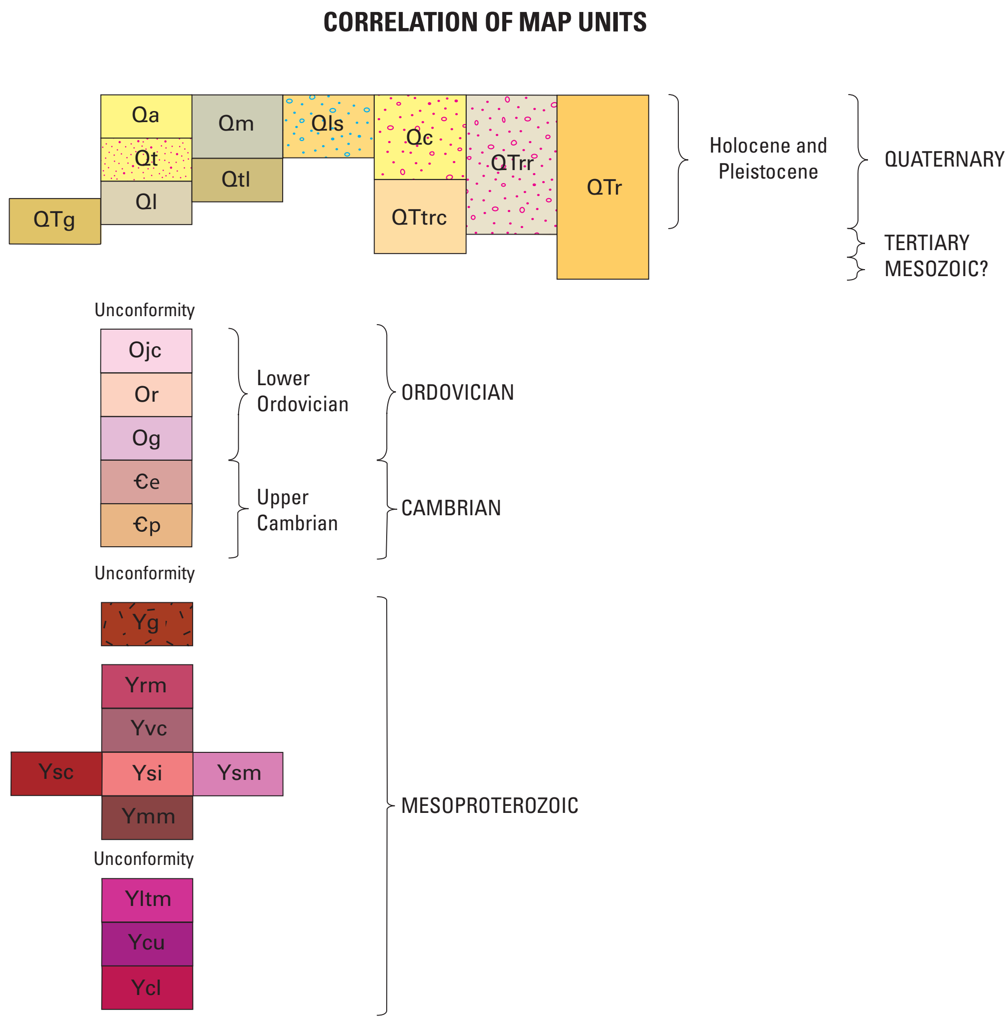

Figure 2. Correlation of map units exposed in the Ozark National Scenic Riverways and adjacent areas along the Current River and Jacks Fork, within the boundary of geologic data in this report.

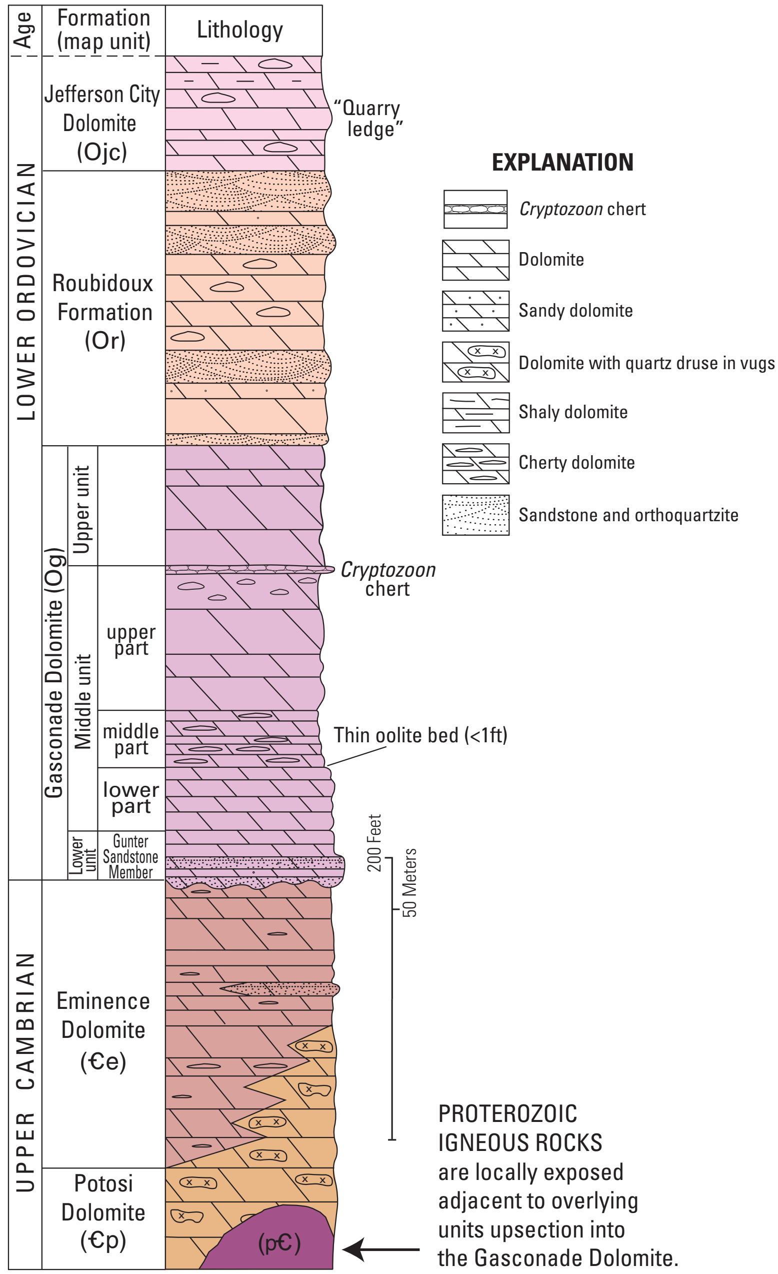

Figure 3. Idealized stratigraphic column for the Ozark National Scenic Riverways area showing lithostratigraphic units which include outcropping Paleozoic formations and Proterozoic rocks. Abbreviation: p€, Precambrian (Mesoproterozoic) rocks.

Description of Map Units

Surficial Units

Qa **Alluvium (Holocene)**—Gravel, sand, and clay confined to the bed and active flood plains of modern stream valleys. Material consists mostly of subrounded to subangular chert, sandstone, and quartzite clasts in a matrix of sand containing silt and clay. Thickness ranges from 0 to as much as 20 ft (6 m)

Qc **Colluvium (Holocene and Pleistocene)**—Boulders, cobbles, and pebbles of sandstone derived from weathering of the Roubidoux Formation. Commonly forms gravity-creep deposits a few feet thick on steep slopes in the upper part of the Gasconade Dolomite immediately below the Roubidoux residuum. Mapped as a unit in the Powder Mill Ferry quadrangle only (McDowell and Harrison, 2000). Widely distributed and common on steep slopes; shown on map only where thickest and most extensive

Qm **Muck and clayey silt (Holocene and Pleistocene?)**—Silt, reworked loess, clay, and organic-rich muck filling sinkholes that intermittently retain water. Mapped as a unit in the Jam Up Cave and Pine Crest quadrangles only (Weary and others, 2013). Thickness unknown

Qls **Landslide deposits (Holocene and Pleistocene?)**—Chaotic jumble of dolomite, chert, sandstone, and quartzite clasts in a clayey and silty matrix. Includes large landslides and large-scale slump bodies with hummocky topography, 20 to 100 ft (6 to 30 m) thick. Mapped in the Van Buren North quadrangle only (Weary and Weems, 2004), but similar deposits are found in areas of steep topography in other quadrangles

Qt **Terrace deposits (Holocene and Pleistocene?)**—Large cobble-size to sand-size, subrounded to subangular chert, sandstone, and quartzite clasts within a matrix of sand, silt, and clay. In some locations a significant fraction of the matrix is reworked silt-size loess. Occurs on margins of modern stream valleys, but above normal seasonal floods of present streams. Terraces along the major streams usually stand at least 6 to 10 ft (2–3 m) above stream level. Thickness at least 10 ft, and possibly more along larger stream courses

Qtl **Loess-covered terrace deposits (Pleistocene?)**—Predominantly silt with lesser sand and clay. Mapped as a unit only in the Stegall Mountain quadrangle (Harrison and others, 2002) and the Van Buren South quadrangle (Weary and Schindler, 2004). Occurs on slopes above the valleys of various large streams and also is preserved in a few large sinkholes. A well-developed soil horizon (probably equivalent to the Sangamon Geosol) occurs beneath the loess. Windblown silt, as much as 1 ft (0.3 m) thick, mantles clay, silt, and sand, with minor pebbles. May be as much as 40 ft (12 m) thick

Ql **Loess (Pleistocene)**—Silt. This unit was mapped in only one location, in the Stegall Mountain quadrangle, but it also occurs as small areas of thin veneer elsewhere in the study area (Harrison and others, 2002). Discontinuous patches occur on hillcrests and ridges, including some of the highest parts of Thorny Mountain. Silt is commonly mixed with residuum, probably because of bioturbation. As much as 5 ft (1.5 m) thick

QTtrc **Residual and colluvial material on terrace-like landforms (Quaternary and Tertiary)**—Silt, clay, sand, and gravel. Unit was mapped in the Stegall Mountain quadrangle only (Harrison and others, 2002). Occurs as terrace-like landforms that are found most commonly adjacent to knobs of Mesoproterozoic volcanic rocks in the northern part of the quadrangle. In part residual and in part colluvial in nature. Commonly covered by a thin veneer of loess, as much as 5 ft (1.5 m) thick. A well-developed soil horizon (possibly equivalent to the Sangamon geosol) commonly occurs beneath the loess. Gradational into Quaternary terrace deposits (Qt, Qtl). As much as 60 ft (18 m) thick

QTrr **Residuum derived from Roubidoux Formation (Quaternary and Tertiary)**—Red and reddish-orange sandy clay containing angular sandstone and chert cobbles and boulders as much as 6 ft (2 m) in diameter. Sandstone cobbles and boulders, fine- to coarse-grained, poorly sorted, and locally containing symmetrical and asymmetrical ripple marks. Chert cobbles and boulders, light- to medium-gray, consisting of banded, sandy, oolitic, and porcelaneous varieties. Unit is widespread but was not mapped in all quadrangles; however, where mapped, only locations where it was identified via ground traverse are indicated. Occurs on hilltops where bedrock of the Roubidoux Formation has been deeply weathered. Roubidoux residuum was mapped only in areas where it directly overlies older formations, and no in-situ Roubidoux bedrock was inferred; unmapped Roubidoux residuum exists virtually everywhere that the Roubidoux Formation occurs. As much as 40 ft (12 m) thick

QTg **Upland gravel deposit (Quaternary and Tertiary)**—Gravel deposits, as high as 300 ft (91 m) above the modern-stream flood plains, containing mostly subrounded to rounded clasts of chert, sandstone, and quartzite in a matrix of silty sand. Mapped only in the Van Buren North quadrangle (Weary and Weems, 2004). Clasts of fossiliferous Mississippian chert are rare to abundant. Thickness generally less than 10 ft (3 m)

QTr **Peck Ranch unit (Quaternary and Tertiary, and Mesozoic?)**—Brown, red, and reddish-orange sandy clay containing angular blocks, cobbles, and pebbles of sandstone, and various varieties of chert. Insoluble, residual material derived from intense in-situ weathering of Paleozoic rocks, largely from the Roubidoux Formation downward through the upper Eminence Dolomite. Unit was mapped only in the Stegall Mountain quadrangle (Harrison and others, 2002). Crude stratigraphic sequence is generally preserved. At least 200 ft (61 m) thick

Paleozoic Bedrock Units

Ojc **Jefferson City Dolomite (Lower Ordovician)**—Dolomite, quartz sandstone, and chert. Dolomite is light brown, medium to fine grained, argillaceous, and thin to thick bedded; commonly weathers powdery pale yellow. Lenses of quartz sandstone and orthoquartzite as well as beds and nodules of white chert are also common. In some areas an interval of brown, medium-grained, thick-bedded to massive, pitted-weathering siliceous dolomite informally known as the "Quarry Ledge" crops out. The "Quarry Ledge" occurs between 25 and 40 ft (8–12 m) above the base of the Jefferson City Dolomite, making it a useful marker for the Roubidoux-Jefferson City contact, which is seldom exposed. The Jefferson City Dolomite weathers to a characteristic yellowish color and produces a more silty, less sandy soil than the underlying Roubidoux Formation. Residual sandstone and orthoquartzite float from the Jefferson City are usually less tabular in shape than those produced from the Roubidoux. These characteristics enable differentiation between Roubidoux and Jefferson City bedrock in areas having no outcrop. The Jefferson City Dolomite is sparsely fossiliferous, but has yielded trilobites and conodonts as reported by Repetski and others (1998). This formation has an average thickness of about 200 ft (61 m) (Thompson, 1995). Typically, considerably less than the full thickness of this unit is exposed in the ONSR area

Or **Roubidoux Formation (Lower Ordovician)**—Sandstone, orthoquartzite, dolomite, sandy dolomite, and chert. Sandstone is white to pale orange, fine to coarse grained, thin to thick bedded, generally poorly sorted, and commonly crossbedded and ripple marked; weathers light brown to reddish brown. Dolomite is light to medium gray, very fine to coarse grained, and thin to medium bedded. Chert is white to medium gray, locally sandy and oolitic; occurs in thin beds, lenses, and nodules. Typically formation is highly weathered and not well exposed. Thickness ranges up to 250 ft (76 m)

Og **Gasconade Dolomite (Lower Ordovician)**—Dolomite, chert, sandstone, and orthoquartzite. Formation can be divided into three informal units, the lower, middle, and upper (fig. 3), which are not shown separately in figure 1. Upper unit is typically light-gray, medium- to coarse-grained, thick-bedded, vuggy dolomite. Weathered surfaces are commonly pitted. Middle unit is further divided into lower, middle, and upper parts. The upper part of the middle unit is typically light-gray, fine- to coarse-grained, medium- to thick-bedded dolomite, and contains white to light-gray chert nodules and lenses. The uppermost bed of the upper part of the middle unit is a regionally persistent white *Cryptozoon* chert, 2 to 10 ft (0.6–3 m) thick, commonly used to map the Roubidoux/Gasconade contact, which rarely is exposed. This contact is placed at approximately 80 to 100 ft (24–30 m) above the *Cryptozoon* chert, which is an average of observed intervals. The middle part of the middle unit is light-gray to very light gray, medium- to coarse-grained, medium-bedded dolomite containing chert as nodules, stringers, and beds. Chert varieties are porcelaneous, oolitic, porous with druse, and stromatolitic. A locally persistent oolite bed, occurring at the base of the middle part of the middle unit (Orndorff and Harrison, 2001), defined the top of the Van Buren Formation of Bridge (1930). Beds of the lower part of the middle unit, formerly called the Van Buren Formation by Bridge (1930), are light-gray to yellowish-gray, fine- to medium-grained, thin- to medium-bedded dolomite. The lower unit of the Gasconade Dolomite, called the Gunter Sandstone Member, is a light-gray to white sandstone, sandy dolomite, or orthoquartzite interbedded with light-gray to tan, fine-grained, thin-bedded dolomite. The Gunter Sandstone Member ranges from 10 to 25 ft (3–8 m) in thickness. In some localities the sandstones in the Gunter thin and exist only as discontinuous thin lenses. In some locations there is no quartz sandstone, making identification of the base of the Gasconade difficult. The thickness of the Gasconade Dolomite ranges from as much as about 770 ft (235 m) to as little as 148 ft (45 m) in areas adjacent to the Proterozoic volcanic knobs. The Gasconade is the youngest Paleozoic unit observed in contact with Mesoproterozoic igneous rocks in the Current River basin. Contact with the underlying Eminence Dolomite, which is unconformable, is placed at the base of the lowest sandstone or sandy dolomite of the Gunter Sandstone Member

Ꞓe **Eminence Dolomite (Upper Cambrian)**—Dolomite, sandstone, and chert. Dolomite is light gray, medium to coarse grained, massive to thick bedded and commonly stromatolitic. It typically weathers bluish gray and medium gray, has a pitted surface, and commonly crops out as small knobs or pinnacles. Many fresh surfaces contain oxidized rust-colored mottles. Unit contains variable amounts of chert throughout, commonly as light-gray and white stringers and nodules. In downstream areas of the Current River basin a 10- to 20-ft (3–6 m)-thick interval consisting of interbedded thin, friable to silicified quartz sandstone and sandy dolomite occurs 50 to 80 ft (15–24 m) below the upper contact. The thickness of the Eminence Dolomite is variable, in part because of the unconformity at the top of the unit and in part because of thinning near knobs of Mesoproterozoic volcanic rocks; thickness ranges from about 80 ft (24 m) to as much as about 919 ft (280 m). Contact with the underlying Potosi Dolomite is indistinct, a condition that is likely related to secondary alteration (silicification) rather than to primary deposition

Ꞓp **Potosi Dolomite (Upper Cambrian)**—Dolomite with chert. Dolomite is light brown, brown, and light gray, fine to medium grained, massive to thick bedded, with vugs that contain quartz druse. Brown dolomite has fetid odor when freshly broken. Quartz druse is developed as botryoidal masses of chalcedony and small quartz crystals coating surfaces. White to light-gray chert forms nodules and stringers. Locally, a 1- to 3-ft (0.3–1 m)-thick bed of rusty-weathering porous chert occurs at or close to the contact with the overlying Eminence Dolomite. The Potosi is the oldest sedimentary unit exposed in the ONSR area. The thickness of the Potosi ranges from about 50 to 575 ft (15–175 m) in the Current River basin; however, in the map area only about 180 ft (55 m) of the upper Potosi is exposed

Mesoproterozoic Intrusive Rocks

Yg **Granite of Sims' (1990) Y1g province and Kisvarsanyi's (1981) Silvermine-Slabtown-type granite (Granite of Weary and McDowell (2006), known informally as Big Spring granite)**—Granite, red, medium-grained and seriate, with clots of altered amphibole set in a semi-graphic intergrowth of quartz and alkali feldspar. The alkali feldspar exhibits Carlsbad twinning and some relict perthite of the herringbone type. Most perthite is disturbed and shows patch texture, chessboard character, and swapped rims. Accessory mineral phases include fluorite, zircon, and magnetite accompanied by secondary clay, sericite, and epidote. The only outcrop in the report area is in the Big Spring quadrangle (sec. 29, T. 27 N., R. 1 E.) (Weary and McDowell, 2006). This outcrop has a U-Pb age of 1,461.8±5.5 Ma (Harrison and others, 2000). Other reported U-Pb ages for unit Yg from drill-hole samples collected outside of but near the report area are 1,473±15 Ma (Van Schmus and others, 1993) in the Van Buren South quadrangle (Weary and Schindler, 2004); 1,480±42 Ma (Van Schmus and others, 1993) in the Winona quadrangle (Orndorff and Harrison, 2001); and 1,473±15 Ma (Bickford and others, 1981) in the Round Spring quadrangle (Orndorff and Weary, 2009). These ages are consistent with other reported ages for unit Yg elsewhere in the Missouri Ozarks (see Van Schmus and others, 1993; Bickford and others, 1981).

Mesoproterozoic Volcanic Rocks

Upper Sequence of Mesoproterozoic Volcanic Rocks

Yrm **Rhyolite of Russell Mountain**—Ash-flow tuff. Named for exposures on Russell Mountain, which spans sec. 2, T. 28 N., R. 2 W. of the Stegall Mountain quadrangle (Harrison and others, 2002) and sec. 35, T. 29 N., R. 2 W. of the Powder Mill Ferry quadrangle (McDowell and Harrison, 2000). Unit is moderately crystal rich, containing 10 to 20 percent (by volume) pink alkali feldspar phenocrysts that are locally altered pale green, with sparse to no quartz, and 5 to 10 percent magnetite and hematite grains. Unit is typically densely welded with well-developed flow banding and eutaxitic texture, although locally it is massive with poorly developed or no flow banding. This ash-flow tuff is interpreted to consist of multiple flows of both simple and compound cooling units. Primary foliations are typically steeply dipping and generally strike N. 40˚–50˚ W.

The steep dip of foliations (ranging from 25° to 90° and averaging about 76°; n=27) is interpreted to have been produced from rotation during caldera collapse (Harrison and others, 2000). Relation to the Tuff of Little Thorny Mountain (Yltm) is uncertain but is possibly, in part, correlative. Thickness of this unit is difficult to determine because of rotation, but it is at least several thousand feet (1,000 m)

Yvc **Volcaniclastic conglomerate, breccia, and sandstone**—Interbedded volcaniclastic conglomerate, breccia, and sandstone. Conglomerate consists of subrounded cobbles, 3 to 5 inches (in.) (8–13 centimeters [cm]) in diameter, and large pebbles derived from the rhyolite of Sutton Creek (Ysc), the upper unit of Coot Mountain (Ycu), and other unidentified volcanic rocks, with a strongly altered, greenish, fine-grained volcaniclastic matrix. Conglomerate is overlain by strongly silicified volcanic breccia, possibly an autobrecciated flow, that consists of aphanitic pink rhyolite and quartz clasts in a quartz matrix. Sandstone is coarse to medium grained. Grains consist of quartz, lithic fragments, and minor feldspar. Volcaniclastic unit was observed only on the southern side of Coot Mountain, in secs. 22 and 23, T. 29 N., R. 3 W., in the Eminence and Powder Mill Ferry quadrangles (Orndorff and others, 1999; McDowell and Harrison, 2000). Contacts with other units not exposed

Ysc **Rhyolite of Sutton Creek**—Lava(?) of alkali rhyolite to rhyolite composition that is generally not flow layered, although flow layering is observed locally. Phenocrysts of 7 to 15 percent pink feldspar in a dark-pink matrix; 15 to 20 percent disseminated magnetite. Contains trace to 10 percent conspicuous, large (as much as 0.4 in.) (1 cm) aggregates (possibly xenoliths) of small pink feldspar phenocrysts in an apple-green matrix, which alter yellowish white. Named for exposures 0.25 mi (0.4 km) north of Sutton Creek in the Eminence quadrangle (Orndorff and others, 1999), in sec. 12, T. 29 N., R. 4 W. Unit is also exposed along the northwest bank of the Current River in a knob 0.5 mi (0.8 km) southeast of the summit of Tip Top Mountain, and along the south bank of the Current River in an unnamed knob 1.0 mi (1.6 km) upstream from the confluence with Jacks Fork. Thickness unknown

Ysi **Rhyolite of Shut-In Mountain**—Dense lava of rhyolite to alkali trachyte. Named for exposures on and around Shut-In Mountain in the Stegall Mountain quadrangle (secs. 2 and 11, T. 28 N., R. 3 W.). Unit varies from moderately crystal rich to crystal rich, with phenocrysts ranging from 12 to 30 percent by volume. This unit typically contains approximately 10 to 15 percent white to pink alkali feldspar; 3 to 5 percent anhedral to euhedral quartz phenocrysts; common (but sporadic) blebs, pods, or disseminations of fluorite; and <1 to 3 percent disseminated magnetite-hematite grains in a dense, light-pink to maroon-red matrix that consists of a cryptocrystalline aggregate of quartz, alkali feldspar, and iron oxides. Flow banding is generally non-existent to poorly developed; however, where present, it typically swirls and commonly displays flow folding. Locally, this unit is autobrecciated. Small zones of hydrothermal brecciation also occur locally. Vesicles mineralized with quartz and feldspar are common. This unit is interpreted as coalesced lava flows and domes. Areas of hydrothermal brecciation and inclusion of exotic aphanitic volcanic clasts are interpreted as marking probable vent sites. U-Pb analyses of one multiple-crystal and five single-crystal fractions from this unit yielded an age of 1,470.4±2.7 Ma (Harrison and others, 2000). In part, this unit is the same as the Stegall Rhyolite of Tolman and Robertson (1969, p. 14–15). Minimum thickness 900 ft (275 m)

Ysm **Rhyolite of Stegall Mountain**—Dense lava of rhyolite to alkali trachyte. Named for exposures on Stegall Mountain in secs. 19 and 20, T. 28 N., R. 2 W., in the Stegall Mountain quadrangle (Harrison and others, 2002). This unit is a variation of the rhyolite of Shut-In Mountain in that it has a lower quartz phenocryst content of 0.5 to 2 percent. Otherwise, it is identical and is interpreted as genetically related. Minimum thickness is 200 ft (61 m)

Ymm **Tuff of Mule Mountain**—Air-fall tuff. Mapped on Mule Mountain and the southern flanks of Stegall Mountain in secs. 19, 20, 21, 29, and 30, T. 28 N., R. 2 W., and sec. 24, T. 28 N., R. 3 W., in the Stegall Mountain quadrangle. Unit is dense, aphanitic, finely laminated, and commonly silicified. Phenocrysts are rare and consist dominantly of angular quartz. Accretionary lapilli (lapilli-size pellets of ash formed by rainfall passing through a downwind ash cloud or by accretion from a moisture-laden eruption column) are relatively common. Base of this unit marks an angular unconformity between the upper and lower sequences of volcanic rocks in the Stegall Mountain area. The contact with overlying units (Ysm and Ysi) is sharp and conformable. The contact with the underlying unit (Yltm) is complex and irregular. Unit was mapped only where its thickness exceeds 30 ft (9 m), but it is present everywhere between upper and lower sequences. Thickness ranges from 15 ft (4.5 m) to perhaps as much as 100 ft (30 m)

Lower Sequence of Mesoproterozoic Volcanic Rocks

Yltm **Tuff of Little Thorny Mountain**—Ash-flow tuff. Named for exposures on Little Thorny Mountain, in sec. 22, T. 28 N., R. 2 W., in the Stegall Mountain quadrangle (Harrison and others, 2002). Unit is dense, dark maroon to purple, moderately crystal rich to crystal rich, and quartz poor. Phenocryst content varies from 5 to 20 percent and consists almost exclusively of alkali feldspar; quartz is very rare to absent. Magnetite and hematite grains constitute 2 to 10 percent of the rock; fluorite blebs and disseminations are common. Sinha and Kisvarsanyi (1976) describe euhedral phenocrysts of relict fayalite, or possibly an iron pyroxene, which are now altered to hematite, calcite, sericite, and epidote. Unit contains fiamme and eutaxitic texture, is moderately to densely welded, and is commonly, but not everywhere, flow banded. Primary foliations are typically steeply dipping and generally strike N. 40˚–50˚ W. Steeply dipping foliations are interpreted as having been produced by rotation during caldera collapse (Harrison and others, 2000). Thickness of unit is difficult to determine because of rotation, but unit is at least several thousand feet thick (1,000 m)

Ycu **Upper Coot Mountain unit**—Rhyolite to alkali rhyolite to alkali trachyte ash-flow tuff, densely welded, with well-developed flow layering and eutaxitic texture; locally, flow layering is poorly developed. Primary foliations are typically steeply dipping. Generally less than 10 percent phenocrysts of pink feldspar and sparse to no quartz; 4 to 10 percent disseminated magnetite throughout; locally contains disseminated fluorite. Vapor-phase feldspar and quartz mineralization are common in pumice. Unit is exposed principally at the summit and along the northeast side of Coot Mountain, along the eastern side of Jerktail Mountain, and on the summit and slopes of Wildcat Mountain in the Eminence and Powder Mill Ferry quadrangles. Unit is approximately the same as the upper unit of Coot Mountain of Fisher (1969)

Ycl **Lower Coot Mountain unit**—Dominantly ash-flow tuff interbedded with air-fall tuff and lava(?). Ash-flow tuff is composed of alkali rhyolite to alkali trachyte to trachyte to rhyolite; commonly massive and dense. Flow layering weakly developed or nonexistent, although moderately developed locally. Five to 25 percent phenocrysts of pink feldspar and sparse to no quartz in a dark-maroon matrix, with 4 to 10 percent disseminated magnetite throughout. Commonly contains quartz occurring as veins and infillings of miarolitic cavities, locally spherulitic. Locally, poorly welded to non-welded, pumice-rich, phenocryst-poor ash-flow tuff is interbedded in this interval. Ash-flow tuff is approximately the same as the middle unit of Coot Mountain of Fisher (1969). Air-fall tuff is composed of rhyolite; is aphanitic, thin to massive bedded, dark maroon, locally silicified, and contains disseminated pyrite. Petrographically consists of microlites less than 0.0004 in. (0.01 mm) in size and devitrified glass shards. Generally, all primary depositional features have been destroyed. Air-fall tuff is approximately the same as the lower unit of Coot Mountain of Fisher (1969). Unit is best exposed in the Eminence quadrangle and central west edge of the Powder Mill Ferry quadrangle, along the southwestern side of Coot Mountain, the western side of Jerktail Mountain, and on an unnamed knob exposed along Missouri Route 106, 1.25 mi (2.0 km) east of the town of Eminence

Structural Geology

The Mesoproterozoic volcanic rocks exposed in the ONSR area exhibit foliation related to original subaerial deposition, gravity flows, and post-depositional shearing of the rocks. Measured planes of foliation strike in various directions and typically dip steeply to vertical, with the lowest recorded dip value being 30°. Some of these steep to vertical dips are related to strike-slip shearing and to rotation of blocks during caldera collapse of the Eminence caldera (Kisvarsanyi, 1977, 1984).

Most of the sedimentary strata in the ONSR are flat-lying to subhorizontal, with the vast majority of bedding measurements indicating dips of less than 3° locally. The regional dip direction for the entire ONSR is generally to the southeast, and the gradient of the Current River follows this incline. The sedimentary rocks commonly dip radially away from exposed and buried igneous knobs in the Mesoproterozoic basement. The highest dip value measured in the study area was 57° in beds adjacent to a buried igneous knob in the Powder Mill Ferry quadrangle (McDowell and Harrison, 2000).

Folds are difficult to identify in the map area due to lack of exposure and to vegetative cover; however, where observed, these folds are open and symmetrical. Individual folds were mapped in only a few quadrangles. These include the Montauk, Cedargrove, Pine Crest, Round Spring, Van Buren North, and, Grandin SW quadrangles.

Faults in the map area are also difficult to observe directly due to vegetation and residuum cover, and usually have to be identified on the basis of indirect evidence. This evidence includes (1) vertical offset of stratigraphically equivalent strata in which observed dip angles are insufficient to explain the change, and (2) cataclastic deformation bands observed in float blocks of sandstone. Although only vertical offset was observed on faults in the map area, the faults are interpreted to be predominantly strike-slip on the basis of observations of similar faults exposed in subsurface base-metal mines in nearby quadrangles. Fault movement has taken place over time, with most strike-slip movement probably occurring during the Ouachita orogeny.

Similar to Mesoproterozoic rocks in the St. Francois Mountains, basement rocks in the map area also lack any penetrative structural fabric, indicating that these rocks have never been buried more than a few kilometers (Kisvarsanyi, 1981). In the field area, the observed and inferred fault pattern developed in Paleozoic rocks is similar to that found in basement rocks, leading to the conclusion that the Proterozoic basement fabric exerted a controlling influence on younger Paleozoic structures. Regionally there are two dominant fault trends, one oriented northeast and the other oriented northwest. Lesser north-trending and east-trending faults have been mapped locally. Similar trends in regional strike patterns are described elsewhere in southeastern Missouri (McCracken, 1971; Harrison and Schultz, 2002). This northeast-northwest bimodal structural trend is widely thought to be inherent from structures in the Proterozoic basement rocks (McCracken, 1971; Kisvarsanyi, 1974; Kisvarsanyi and Kisvarsanyi, 1976; Clendenin and others, 1989, 1993; Lowell, 2000; Harrison and Schultz, 2002).

On the basis of tectonically disturbed strata, three broad age groups of faults are discernible: (1) those showing evidence that they were active only during the Mesoproterozoic, (2) those that were active at one or more times prior to deposition of the Ordovician section (that is, Neoproterozoic through Late Cambrian), and (3) those that were active at one or more times in the Phanerozoic and probably during the Proterozoic. From field relations observed in the map area, we can determine that the youngest faulting is post-Ordovician in age. Faults of age group 3, in part, are likely associated with the late Paleozoic ancestral Rocky Mountain-Ouachita-Alleghenian orogenic systems, as the Ouachita front is only about 125 mi (200 km) to the south; see Cox (2009) and Hudson (2000) for analyses of Late Paleozoic faulting in the Ozark region. Tectonic features (Craig and Connor, 1979) show that uplift in northwestern and central Missouri had begun in the Late Mississippian, producing an elongated northwest-trending ridge that projects through the map area along the central Missouri tectonic zone of Kisvarsanyi (1981, 1984).

Paleontology

The igneous rocks comprising the Proterozoic basement complex beneath the ONSR are devoid of fossils. The Paleozoic sedimentary rocks contain a variety of fossils of various types. Algal structures such as laminae, stromatolites, and other *Cryptozoon* buildups are ubiquitous and common locally throughout the dolomite and chert parts of the section. They are particularly well preserved in chert beds, one notable example being the *Cryptozoon* chert that occurs in the uppermost part of the middle interval of the Gasconade Dolomite (Bridge, 1930; Lowell and others, 2010).

Trace fossils such as marine worm burrows and arthropod feeding traces are locally common in all Paleozoic rock types, although in the Potosi Dolomite they are relatively rarer, being obscured by more extreme recrystallization of the rock fabric in that unit (Bridge, 1930; Lowell and others, 2010).

Invertebrate macrofossils are relatively rare in the Paleozoic rocks of the ONSR. The depositional environments for most of the units were probably somewhat hypersaline and with restricted circulation, and were not conducive for diverse faunas. In addition, pervasive dolomitization has obscured much of the shelly record that did exist. Mollusks are the most abundant and diverse of these macrofossils. Trilobites are known from relatively few intervals; and brachiopods have been very useful in some of the Cambrian units. Most of these faunas were described in a very few works in the 1930s, 1940s, and 1950s. Occasional beds in the Gasconade Dolomite and the Roubidoux Formation yield molds and casts of gastropods and trilobite fragments (Harrison and others, 1996; Heller, 1954).

Residual chert and quartz sandstone cobbles in the larger streams and in high-level terrace deposits occasionally contain crinoids and brachiopods of Mississippian age. These cobbles are derived from Mississippian units that once lay over the Ordovician rocks exposed in the ONSR, but have been largely removed by weathering and erosion (Unklesbay and Vineyard, 1992).

Conodont microfossils have been recovered and provide age control for the Eminence and Gasconade Dolomites, the Roubidoux Formation, and the Jefferson City Dolomite (Kurtz, 1981; Repetski and others, 1998; Repetski and others, 2000a, 2000b).

Geologic Resources

Potential geologic resources in the ONSR and adjacent areas include dimension stone, aggregate, and gravel. Decorative stone was once quarried from a granite body exposed just to the north of Big Spring, in an operation that took advantage of the easy transport provided by a now-abandoned narrow-gauge railroad.

Significant Mississippi Valley-type base-metal deposits, predominantly lead and zinc minerals hosted in the subsurface Bonneterre Formation, are known to exist near the ONSR. The closest reported occurrences are (1) below the Blair Creek drainage, a tributary of the Current River about 12 mi (19 km) northeast of the town of Eminence (fig. 1) (Kisvarsanyi, 1977); and (2) an area beneath the small drainages of Becky Hollow, Mine Hollow, McCormack Hollow, and Threemile

Hollow, about 21 mi (34 km) south of the town of Eminence (fig. 1). These drainages are tributaries of the Eleven Point River, located south of the map area. See Weary and others (2014) for further discussion of these deposits.

Small, low-grade deposits of iron and manganese occur sporadically across the region (Crane, 1910; Grawe, 1943).

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