Table 1.—Summary of drill-hole data in the Van Buren North quadrangle, Missouri.

[There are no logs for the upper parts of most of the drill holes. Og, Gasconade Dolomite; Єe, Eminence Dolomite; Єp, Potosi Dolomite; Єdd, Derby-Doerun Dolomite (usage of Missouri Geological Survey, 1979); Єd, Davis Formation; Єb, Bonneterre Formation; Єl, Lamotte Sandstone; Yrm, Rhyolite of Russell Mountain; Yg, Mesoproterozoic granite. nd, no data available. Datum is mean sea level]

Drill-hole number	Location	Collar elevation, in feet	Contact elevation, in feet	Bottom elevation, in feet
Drill-hole data on file with Missouri Department of Natural Resources, Geological Survey and Resource Assessment Division				
19649	SW1/4SW1/4 sec. 7, T. 28 N., R. 1 W.	530	No data to 402 315 Єe-Єp -101 Єp-Єdd -240 Єdd-Єd -410 Єd-Єb -760 Єb-Єl -871 Єl-Yg	-895
19669	SE1/4SW1/4 sec. 9, T. 28 N., R. 1 W.	510	No data to 495 412 Єe-Єp -005 Єp-Єdd -110 Єdd-Єd -265 Єd-Єb nd Єb-Єl -360 Єl-Yg	-404
19737	SW1/4SW1/4 sec. 12, T. 28 N., R. 1 W.	850	No data to 710 650 Og-Єe 340 Єe-Єp -140 Єp-Єdd -240 Єdd-Єd -415 Єd-Єb -815 Єb-Єl -830 Єl-Yg	-835
20118	NW1/4SW1/4 sec. 8, T. 28 N., R. 1 W.	850	No data to 825 635 Og-Єe 310 Єe-Єp -088 Єp-Єdd -230 Єdd-Єd -405 Єd-Єb nd Єb-Єl -793 Єl-Yg	-805
20189	NW1/4SE1/4 sec. 4, T. 28 N., R. 1 W.	580	No data to 550 550 Єe-Єp 85 Єp-Єdd -40 Єdd-Єd -210 Єd-Єb -400 Єb-Єl	-445
20241	SE1/4NE1/4 sec. 13, T. 28 N., R. 2 W.	600	No data to 585 250 Єe-Єp -150 Єp-Єdd -255 Єdd-Єd -430 Єd-Єb nd Єb-Єl -840 Єl-Yrm	-855
21589	NW1/4NW1/4 sec. 12, T. 27 N., R. 1 W.	649	524 Og-Єe 169 Єe-Єp -181 Єp-Єdd -321 Єdd-Єd -496 Єd-Єb -1086 Єb-Єl -1096 Єl-Yg	-1096
21668	NW1/4SE1/4 sec. 15, T. 28 N., R. 1 W.	760	No data to 696 631 Og-Єe 291 Єe-Єp -104 Єp-Єdd -254 Єdd-Єd -429 Єd-Єb -632 Єb-Yg	-658
22002	NE1/4NW1/4 sec. 12, T. 27 N., R. 1 W.	660	553 Og-Єe 190 Єe-Єp -146 Єp-Єdd -355 Єdd-Єd -540 Єd-Єb -955 Єb-Єl	-1001
23113	SW1/4NE1/4 sec. 27, T. 28 N., R. 1 W.	500	No data to 475 225 Єe-Єp -180 Єp-Єdd -335 Єdd-Єd -505 Єd-Єb -854 Єb-Єl -1078 Єl-Yg	-1081
20977	NW1/4SW1/4 sec. 17, T. 27 N., R. 1 W.	700	No data to 685 470 Og-Єe 115 Єe-Єp -255 Єp-Єdd -400 Єdd-Єd -575 Єd-Єb -1090 Єb-Єl	-1137
Drill-hole data on file with U.S. Bureau of Land Management				
CT-3	SE1/4NW1/4 sec. 33, T. 28 N., R. 1 W.	510	No data to 255 255 Єe-Єp -160 Єp-Єdd -330 Єdd-Єd -505 Єd-Єb -795 Єb-Єl	-806
PD-15-1	NE1/4SE1/4 sec. 15, T. 27 N., R. 1 W.	706	No data to -126 -126 Єp-Єdd -299 Єdd-Єd -430 Єd-Єb -630 Єb-Єl -632 Єl-Yg	-658
SH-4	NE1/4NW1/4 sec. 21, T. 28 N., R. 1 W.	520	No data to -838 -838 Єl-Yg	-860
SH-12	SE1/4NW1/4 sec. 7, T. 28 N., R. 1 W.	560	No data to -908 -908 Єl-Yg	-915
SH-35	SW1/4NW1/4 sec. 14, T. 28 N., R. 1 W.	580	No data to -800 -800 Єl-Yg	-804

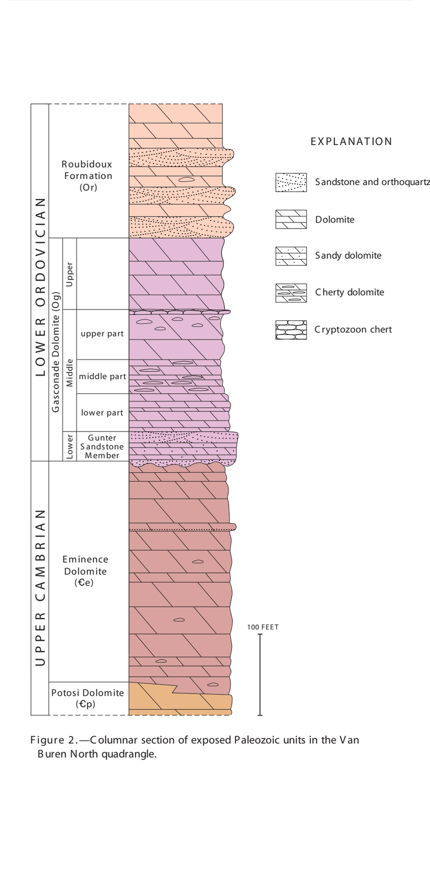
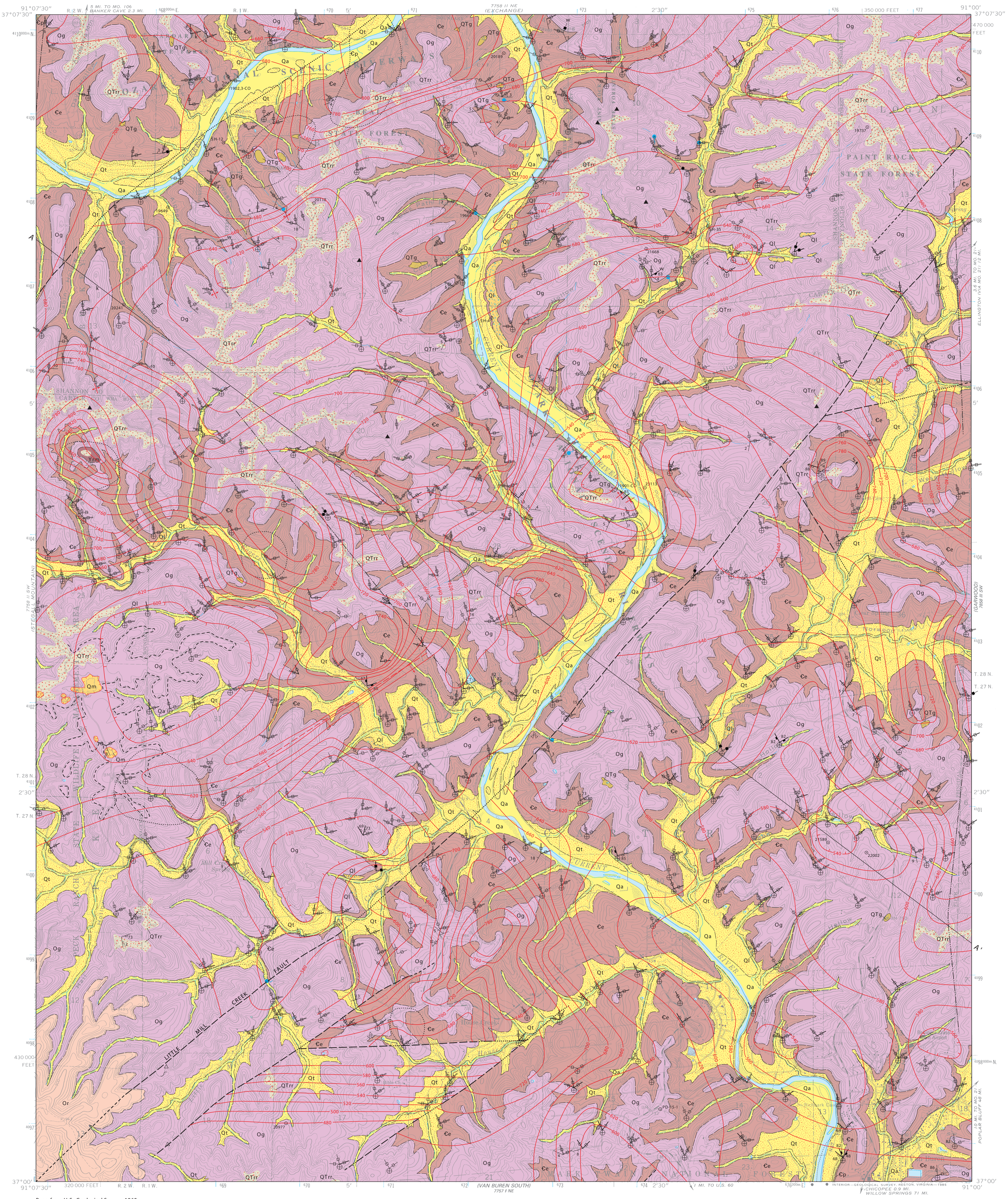


Figure 2.—Columnar section of exposed Paleozoic units in the Van Buren North quadrangle.



Base from U.S. Geological Survey, 1965; Photorevised 1985

Polyconic projection. 1927 North American datum
10,000-foot grid ticks based on Missouri coordinate system, east zone

1000-meter Universal Transverse Mercator grid ticks, zone 15, shown in blue

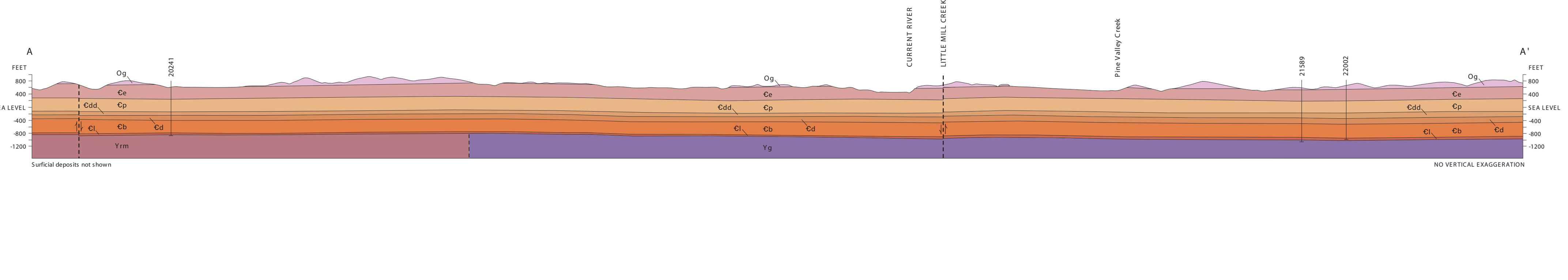
APPROXIMATE MEAN DECLINATION, 2004

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET

MAP LOCATION

Geology mapped in 1997 and 1998



CORRELATION OF MAP UNITS

Units	Age	
Ql, Qa, Qm, Qt	Holocene and Pleistocene	QUATERNARY
QTrr, QTg		TERTIARY
Unconformity		
Or, Og	Lower Ordovician	ORDOVICIAN
Єe, Єp, Єdd*, Єd*, Єb*, Єl*	Upper Cambrian	CAMBRIAN
Unconformity		
Yrm, Yg*		MESOPROTEROZOIC

* In cross section only

DESCRIPTION OF MAP UNITS

Qa Alluvium (Holocene and Pleistocene?)—Gravel, sand, and clay along 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 20 ft

Ql 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 thick

Qm Muck and clayey silt (Holocene and Pleistocene)—Silt, clay, and muck filling sinkholes that intermittently retain water. Thickness unknown

Qt Terrace deposits (Pleistocene?)—Relatively flat areas along floors and flanks of modern stream valleys, but above normal seasonal floods of present streams. Material consists of 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 silt-size reworked loess. Terraces abutting the Current River and major streams generally have a 6- to 10-ft-high cutbank descending to the water or a pronounced slope descending to a lower, flat area of Qa. Thickness at least 10 ft and possibly more along larger stream courses

QTrr Residuum derived from the Roubidoux Formation (Quaternary and Tertiary)—Sandstone and cherty sandstone slabs and sandy chert boulders and cobbles with sandy soils. Commonly occurs on hilltops, minor knobs, and ridge crests where carbonates from the Roubidoux Formation and some carbonates from the underlying upper part of the Gasconade Dolomite have been removed by in-situ weathering. Contact with the Gasconade Dolomite is placed where identifiable clasts derived from the Gasconade become part of the residuum, or where residuum thickness approaches zero. Unit thickness may exceed 40 ft on some knobs and tapers down to zero on flanking hillsides

QTg Upland gravel deposit (Quaternary and Tertiary)—Gravel deposits, as high as 300 ft above the modern stream flood plains, containing mostly subrounded to rounded clasts of chert, sandstone, and quartzite in a matrix of silty sand. Clasts of fossiliferous Mississippian chert rare to abundant. Thickness generally less than 10 ft

Or Roubidoux Formation (Lower Ordovician)—Dolomite, sandstone, and chert. Dolomite, very light gray to medium-gray, pale-orange, or pinkish-gray, very fine grained to medium-grained, thin-bedded to laminated; interbedded with quartz sandstone, white to pale orange, weathering to light-brown or reddish-brown, very fine grained to coarse-grained, poorly sorted, thin- to thick-bedded, commonly crossbedded or ripple-marked; well-rounded quartz grains commonly have angular overgrowths; most beds dolomite-cemented, some silica-cemented. Dolomite commonly replaced by white, gray, or brown chert, commonly stromatolitic and occasionally oolitic or fossiliferous. Heavy mineral fraction dominated by tourmaline, zircon, and garnet. Basal 30 ft contains abundant 1- to 5-ft-thick layers of sandstone; overlying beds are dominantly dolomite and chert. Fossils are rare except for occasional impressions of the snail *Lecanospira*. Bedding surfaces of sandstone beds commonly contain ripple marks formed by currents. Lower contact of unit mapped at lowest orthoquartzite or sandstone bed encountered above the Gasconade Dolomite. Regionally the Roubidoux ranges from 100 to 250 ft thick; the thickness preserved in the map area ranges from 0 to about 165 ft

Og Gasconade Dolomite (Lower Ordovician)—Dolomite, chert, sandstone, and orthoquartzite. Formation is divided into five units, illustrated in figure 2 but not shown separately on this map. Dolomite of upper unit, light-gray, medium- to coarse-grained, thick-bedded, vuggy; weathers to a pitted surface. Dolomite of upper part of middle unit, light-gray, fine- to coarse-grained, medium- to thick-bedded, with white to light-gray chert nodules and lenses. The uppermost bed of upper part of middle unit is a persistent white Cryptozoon chert, 2 to 5 ft thick. Dolomite of middle part of middle unit, light-gray to very light gray, medium- to coarse-grained, medium-bedded; contains chert as nodules, stringers, and beds; chert varieties are porcelaneous, oolitic, porous with druse, and stromatolitic. A persistent oolite bed occurs at base of middle part of middle unit. Dolomite of lower part of middle unit, formerly called the Van Buren Formation of Bridge (1930), light-gray to yellowish-gray, fine- to medium-grained, thin- to medium-bedded. The lower unit is the Gunter Sandstone Member, light-gray to white sandstone, sandy dolomite, or orthoquartzite interbedded with light-gray to tan, fine-grained, thin-bedded dolomite. Contact with underlying Eminence Dolomite is placed at base of lowest sandstone or sandy dolomite of the Gunter Sandstone Member. Thickness of the Gunter ranges from 15 to 44 ft. Maximum thickness of exposed Gasconade Dolomite is about 280 ft

Єe Eminence Dolomite (Upper Cambrian)—Dolomite, light- to medium-gray, occasionally mottled red, pink, or green; medium- to coarse-grained, medium- to thick-bedded, commonly massive; minor amounts of chert, locally oolitic or drusy, in nodules and angular fragments, mostly in upper half of formation; minor quartz sandstone, medium- to thick-bedded. Contact with underlying Potosi Dolomite is gradational and placed above the highest bed of brown or drusy dolomite. Unit is variably thick near and over the Proterozoic knobs in the region. Exposed thicknesses range from 140 ft to as much as 270 ft; in well logs the thickness is as much as 363 ft (table 1)

Єp Potosi Dolomite (Upper Cambrian)—Dolomite, light-brownish-gray to pale-yellowish-brown, fine- to medium-grained, thick-bedded, vuggy and porous, with drusy chert; locally stromatolitic; bituminous odor typical of freshly broken rock. Thickness ranges from 336 to 480 ft on the basis of drill hole data (table 1)

Єdd Derby-Doerun Dolomite (usage of Missouri Geological Survey, 1979) (Upper Cambrian)—Shown in cross section only. Dolomite, siltstone, and shale. Dolomite, buff to brown or light-gray, fine- to medium-grained, thin- to medium-bedded, argillaceous, silty, with minor amounts of chert and sparse sulfide minerals; vuggy and porous. Siltstone and shale, thin-bedded, interbedded with dolomite. Thickness ranges from 100 to 209 ft on the basis of drill hole data (table 1)

Єd Davis Formation (Upper Cambrian)—Shown in cross section only. Shale, siltstone, sandstone, dolomite, and limestone conglomerate. Shale, dark-green, fissile, thin- to thick-bedded; as much as 50 percent of formation. Limestone, light-gray, fine-grained to cryptograined, dense, locally glauconitic. Contains intraformational sedimentary breccias and grainstones. Ranges from 131 to 185 ft thick on the basis of drill hole data (table 1)

Єb Bonneterre Formation (Upper Cambrian)—Shown in cross section only. Dolomite, limestone, siltstone, and shale. Dolomite, light-gray, fine- to medium-grained, medium-bedded; contains algal structures; locally glauconitic and shaly; sparse to abundant sulfide minerals. Limestone, brownish-gray to pink, fine-grained, thin-bedded, fossiliferous, locally oolitic; more common in lower part of formation. Siltstone, quartzose, light- to dark-gray, laminated. Shale, dark-green, thin-bedded; occurs as sparse thin beds and partings. Where the underlying Lamotte Sandstone is missing, basal 2 to 20 ft of Bonneterre consists of dolomite-cemented porphyry pebbles and cobbles. Major lead-bearing unit in the Ozark region. Thickness in the Van Buren North quadrangle ranges from less than 95 ft to 515 ft on the basis of drill hole data (table 1)

Єl Lamotte Sandstone (Upper Cambrian)—Shown in cross section only. Sandstone, quartzose, light-gray, yellow, brown, or red; dominantly medium-grained, moderately to well-sorted, well-indurated; locally contains interbedded red to purple silty shale and, in upper part, scattered lenses of arenaceous dolomite. Felsite pebble or boulder conglomerate commonly present at base. Thickness ranges from 2 to 224 ft on the basis of drill hole data (table 1)

Yrm Rhyolite of Russell Mountain (Mesoproterozoic)—Ash-flow tuff; porphyritic, trachytic to rhyolitic, purple to dark-purplish-red. Probably equivalent to either the Rhyolite of Russell Mountain (McDowell and Harrison, 2000) or the Tuff of Little Thorny Mountain (Harrison and others, 2002)

Yg Granite (Mesoproterozoic)—Shown in cross section only

EXPLANATION OF MAP SYMBOLS

Contact—Dashed where approximately located; dotted where concealed

Fault—Long-dashed where approximately located; short-dashed where inferred; dotted where concealed. In cross section, paired arrows indicate local vertical offset

680 Structure contour—Drawn on base of Gunter Sandstone Member of Gasconade Dolomite; projected where above land surface. Contour interval 20 ft

Cryptozoon chert bed of the Gasconade Dolomite—Dashed line where approximately located; triangle where observed in float

Aeromagnetic anomaly—Indicates area of high magnetic intensity

Aeromagnetic lineament

Monocline

Minor anticline

Minor syncline

PLANAR FEATURES

Strike and dip of beds

- 5 Inclined
- Horizontal

Strike and dip of joints—Point of observation at intersection of multiple symbols. Apertures are narrow (<0.5 in), except where noted by w (solutionally widened)

Throughgoing, vertical
- Widely spaced (> 6 ft)
- Moderately spaced (2–6 ft)
- Closely spaced (< 2 ft)

Throughgoing, inclined
- 48 Closely spaced (< 2 ft)

Non-throughgoing, vertical
- Widely spaced (> 6 ft)
- Moderately spaced (2–6 ft)
- Closely spaced (< 2 ft)

Non-throughgoing, inclined
- 85 Widely spaced (> 6 ft)
- 80 Moderately spaced (2–6 ft)
- 73 Closely spaced (< 2 ft)

OTHER FEATURES

20118 Drill hole—Number refers to well records from Missouri Department of Natural Resources or U.S. Bureau of Land Management; see table 1 for summary of well data

11901-CO Sample locality for conodont collections—See text

5 Horizontal slip lineation or slickenside—Showing bearing and direction of offset

85 Minor fault—Arrow shows direction and plunge of lineation on fault

Slickensides or cataclastic deformation bands in sandstone float—Queried where relation to faulting is uncertain

Sandstone breccia

Mississippian chert

Spring

Large sinkhole—Greater than or equal to 100 ft in diameter

k Small sinkhole—Less than 100 ft in diameter

DISCUSSION

INTRODUCTION

The Van Buren North 7.5-minute quadrangle is located in south-central Missouri on the Salem Plateau of the Ozark Plateaus physiographic province (Fenneman, 1938; Bretz, 1965; Imes and Emmett, 1994) (fig. 1). Most of the land within the quadrangle is publicly owned, and much of the area along the Current River is administered by the Ozark National Scenic Riverways of the National Park Service. Most land along the western quadrangle margin is part of the Peck Ranch State Conservation Area, and much of the remaining land is within the Mark Twain National Forest and the Cardareva, Beal, and Paint Rock State Conservation Areas. Privately owned areas are used largely for farming, timber growth, and recreation. The northern part of the town of Van Buren occupies the extreme southeast corner of the map area, but most of the quadrangle is undeveloped. The only major roads in the area are U.S. Highway 60 and Business 60 in the southeast corner of the quadrangle, Missouri Highway D along the eastern margin, and Missouri Highway M through the south-central area. The map area has topographic relief of about 550 ft, with elevations ranging from about 450 ft along the southeast quadrangle margin to more than 1,000 ft in the west-central area.

Geologic mapping was conducted during the winter months of 1997 and 1998. Bedding and joint attitudes were recorded from bedrock exposures wherever observed. Many contact elevations were determined by hand-leveling from a point of known elevation.

MESOPROTEROZOIC ROCKS

Proterozoic igneous rocks exposed in the Van Buren North quadrangle are a southwestern extension of the rocks in the St. Francois Mountains of eastern Missouri (fig. 1). Uranium-lead isotopic analyses yielded radiometric ages of (1) 1,480±42 Ma for granite from a corehole in the Winona quadrangle to the west (Van Schmus and others, 1993), (2) 1,473±15 Ma for granite from a corehole in the Round Spring quadrangle to the northwest (Bickford and others, 1981), and (3) 1,470.4±2.7 Ma for the rhyolite of Shut-In Mountain in the Stegall Mountain quadrangle to the west (Harrison and others, 2002).

One small outcrop of rhyolite (unit Yrm) occurs in the map area in the center of sec. 24, T. 28 N., R. 2 W.; it is porphyritic, trachytic to rhyolitic, and purple to dark purplish red. Whole-rock major-oxide analyses yielded the following composition: SiO_2, 72.64 percent; Al_2O_3, 12.27 percent; Fe_2O_3, 3.14 percent; MgO, 0.21 percent; MnO, 0.06 percent; CaO, 0.52 percent; TiO_2, 0.24 percent; Na_2O, 1.91 percent; K_2O, 7.31 percent; P_2O_5, 0.03 percent; and LOI (loss on ignition), 1.55 percent. Generally, however, Mesoproterozoic rocks are encountered only in deep (1,000–2,000 ft) exploration drill holes (table 1). All but one of the drill holes in the quadrangle encountered rocks that were described as granites. The only nearby granite outcrop is in the Big Spring quadrangle about 2 mi to the southeast of the southeast corner of the map area. The granite and its surrounding volcanic deposits were deformed, tilted, and subjected to uplift and erosion throughout Late Proterozoic time. The regional relief on this buried erosional surface has been reported to be as much as 2,000 ft (Houseknecht and Ethridge, 1978).

PALEOZOIC STRATIGRAPHY

The Van Buren North quadrangle is underlain by lower Paleozoic marine strata ranging from about 1,200 to 2,300 ft in thickness; the rocks consist chiefly of dolomite, chert, sandstone, and orthoquartzite. From oldest to youngest, these units are the Upper Cambrian Lamotte Sandstone, Bonneterre Formation, Davis Formation, Derby-Doerun Dolomite (usage of Missouri Geological Survey, 1979), Potosi Dolomite, and Eminence Dolomite; and the Lower Ordovician Gasconade Dolomite and Roubidoux Formation. Only the last four units are exposed in the quadrangle. The stratigraphic column, figure 2, summarizes the general lithologies and thickness of the Paleozoic strata that crop out in the Van Buren North quadrangle.

In Late Cambrian time, the Ozark region was flooded by an epicontinental sea that covered most of the Midwestern part of the United States. Because of strong topographic relief on the Mesoproterozoic bedrock, initially only low areas were submerged, and high areas remained above water as islands. In the map area, the basal Cambrian unit, the Lamotte Sandstone, onlaps the flanks of these Mesoproterozoic bedrock hills.

During deposition of the Bonneterre Formation, algal reefs developed along the flanks of the islands of Proterozoic rocks in the Late Cambrian sea (Lyle, 1977). These reefs, especially to the northwest along a mining district known as the Viburnum Trend (about 30 mi northwest of the map area), later became the focus of precipitation of important lead deposits (Thacker and Anderson, 1977). Most of the island hills in the map area were entirely buried by the end of Bonneterre deposition, but subsequently these topographic features have affected depositional patterns through differential compaction of sediments deposited on and around their flanks.

Deposition, mostly of carbonate sediments, continued through the rest of the Cambrian and into the beginning of the Ordovician, sequentially accumulating the Davis Formation, Derby-Doerun Dolomite, Potosi Dolomite, and Eminence Dolomite.

The Davis Formation was probably named for exposures on Davis Creek, St. Francois County, Mo., by Buehler (1907). The Davis Formation conformably overlies the Bonneterre Formation and comprises shale, siltstone, sandstone, dolomite, and limestone conglomerate. The Davis, along with the overlying Derby-Doerun Dolomite, has low primary permeability and acts as an aquitard, part of the St. Francois confining unit, between the lower St. Francois aquifer and the upper Ozark aquifer (Kleeschulte and Seeger, 2000).

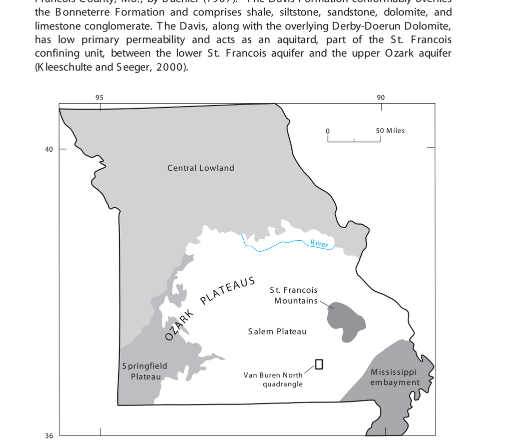


Figure 1.—Map showing location of the Van Buren North 7.5-minute quadrangle and the geomorphic subdivisions of Missouri. The St. Francois Mountains region is underlain mostly by Cambrian and Proterozoic rocks, the Salem Plateau by Cambrian and Ordovician rocks, the Springfield Plateau by Mississippian rocks, the Central Lowland province by Ordovician to Pennsylvanian rocks and Quaternary periglacial sediments, and the Mississippi embayment by Cretaceous to Quaternary sediments (adapted from Imes and Emmett, 1994).

The Derby-Doerun Dolomite was originally two separate formations described from outcrops near mines operated by the Derby Lead Co. and the Doe Run Lead Co. in St. Francois County, Mo. (Thompson, 1995). The formation comprises thin- to medium-bedded dolomites intercalated with thin-bedded siltstone and shale.

The Potosi Dolomite of Late Cambrian age is the oldest Paleozoic unit exposed in the Van Buren North quadrangle. The Potosi crops out in two small areas at the base of the bluffs in sec. 5, T. 28 N., R. 1 W., and along the eastern margin of the Current River flood plain at the southeastern edge of the map area. The name Potosi was originally used by Winslow (1894) in a much broader sense for rocks exposed near the town of Potosi in Washington County, Mo. Dake (1930) redefined the Potosi Dolomite as used presently. The Potosi is a fine- to medium-grained, light-brownish-gray to pale-yellowish-brown dolostone, locally stromatolitic, that has siliceous druse as a permineralization of the dolomite or as vug linings, and a fetid smell on freshly broken surfaces. In outcrop in the map area, and in the Van Buren South and Big Spring quadrangles to the south and east, the Potosi characteristically is more intensely jointed than the overlying formations, with subvertical fractures. Pronounced cavern development exists at or near the contact between the Potosi and the overlying Eminence Dolomite and is marked by bedding anastomoses and minor caves, suggesting a permeability contrast across that boundary. The Potosi is characteristically unfossiliferous. Its contact with the overlying Eminence Dolomite is gradational through a few tens of feet and is interfingering, with alternating beds of light-gray dolomite and brown dolomite. This suggests a lateral facies relation between the two formations, especially near the Mesoproterozoic knobs in the region (Orndorff and others, 1999).

The Eminence Dolomite was described by Ulrich (1911) from exposures in the vicinity of the town of Eminence, Mo. Most of the exposures occur in the floor and along the walls of the valley of the Current River and its main tributaries. The Eminence comprises medium- to thick-bedded and commonly massive, medium- to coarse-grained, light- to medium-gray dolomite and cherty dolomite with a few minor sandstone beds and white cherts. Many of the beds are stromatolitic, with pits and vugs developed between the laminae, and others are crossbedded. The thick, non-cherty dolomite beds commonly weather into irregular pinnacles, especially beds lying subjacent to sandstone of the Eminence or of the overlying Gunter Sandstone Member of the Gasconade Dolomite.

A conspicuous interval of sandstone and dolomite about 10 ft thick occurs within the Eminence between 30 and 90 ft below the top of the formation. The base of the interval is marked by a quartz sandstone bed, 18 to 24 in thick, which is overlain by several feet of medium-bedded dolomite and an upper sandstone, 4 to 12 in thick. Although Bridge (1930) believed the sandstone in the Eminence to be localized lenses, this sandstone-dolomite interval was observed in outcrops scattered throughout the map area, has been reported in the Stegall Mountain 7.5-minute quadrangle to the west (Harrison and others, 2002), and has been observed in the Van Buren South and Big Spring 7.5-minute quadrangles to the south and southeast. Assuming that this interval is correlative across this multi-quadrangle area, it may mark a regressive event similar to, but less widespread than, the regression indicated by the unconformity beneath the basal Gunter Sandstone Member of the overlying Gasconade Dolomite. The sandstone in this interval is easily mistaken for the Gunter in some localities. The variation of thickness of the Eminence above the sandstone-dolomite interval is probably due to erosion down into the Eminence prior to deposition of the overlying Gunter.

Bridge (1930) reported the Eminence to be abundantly fossiliferous, especially with trilobites and gastropods in residual cherts. No such fossils were observed during the course of this study. Conodonts recovered from two samples about 80 ft below the top of the Eminence in south-central sec. 6, T. 28 N., R. 1 W. (U.S. Geological Survey (USGS) Nos. 11902-CO and 11903-CO), indicate Late Cambrian to very Early Ordovician ages (J.E. Repetski, USGS, written commun., 2001). Previous maps produced by this USGS project placed the Cambrian-Ordovician boundary in the upper part of the Eminence Dolomite (McDowell, 1998; Orndorff and others, 1999; McDowell and Harrison, 2000; Orndorff and Harrison, 2001; Harrison and others, 2002; Weems, 2002; Harrison and McDowell, 2003). However, recent international agreement on redefinition of this boundary requires that it be placed at the contact between the Eminence and Gasconade Dolomites (Cooper and others, 2001). Bridge (1930) speculated that an important unconformity exists at the base of the Gasconade. Conodont biostratigraphy suggests that there may be multiple unconformities within the basal Gasconade interval and that the basal Gasconade is significantly diachronous across the area between Van Buren and the town of Eminence, about 22 mi to the northwest (Repetski and others, 2000).

The thickness of the Eminence ranges from about 140 ft to as much as 270 ft exposed in the map area and up to 363 ft reported from drill holes (table 1). Variability in thickness is the result of the non-planar transition from the underlying Potosi Dolomite and erosional beveling by the unconformity at the base of the overlying Gasconade Dolomite.

The Eminence Dolomite is the main cave-bearing formation in the Van Buren North quadrangle, and caves are concentrated just below the Gunter Sandstone Member of the overlying Gasconade Dolomite and to a lesser extent below the sandstone-dolomite interval within the Eminence.

In earliest Ordovician time a regression of the sea produced an unconformity on top of the Eminence Dolomite. A subsequent marine transgression in the Early Ordovician resulted in deposition of the Gasconade Dolomite. The Gasconade was named by Nason (1892) for exposures along the Gasconade River in Laclede, Pulaski, and Phelps Counties, central Missouri. The basal 15 to 44 ft consists of interbedded sandstone, orthoquartzite, and thin-bedded dolomite and sandy dolomite named the Gunter Sandstone Member by Ball and Smith (1903) for exposures along the Niangua River at Gunter (now Hahatonka Springs), Camden County, central Missouri. The lower part of the Gunter is composed of relatively thin quartz sandstone and dolomite and may be buried in residuum from the beds above. The upper part of the Gunter is typically thick-bedded or massive, light-gray to white quartz sandstone as much as 15 ft thick, producing a prominent topographic bench on many of the hillsides.

Bridge (1930) speculated that a significant unconformity exists at the base of the Gunter Sandstone Member. Conodont biostratigraphy suggests that there may be multiple unconformities within the Gunter interval and that the basal Gunter is significantly diachronous across the area between Van Buren and the town of Eminence, about 22 mi to the northwest (Repetski and others, 2000). The character of the Gunter in the Van Buren North quadrangle is different from that in outcrops observed in some areas to the northwest (Orndorff and others, 1999), where the total thickness rarely exceeds 15 ft and the lower sandstone is more prominent than the upper. Bridge (1930) used the name Van Buren Formation for the Gunter Member and superjacent medium-bedded non-cherty and cherty dolomite below an oolite bed in the middle part of the Gasconade Dolomite. The Van Buren was defined by its faunal content, and the name Van Buren Formation is no longer used. Pratt and others (1992) described a lower part and an upper part of the Gasconade Dolomite that are divided by a persistent Cryptozoon chert. This Cryptozoon chert is distinctive and is located about 80 to 100 ft below the top of the Gasconade. No outcrops of the chert bed were observed in the Van Buren North quadrangle. However, Cryptozoon chert boulders indicating this horizon were observed in numerous locations at higher elevations within the area, especially in the area of sec. 36, T. 28 N., R. 2 W. As shown in figure 2, the lower part of the Gasconade is the Gunter Sandstone Member. The middle part of the Gasconade includes the upper, cherty part of Bridge's Van Buren Formation and dolomite above the oolite bed, up to and including the Cryptozoon chert. The upper part of the formation above the chert is thick-bedded dolomite.

Fossils are rare in the Gasconade within the map area, though the presence of planispiral gastropods and cephalopods from cherts within this unit have been reported at Fort Leonard Wood, about 75 mi to the northwest, and at a locality just northeast of the town of Van Buren (Harrison and others, 1996; J.E. Repetski, oral commun., 2000). Conodonts collected from just above the Gunter Sandstone Member in the NW1/4 sec. 27, T. 28 N., R. 1 W. (USGS No. 11901-CO), indicate an early Early Ordovician age (early Ibexian, middle part of *Rossodus manitouensis* Biozone) (J.E. Repetski, written commun., 2001). Conodonts collected from the Gasconade in the Low Wassie quadrangle to the southwest also are indicative of an early Early Ordovician (early Ibexian) age (J.E. Repetski, written commun., 1997).

The Roubidoux Formation was named for exposures in the area of Roubidoux Creek in Pulaski County, Mo. (Nason, 1892). The contact between the Roubidoux and the underlying Gasconade is probably conformable and is marked at the base of the first significant orthoquartzite or sandstone in the Roubidoux. In this area the first sandstone bed is generally about a foot thick, with thicker sandstone beds above. The Roubidoux consists of interbedded dolomite, cherty dolomite, sandy dolomite, dolomitic sandstone, quartz sandstone, orthoquartzite, and chert. The carbonate in the formation is generally removed or obscured by residuum, so the sandstones are the most prominent lithology in outcrops and residuum. The Roubidoux probably accumulated in shallow water, because dolomite-rich intervals contain common algal stromatolites and oolites, while sandstone-rich intervals contain abundant desiccation cracks and ripple marks suggestive of periodic exposure and widely variable current directions.

No outcrops of Roubidoux were observed in the Van Buren North quadrangle, but the formation was identified in the southwest corner of the quadrangle on the basis of (1) stratigraphic thickness above the base of the Gasconade Dolomite or above the Gasconade Cryptozoon chert, (2) abundance of sandstone residuum, and (3) changes in local physiography, such as a break in slope.

Fossils generally are rare in the Roubidoux Formation, though impressions of snails (mostly *Lecanospira*) locally are common in chert and sandstone. A few fossiliferous beds were reported by Bridge (1930) but none was observed in the course of this study. Heller (1954) reported brachiopods, cephalopods, and trilobites from this formation elsewhere within the Salem Plateau, and Harrison and others (1996) reported the occurrence of conodonts indicative of early Early Ordovician (early to middle Ibexian) age. Carver (1961), on the basis of petrographic studies, concluded that most of the gastropod and brachiopod fossils in this unit have been obscured by dolomitization.

The top of the Roubidoux has been removed by erosion in the map area. The Roubidoux is reported to be as much as 250 ft thick in other parts of Missouri (Thompson, 1995). As much as 165 ft of Roubidoux may be present in the southwestern part of the Van Buren North quadrangle.

After deposition of the Roubidoux, a number of younger Early Ordovician units accumulated which are preserved elsewhere in and around the Ozark Plateaus. These probably were present at one time in the map area.

Local residual concentrations of fossiliferous Mississippian (Osagean) chert that probably accumulated in paleo-sinkholes were found in two locations in the southwest corner of the Van Buren North quadrangle in sec. 18, T. 27 N., R. 1 W.; they are marked by triangles on the map. Similar deposits have also been found to the southwest in the Birch Tree quadrangle, to the west in the Bartlett and Winona quadrangles, and to the north in the Exchange quadrangle (Bridge, 1930). The parent unit of these residual rocks probably once extended across the Van Buren North quadrangle, but subsequently was stripped away by erosion. Pennsylvanian deposits, although unknown from the quadrangle, are known from the northern Ozark region (Unklesbay and Vineyard, 1992). This suggests that a regional transgression may have occurred across the Ozarks in Pennsylvanian time. No evidence has been found to suggest Permian deposition in the Ozark region.

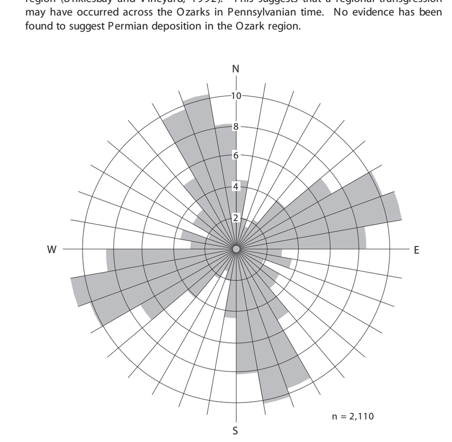


Figure 3.—Compass-rose diagram showing the dominant joint trends in the Paleozoic rocks of the Van Buren North quadrangle. Joint sets were weighted by counting closely spaced joint sets three times, moderately spaced sets two times, and widely spaced sets one time. This system approximates the importance of each set relative to the volume of the rocks. Interval is 10 degrees. Numbers on diagram are percent of total. n, number of joints.

POST-PALEOZOIC HISTORY

The Mesozoic history of the Ozark region is virtually unknown. Deposits of this age, if they once were present, have been eroded from the area. Based on depositional patterns in Mesozoic rocks throughout North America, the Ozark region probably was emergent and undergoing erosion in Triassic, Jurassic, and Early Cretaceous time. During the Late Cretaceous, however, the Ozark region probably was covered by an inland sea that covered most of the United States west of the present Mississippi River (Smith and others, 1994). It has been suggested that glauconitic Cretaceous sediments, now stripped away, may have been the source of the iron contained in the "primary limonites" that occur in the southeastern Ozark region (Potter, 1955, p. 125). Although missing today from the Ozark Plateaus, Upper Cretaceous deposits still are preserved to the southeast in the Mississippi embayment.

The Ozark region may also have been covered by the sea in early Paleocene time (Smith and others, 1994), but throughout the remainder of the Tertiary Period the Ozark dome seems to have been above sea level and undergoing weathering and erosion. This implies that the existing stream patterns were established no earlier than the Tertiary. The widespread occurrence of thick residual soils indicates that the Ozark area has undergone prolonged weathering, at least since middle Tertiary time (McKeown and others, 1988). The existing rolling upland topography, with its deeply incised stream valleys, probably has resulted from regional Quaternary uplift, which was accompanied by the capture of much of the paleo-Gasconade River drainage basin by tributaries of the White River (Elfrink and Siemens, 1977). The development of several Pliocene to Pleistocene terrace deposits at successively lower elevations indicates that uplift and downcutting have been episodic and not continuous (Flint, 1941). It remains controversial whether these episodic intervals of uplift, with concomitant cave development, have resulted in the formation of regional flat erosional surfaces called peneplains (Bretz, 1956, 1962, 1965), or whether the existing landforms represent a dynamic equilibrium between bedrock hardness and erosion rates (Hack, 1960; Reams, 1968).

SURFICIAL GEOLOGY

Several levels of surficial terrace deposits occur along the Current River. Detailed differentiation and mapping of these terraces across the map area was beyond the scope of the present project. In several upland areas of the map, thin patchy deposits of subrounded to rounded cobbles and pebbles of chert, sandstone, and quartzite were observed (QTg). These upland gravels may be as high as 300 ft above the present river level and possibly are fluvial deposits from the major streams prior to downcutting of the present steep valleys. It is also possible that some isolated deposits of unit QTg on high, conical knobs actually may be sinkhole fills, which have weathered into inverted topography.

Valley floors are underlain by alluvial deposits of Holocene to possibly late Pleistocene age (Haynes, 1985; Albertson and others, 1995) that were derived mostly by the washing of clay, silt, and chert fractions from the adjacent upland residual soils and to a lesser extent by the reworking of loess.

Pleistocene loess is thin or absent over most of the Salem Plateau (Ebens and Connor, 1980). However, the Van Buren North quadrangle includes extensive areas of soils having a loess component (Gott, 1975). In most areas, these soils do not constitute a mappable geologic unit, because they are thin and intermingled with underlying clayey residuum due to bioturbation. In some of the larger sinkholes and on some large flat ridges, however, loess deposits capped by Holocene and Pleistocene muck (Qm) are thick enough to be mapped as a separate unit. Only gray silts, probably Wisconsinan loess, were observed, but older loess deposits could be present locally at depth beneath them (Rath, 1975).

In upland areas, there is a pervasive mantle of residuum. Generally, the leaching of dolomite leaves a residue of pebbles, cobbles, and boulders of angular chert, quartzite, and sandstone floating in a matrix of clayey silt to silty clay. On most slopes, the residual soils have undergone downhill creep, producing a thin mantle of colluvium along most valley walls. Because this veneer typically is nearly ubiquitous but thin, in most areas it is not mapped as a separate unit. In a few areas, however, large-scale slumping or landsliding of rock or soil has occurred. In those areas, the colluvial materials are mapped as landslide deposits (Ql).

Many of the high ridges and knobs underlain by Gasconade Dolomite bedrock are capped with residual deposits (QTrr) ranging from 0 to greater than 40 ft thick, consisting of quartz sandstone and cherty sandstone slabs and boulders, white sandy chert boulders and cobbles, and sandy soils derived from the in-situ weathering of the overlying Roubidoux Formation. Although many of these areas were previously mapped as Roubidoux Formation (Bridge, 1930), they clearly are not, as there is no sandstone outcrop and the underlying Gasconade is less than its full thickness.

In Shannon and Oregon Counties, cave deposits of late Pleistocene age have yielded remains of a few extinct animals, such as the stilt-legged deer (?*Sangamona* sp.), short-faced bear (*Arctodus simus*), jaguar (*Panthera* cf. *onca*), and dire wolf (*Canis dirus*). Most fossils, however, are from animal species still living in the area today, such as porcupine (*Erithizon dorsatum*), beaver (*Castor canadensis*), deer (*Odocoileus* sp.), cougar (*Felis concolor*), black bear (*Ursus americanus*), and gray wolf (*Canis lupus*) (Hawksley, 1986). No Pleistocene vertebrate fossils older than Wisconsinan have been found in any of the caves of Missouri (Reams, 1968).

STRUCTURAL GEOLOGY

The regional style of deformation is brittle, with predominantly vertical jointing and strike-slip faulting. Strata within the quadrangle are generally gently dipping; the maximum measured dip is 18 in the SE1/4 sec. 4, T. 27 N., R. 1 W. Gentle folding occurs as compressional strain near faults, as compaction draping over buried Proterozoic igneous knobs, and, possibly, as subsidence into large karstic voids.

The rocks in this quadrangle are pervasively jointed. Joints were characterized by their orientation, spacing, persistence, and aperture. Spacing refers to the mean perpendicular distance between parallel joints in a joint set. Descriptively, widely spaced joints have greater than 6-ft spacing, moderately spaced joints have 2- to 6-ft spacing, and closely spaced joints have less than 2-ft spacing. Gasconade Dolomite joints are similar in orientation to those of the Eminence Dolomite, and both are dominantly vertical. Joints confined to individual beds are classified as non-throughgoing, and joints extending across bedding planes into surrounding beds are classified as throughgoing. Measurement of joint aperture includes all effects of dissolution along the joint planes (Harrison and others, 1996). Cumulative orientations of all the joint measurements observed in outcrop are shown in figure 3. The two primary joint sets trend east-northeast and north-northwest and are indicative of development under a regional stress-field.

Cataclastic deformation bands occur in sandstones within the quadrangle. All were found in float blocks, thus diminishing their usefulness for indicating direction of fault movements. The deformation bands are of tectonic origin and are created by millimeter-scale displacements through shearing that involves a combination of pore-space collapse and fracturing of grains (Davis, 1999; Harrison and Schultz, 2002). Because development of deformation bands is a strain-hardening mechanism (Davis, 1999), the bands are usually more resistant to weathering than the surrounding rock and are commonly found in raised relief on the surfaces of sandstone boulders.

Faults in this area are very difficult to observe directly, due to vegetation and residuum cover, and they have to be inferred on the basis of indirect evidence. This evidence includes (1) vertical offset of strata having insufficient observed dip to explain the change (vertical stratigraphic offset along faults may reverse in sense as the result of horizontal offset of gentle folds along both sides of the fault); (2) cataclastic deformation bands and slickensides observed in float blocks of sandstone or chert; (3) localized areas of brecciation in the Gunter Sandstone Member of the Gasconade Dolomite; and (4) linear anomalies in the pattern of aeromagnetic contour data, reflecting offset and juxtaposition of magnetically contrasting basement lithologies.

The longest fault in the quadrangle, the Little Mill Creek fault, is named for the area just north of Little Mill Creek in sec. 7, T. 27 N., R. 1 W., where cataclastic deformation bands are abundant. There is also significant offset (more than 100 ft) of the base of the Gasconade, as well as brecciation and slickensides in sandstone float along Mill Creek, in secs. 4 and 5, T. 27 N., R. 1 W. The fault extends from the southwest corner nearly to the northeastern edge of the quadrangle. It is interpreted to be a strike-slip fault, with minor vertical offsets along its length caused by juxtaposition of minor synclines and anticlines. Since no kinematic indicators were found in outcrop, it is difficult to discern whether this fault reflects right-lateral or left-lateral motion.

Several other faults in the southwest and northeast corners of the quadrangle are mapped as en echelon offsets that are subparallel to the trend of the Little Mill Creek fault. A northeast-trending fault also runs through the northwest corner of the map area and is an extension of a fault mapped in the adjacent Stegall Mountain quadrangle to the west (Harrison and others, 2002).

A series of three minor anticlines having amplitudes of only a few feet was observed in the axes of stream valleys in the northwest quadrant of the map area. They exhibit bedding-parallel partings at their axes, and one, in the SE1/4 sec. 7, T. 28 N., R. 1 W., has a spring issuing from the partings. These anticlines may be the result of crustal unloading caused by the removal of overburden in the stream valleys, or they are associated with compaction and compression of sediment between the buried Proterozoic knobs, or they are caused by compression along the nearby strike-slip fault to the northwest.

Localized areas of high magnetic intensity are plotted on the map and interpreted to be buried knobs of Proterozoic volcanic rocks. A large area of low magnetic intensity is located in the eastern part of the map area and is interpreted to be a granitic pluton. Aeromagnetic contours for the entire map area, taken from the Missouri Division of Geological Survey and Water Resources (1968), are shown in figure 4.

ECONOMIC GEOLOGY

Small, low-quality deposits of iron and manganese were reported in Carter and Shannon Counties by Crane (1910) and Grawe (1943); however, no deposits were described in the Van Buren North quadrangle.

Gravel, derived from alluvial stream bottoms, and fill earth, derived from residuum, are widely available and are used locally for dam and road-base construction.

The lower Paleozoic carbonate rocks in the Van Buren North quadrangle were strongly affected by late Paleozoic warm Na-Ca-Cl brines that migrated northward from the Arkoma basin and (or) northwestward from the southern Appalachians (Goldhaber and others, 1995). As these brines moved through the Lamotte Sandstone, they leached lead from that unit, and possibly from the directly underlying weathered basement rocks as well. This lead was carried in solution toward the St. Francois Mountains region. In areas where the Lamotte pinches out against Precambrian basement knobs, the solutions probably were forced upward into the Bonneterre Formation (Goldhaber and others, 1995), where they interacted with dolomitic strata and locally precipitated large quantities of galena and pyrite (Panno and Moore, 1994). The resulting deposits have been mined extensively in the Viburnum Trend mining district to the northwest of the Van Buren North quadrangle. Samples of the mineralized material retain paleomagnetic pole positions that were imprinted during latest Pennsylvanian to earliest Permian time (Wu and Beales, 1981; Wisniowiecki and others, 1983), suggesting that the mineralization of these samples occurred at about 290 Ma. Dolomitization of the Cambrian and Ordovician carbonate units in the Salem Plateau also may be contemporaneous with the emplacement of the galena and pyrite (Gregg, 1985), though Carver (1961) argued that pervasive dolomitization could occur only before lithification of the ancestral carbonate muds from which these units were formed.

HYDROLOGY

With the exception of the Current River, most water flow in the map region is subterranean, with surface flow occurring only at times of abundant rainfall. Within the map area, the Potosi Dolomite, Eminence Dolomite, and Gasconade Dolomite are the major stratigraphic units that produce ground water (Dreiss, 1983). Collectively, these units are part of the regional Ozark aquifer that underlies the Salem Plateau (Imes and Emmett, 1994). Water generally is abundant and readily available from either springs or drilled wells, though successful recovery of well water can be erratic depending on local variations in subsurface jointing patterns and the presence or absence of caves. Water from caves can be contaminated with red clay during periods of high water, rendering it undesirable for most use.

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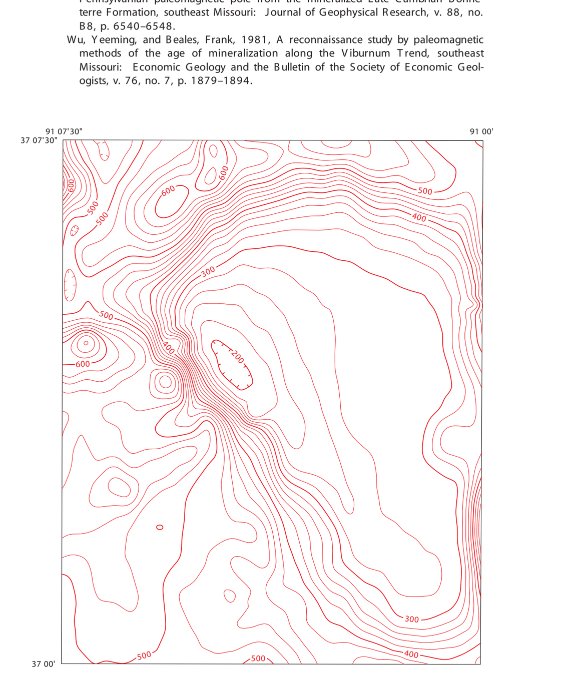

Figure 4.—Aeromagnetic map of the Van Buren North quadrangle showing total-intensity magnetic field of the earth in gammas relative to an arbitrary datum. Contour interval 20 gammas. Modified from Missouri Division of Geological Survey and Water Resources (1968).

GEOLOGIC MAP OF THE VAN BUREN NORTH QUADRANGLE, CARTER, REYNOLDS, AND SHANNON COUNTIES, MISSOURI

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2004

ISBN 0-607-97549-0

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