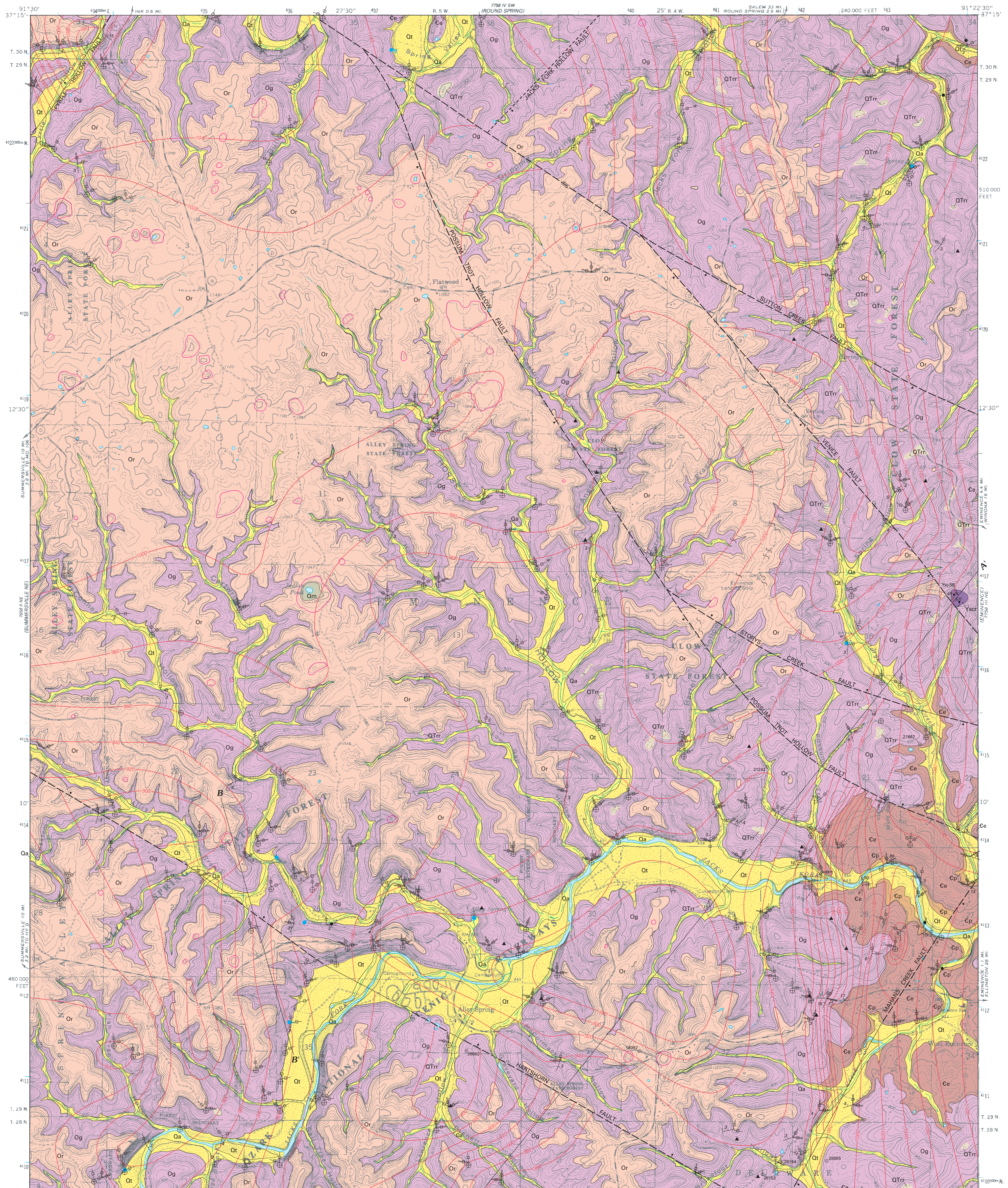
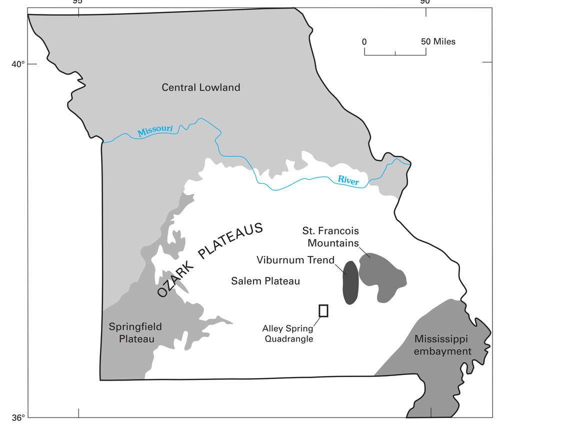
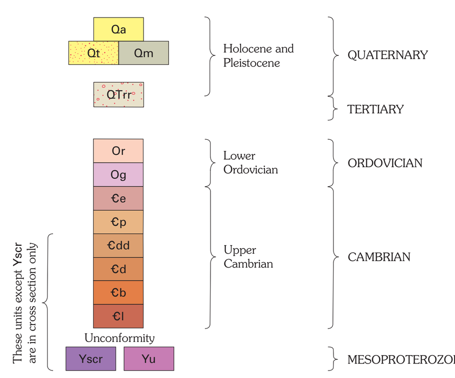






Sample locality for geochemistry of Mesoproterzoic rocks—See table 1 for analysis

***Cryptozoon*-bearing chert bed of Gasconade Dolomite**—Locality where chert bed was observed in outcrop or in highest float

Cataclastic deformation bands in sandstone float

Spring

Sinkhole

DISCUSSION

INTRODUCTION

The Alley Spring 7.5-minute quadrangle is located in south-central Missouri within the Salem Plateau region of the Ozark Plateaus physiographic province (Fenneman, 1938; Bretz, 1965) (fig. 1). Most of the land in the quadrangle is privately owned and used primarily for grazing cattle and horses and growing timber. A large minority of the land within the quadrangle is publicly owned, either by the Missouri State Forests or by the Ozark National Scenic Riverways, administered by the National Park Service. The map area has topographic relief of about 535 feet (ft), with elevations ranging from about 630 ft where the Jacks Fork River exits the lower east edge of the quadrangle, to about 1,165 ft approximately 0.25 mile (mi) southeast of the intersection of State Highway 19 and State Road D in the northeastern part of the map area. The most prominent physiographic feature of the quadrangle is the valley of the Jacks Fork River in the southern portion of the map area. The namesake for the quadrangle, Alley Spring, is a first-magnitude spring flowing at an average rate of about 81 million gallons per day (125 cubic feet per second or 3.5 cubic meters per second) (Vineyard and Feder, 1982). Alley Spring is located in the south-central part of the quadrangle (fig. 2).

STRATIGRAPHY
Mesoproterozoic Basement Rocks

The basement rocks underlying the quadrangle are part of a Mesoproterozoic granite/rhyolite terrane, which is extensive in the Midcontinent region. Outcrops of this terrane also occur in the Big Spring, Eminence, Powder Mill Ferry, Stegall Mountain, and Van Buren North quadrangles to the east and southeast and in the St. Francois Mountains 50 mi to the northeast (fig. 1). These granites and their surrounding volcanic deposits were deformed, faulted, tilted, and subjected to uplift and erosion beginning in the Mesoproterozoic and continuing through Neoproterozoic time. The regional relief on this buried erosional surface has been reported to be as much as 2,000 ft (Kisvarsanyi, 1975).

The rhyolite of Storys Creek (map unit Yscr) is exposed in one small area of the Alley Spring quadrangle in sec. 15, T. 29 N., R. 4 W., about 0.5 mi south of State Highway 19 near the central east edge of the map area. The rock is aphanophyric, having about 3 to 5 percent phenocrysts of alkali feldspar. The matrix is colored medium gray to medium dark gray or brownish gray and the phenocrysts are pale pink to pale reddish purple. Pale-pink flow bands in the matrix are also present locally. Some of the fractures in the rock contain thin vein quartz. Table 1 presents a single sample analysis of the chemistry of the rhyolite of Storys Creek. This is the westernmost outcrop of Mesoproterozoic rocks in the Eminence-Van Buren volcanic field (Lowell and others, 2005; Lowell and others, 2010).

Uranium-lead (U-Pb) isotopic analyses on these rocks in nearby quadrangles yielded radiometric ages of (1) 1,461.8±5.5 Ma for granite exposed in the Big Spring quadrangle (Harrison and others, 2000), (2) 1,480±42 Ma for granite from a corehole in the Winona quadrangle to the southeast (Van Schmus and others, 1993) and (3) 1,473±15 Ma for granite from a corehole in the Round Spring quadrangle to the north (Bickford and others, 1981). A U-Pb age of 1,470.4±2.7 Ma was obtained from the "Rhyolite of Shut-In Mountain" in the Stegall Mountain quadrangle to the southeast (Harrison and others, 2000).

Paleozoic Stratigraphy

The Alley Spring quadrangle is underlain by about 1,990 ft of lower Paleozoic marine strata, chiefly 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 crop out in the quadrangle. The columnar section, figure 3, summarizes the general lithologies and thickness of the Paleozoic strata that crop out in the Alley Spring quadrangle. No drill holes in the quadrangle penetrated below the Derby-Doerun Dolomite; therefore thicknesses of the lowest three Paleozoic formations listed here, and portrayed in the cross section, are estimates based on reported thicknesses from neighboring quadrangles.

During Late Cambrian time, the Ozark region was flooded by an extensive epicontinental sea that covered most of the midwestern part of the United States. Because of topographic relief on the Mesoproterozoic paleosurface, initially only low areas were covered by the sea, 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. The Lamotte is estimated to reach a thickness of about 275 ft in the map area.

During deposition of the Bonneterre Formation, algal reefs developed along the flanks of the remnant islands of Mesoproterozoic rocks in the Late Cambrian sea (Lyle, 1977). These reefs, especially to the northeast along the Viburnum Trend (fig. 1), later became the focus of precipitation of Mississippi Valley-type base-metal deposits (Thacker and Anderson, 1977). Most of the islands were entirely buried near the end of deposition of the Bonneterre. However, they affected depositional patterns even after they were completely buried, owing to differential compaction of sediments deposited on and around their flanks. The Bonneterre is estimated to be about 390 ft thick in the map area.

The Davis Formation probably was named for exposures on Davis Creek, St. Francois County, Mo. (Buehler, 1907). The Davis Formation conformably overlies the Bonneterre Formation and comprises shale, siltstone, sandstone, dolomite, and limestone conglomerate. Shales within the Davis have low primary permeability and act as aquitards (part of the St. Francois confining unit) between the underlying St. Francois aquifer and the overlying Ozark aquifer (Kleeschulte and Seeger, 2000). The Davis is estimated to be about 175 ft thick in the Alley Spring quadrangle.

The Derby-Doerun Dolomite (usage of Missouri Geological Survey, 1979) was originally two separate formations described from outcrops near mines operated by

The upper unit of the Gasconade Dolomite is one of the main cave-bearing intervals in the Alley Spring quadrangle. Caves and springs typically are concentrated just below the overlying sandstones of the Roubidoux Formation (Orndorff and others, 2006).

The Roubidoux Formation was named for exposures in the area of Roubidoux Creek about 50 mi to the northwest in Pulaski County, Mo. (Nason, 1892). The Roubidoux consists of interbedded dolomite, cherty dolomite, sandy dolomite, dolomitic sandstone, quartz sandstone, orthoquartzite, and bedded chert. The contact between the Roubidoux and the underlying Gasconade is probably conformable and is placed at the base of the first significant orthoquartzite or sandstone in the Roubidoux. The lower 20 to 30 ft of the Roubidoux is sandstone-rich and commonly produces a topographic bench that sheds sandstone float onto the slopes below. The middle part of the Roubidoux is chiefly thick-bedded gray dolomite, which resembles the dolomite of the upper part of the Gasconade. The upper part of the Roubidoux is sandstone-rich and forms another topographic bench. Upon weathering the Roubidoux produces a sandy, orange-colored soil that in places is littered with tabular sandstone and orthoquartzite float blocks as well as white chert cobbles and boulders.

Fossils generally are rare in the Roubidoux Formation, though impressions of snails (mostly *Lecanospira*) locally are common in cherts and sandstones. Heller (1954) reported the occurrence of brachiopods, cephalopods, and trilobites from this formation elsewhere within the Salem Plateau. Harrison and others (1996) reported the occurrence of conodonts indicative of early Early Ordovician (early to middle Ibexian) age.

The top of the Roubidoux Formation is not present in the map area, having been removed by erosion. The Roubidoux is reported to be as much as 250 ft thick in other parts of Missouri (Thompson, 1995). A thickness of about 140 ft of the Roubidoux is exposed in the northwestern part of the quadrangle.

Surficial Geology

Alluvial deposits (Qa) and terrace deposits (Qt) were mapped within the stream valleys and are similar in composition. The terraces comprise Holocene to possibly late Pleistocene alluvial deposits (Haynes, 1985; Albertson and others, 1995) that were derived mostly by washing out and reworking of the clay, silt, and chert fractions from the adjacent upland residual soils and to a lesser extent by reworking of loess. Terraces were mapped as geomorphic features along the sides of the stream valleys at higher elevations than the present-day flood plain. Along the Jacks Fork River and its major tributaries, several levels of surficial terrace deposits occur. Detailed differentiation and mapping of these terraces across the map area were beyond the scope of the present project. Therefore, all terrace deposits were mapped as a single unit (Qt).

Pleistocene loess is reported as thin or absent over most of the Salem Plateau (Ebens and Connor, 1980). Nevertheless, the Alley Spring region includes 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. Small areas having these soils were observed in the Alley Spring quadrangle in saddles between hills and on flat uplands. These areas are not extensive enough to be mapped as a separate unit. Some of the larger sinkholes are filled with deposits of Holocene and Pleistocene(?) muck (Qm) that are large enough to be mapped as a separate unit. Only one area, however, surrounding Indian Pond (sec. 14, T. 29 N., R. 5 W.), was delineated on this map.

In upland areas, a pervasive mantle of residuum represents the weathering-in-place of fresh bedrock into soil. Generally, dolomites have been leached away, leaving a residue of angular pebbles, cobbles, and boulders composed of 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, it is not mapped as a separate unit.

Many of the high ridges and hills in the quadrangle underlain by Gasconade Dolomite bedrock are capped with residual deposits consisting of quartz sandstone slabs and boulders, white chert boulders and cobbles, and sandy soils clearly derived from the in-place weathering of the overlying Roubidoux Formation and ranging from 0 to about 40 ft thick. These deposits also occur as colluvium on steep hillsides. They have been mapped as a separate unit designated QTrr (Quaternary and Tertiary Roubidoux residuum).

KARST

Karst features in the Alley Spring quadrangle include caves, springs, sinkholes, disappearing and losing streams, and small-scale solutional features on exposed carbonate bedrock surfaces. Caves can be found anywhere in the stratigraphic section but are concentrated at particular stratigraphic horizons. Many caves are in the upper part of the Eminence Dolomite (just beneath the Gunter Sandstone Member of the overlying Gasconade Dolomite), and in the upper part of the Gasconade Dolomite, near the contact with the Roubidoux Formation (Orndorff and others, 2006; Lowell and others, 2010). Most sinkholes are filled with sediment and residuum, and many were formed by subsidence of the land surface into caves below. Sinkholes can be found in all of the formational units, but they are larger and more numerous in the lower part of the Roubidoux Formation where it collapses into caves in the upper part of the underlying Gasconade Dolomite. Sinkholes observed during the course of field studies in the quadrangle as well as sinkholes implied by closed contours on the topographic map are delineated on the geologic map. Most locations were checked using a global positioning system (GPS) to provide precise coordinates; sinkhole shapes and sizes are approximate and based on visual estimates.

Alley Spring, the largest karst spring in the quadrangle, has an average discharge of 81 million gallons per day (Vineyard and Feder, 1982). There is at least a 25-year history of scuba diving in the spring and in the large water-filled cave that is a conduit supplying groundwater to the spring. Recent (2000 to present) explorations by the Ozark Cave Diving Alliance (OCDA) have extended the mapped portion of the cave. The point of farthest exploration to date is about 2,000 ft west-southwest of the spring, at an elevation approximately 100 ft below the surface of the rise pool. Dye traces indicate that some of the water feeding Alley Spring flows from as far away as 37 mi to the west-northwest (Aley and Aley, 1987).

Preliminary analysis of audio-magnetotelluric data collected near Alley Spring has yielded inconclusive results as to the exact location of the conduit(s) to the west and northwest of the known cave (Pierce and Weary, 2009; Lowell and others, 2010). Recent cave diving by the OCDA produced video and photos and supplied rock samples from various parts of the system to allow the USGS to relate the conduit system to the local geology. Cave diving in various Ozark springs has shown in many instances that the rise pool is supplied by a conduit that descends obliquely to depths as great as 300 ft before leveling off and continuing subhorizontally. The angle of descent typically is 25° to 35°. The cave diving survey of Alley Spring shows that the conduit becomes horizontal beneath the Gunter Sandstone Member of the Gasconade Dolomite (about 130 ft below the surface of the rise pool). This demonstrates a stratigraphic control on cave level similar to that observed in dry caves studied throughout the region (Orndorff and others, 2006).

STRUCTURAL GEOLOGY

The regional style of deformation in southeastern Missouri is brittle, with vertical jointing and strike-slip faulting predominant along northeast and northwest trends (Clendenin and others, 1989; Harrison and Schultz, 2002). Strata within the Alley Spring quadrangle are generally subhorizontal to gently dipping. Gentle folding occurs as compressional or transpressional strain near faults and possibly as subsidence into large karstic voids. The steepest dip measured in the quadrangle was 17° to the northwest in rocks exposed along State Highway 106 in sec. 33, T. 29 N., R. 4 W. This high dip is probably associated with deformation of the rocks between the Hartshorn, Mahans Creek, and Possum Trot Hollow faults. It also is possible that there is a buried knob of igneous Mesoproterozoic basement rocks in the southeast corner of sec. 28, T. 29 N., R. 4 W., and the overlying Paleozoic sedimentary rocks are dipping off of it as described in earlier studies in the area (Bridge, 1930; Harrison and others, 2002). Most of the steeper dips measured in the quadrangle are found in this general area.

The rocks of 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. Joints confined to individual beds are classified as non-throughgoing, and joints extending across bedding planes into overlying and (or) underlying beds are classified as throughgoing. Most joints in the carbonate rocks are open (containing no mineralized infilling) and have narrow apertures. However, some joints have been widened by solution and are as much as 10 inches (in.) wide. Cumulative orientations of all the joint measurements observed in outcrop are shown in figure 4. The two primary joint sets trend north-northwest and east-northeast and are indicative of development under a regional stress field. Cox (1995) interpreted similarly oriented joints throughout the Ozarks as far-field deformation related to the Ouachita and Appalachian orogenies.

Cataclastic deformation bands occur locally in sandstones within the quadrangle. All were found in float blocks, diminishing their usefulness for indicating direction of fault movement. 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 difficult to observe directly, due to vegetation and residuum cover, and have to be inferred on the basis of indirect evidence. This evidence includes (1) vertical offset of strata having insufficient observed dip to explain that offset (vertical stratigraphic offset along faults may reverse in sense as the result of horizontal offset of gentle folds along both sides of the fault, sometimes referred to as scissor faults) and (2) cataclastic deformation bands observed in float blocks of sandstone.

Although only indications of vertical offset were observed on faults in the quadrangle, 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.

The Hartshorn fault traverses the southern part of the quadrangle and trends northwest. This fault has been mapped by the USGS in reconnaissance for tens of miles northwestward from Alley Spring. The mapping of this fault was originally based on small vertical stratigraphic offsets observed in sparse outcrops and well logs and also on interpretation of regional aeromagnetic data (R.W. Harrison, USGS, unpub. data, 2010). Recently acquired electrical resistivity profiles confirm the location of the fault in the vicinity of Alley Spring (fig. 5, cross section *B–B'*) (Pierce and Weary, 2009; Lowell and others, 2010). Total offset on this fault is difficult to determine; the horizontal slip is undetermined and the vertical offset varies locally, ranging from as much as 100 ft to as little as 20 ft, with the southwestern block up in relation to the northeastern block in the Alley Spring quadrangle. The Hartshorn fault continuing to the northwest may be the same structure as the Arthur Creek fault, mapped by Satterfield (1976) near the town of Raymondville, about 20 mi northwest of the Alley Spring quadrangle. The Hartshorn fault trace also approximates the trace of a topographic lineament named the Alley Hollow lineament by Aley and Aley (1987).

Another regional strike-slip fault that traverses the Alley Spring quadrangle is the Sutton Creek fault, which crosses the northeastern part of the map area along a northwesterly trend. This fault was mapped in the Eminence quadrangle adjoining to the east (Orndorff and others, 1999) and is mentioned in a report on the copper deposits of Shannon County (Bowles and Davidson, 1921). It extends southeastward into the central part of the Eminence quadrangle and, like the Hartshorn fault, extends for tens of miles to the northwest of the Alley Spring quadrangle. The Sutton Creek fault is probably the same structure as the Oscars fault, mapped in the Raymondville area by Satterfield (1976). In the Alley Spring quadrangle, the block on the southwest side of the fault is down relative to the northeastern block, with vertical offsets ranging from 20 to 40 ft. Geometric relations to adjoining faults indicate left-lateral movement on the Sutton Creek fault.

Two smaller faults in the Alley Spring quadrangle, the Venice and Possum Trot Hollow faults, are interpreted to be splays off the Sutton Creek fault. The Venice fault diverges from the Sutton Creek fault in the northeastern part of the Alley Spring quadrangle and terminates against the McCabe Hollow fault in the western part of the Eminence quadrangle (Orndorff and others, 1999). The Venice fault has an apparent vertical offset ranging from approximately 20 ft to about 140 ft, with the southwestern block down relative to the northeastern block. Vertical offset of the Mesoproterozoic basement rocks may be greater, implying pre-Gasconade movement along this fault. This fault bounds the southwestern margin of the small outcrop area of the Mesoproterozic rhyolite of Storys Creek (map unit Yscr). The Possum Trot Hollow fault diverges from the Sutton Creek fault near the northern edge of the Alley Spring quadrangle and trends toward the southeast, where it continues into the south-central part of the Eminence quadrangle and terminates against the Shawnee Creek fault (Orndorff and others, 1999). Vertical offsets on the Possum Trot Hollow fault range from 20 to 90 ft, down on the southwestern side, along most of its trace.

A splay off the Possum Trot Hollow fault extends east-southeastward into the Eminence quadrangle, where we interpret it to join the Venice fault. This fault, herein named the Storys Creek fault, has a vertical offset of as much as 60 ft. The southern block is down relative to the northern block east of Storys Creek, while the reverse is true west of Storys Creek. The Venice, Possum Trot Hollow, and Storys Creek faults were unrecognized at the time of mapping of the Eminence quadrangle (Orndorff and others, 1999).

A relatively short, northeast-trending fault is mapped in the southeastern part of the Alley Spring quadrangle and is herein named the Mahans Creek fault. This fault trace runs between the Possum Trot Hollow fault to the north and the Hartshorn fault to the south. The Mahans Creek fault separates blocks that are up to the northwest and down to the southeast, with a relative vertical displacement across the fault ranging from about 60 ft to 140 ft. The northeastern part of the northwestern block adjacent to the Mahans Creek fault is warped into an anticline that exposes the Potosi Dolomite in bluffs along the Jacks Fork River.

The Pyrtle Hollow fault crosses the northwest corner of the Alley Spring quadrangle and offsets the northwestern block down as much as 150 ft relative to the southeastern block. This fault extends to the northeast into the Round Spring quadrangle, where it terminates against the southeast-trending Sutton Creek fault (Orndorff and Weary, 2009). The Pyrtle Hollow fault probably extends to the southwest into the Summersville NE 7.5-minute quadrangle, where stratigraphic offset was recognized in earlier mapping and interpreted to be caused by a solutionally let-down synform (Anderson and Wharton, 1975).

At the north-central edge of the map area the Jacks Fork Hollow fault, mapped in the Round Spring quadrangle (Orndorff and Weary, 2009), is inferred to extend to the southwest where it terminates against the Sutton Creek fault. Vertical offset is believed to be as much as 120 ft, with the northwestern block up in relation to the southeastern block.

ECONOMIC GEOLOGY

Generally low-quality and low-volume deposits of iron (Crane, 1910) and manganese (Grawe, 1943) have been reported in the Alley Spring region. Gravel, derived from alluvial stream bottoms, and fill earth, derived from residuum, are widely available and are used locally for road-base and dam construction. Dolomite bedrock in the quadrangle, especially the Gasconade Dolomite, could be quarried for road metal or dimension stone.

HYDROLOGY

With the exception of the Jacks Fork River and its major tributaries, most water flow in the Alley Spring quadrangle is subterranean, with surface flow occurring only at times of abundant rainfall. Many small streams have short reaches where water flows from springs or seeps and then is lost to subterranean drainage downslope. Locations of springs that were encountered during fieldwork for this map are indicated by spring symbols. No formal estimate of spring flow was made. As noted in the preceding karst section, Alley Spring is a very large perennial spring and, with the exception of the Jacks Fork River, is the most significant hydrologic feature in the quadrangle. Within the map area, the Gasconade, Eminence, and Potosi Dolomites are the major stratigraphic units that produce groundwater (Dreiss, 1983). Collectively, these units are part of the regional Ozark aquifer that underlies the Salem Plateau (Imes and Emmett, 1994).

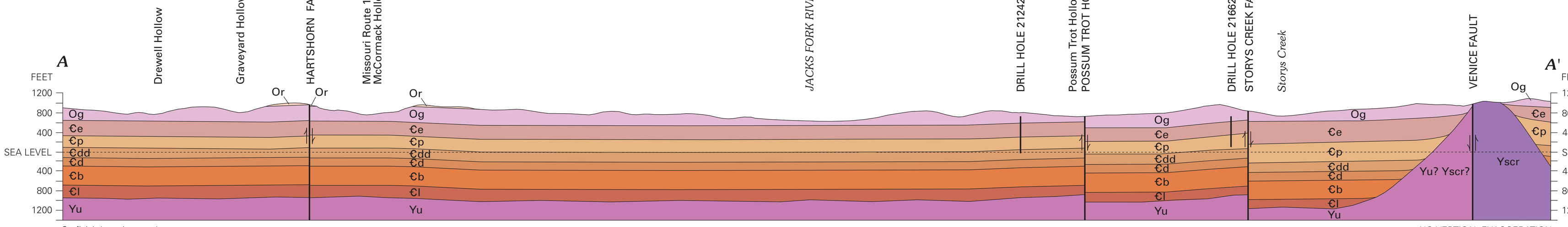


Table 1.—Major-oxide analysis of a representative Mesoproterozoic volcanic rock (map unit Yscr) in the Alley Spring quadrangle, Missouri.

[Sample locality shown on map. Data in weight percent. Whole-rock geochemistry using fusion-inductively coupled plasma emission spectrometry with 0.01 percent detection limits provided by Actlabs, Inc., Wheat Ridge, Colo. LOI, Loss on ignition]

Sample number	Location	UTM North	UTM East	Unit	SiO_2	Al_2O_3	Fe_2O_3	MgO	MnO	CaO	TiO_2	Na_2O	K_2O	P_2O_5	LOI	Total
Yst-58	sec. 15, T. 29 N., R. 4 W.	643985	4117056	Yscr	76.38	12.32	2.71	0.10	0.05	0.48	0.23	6.71	2.17	0.03	0.35	101.53

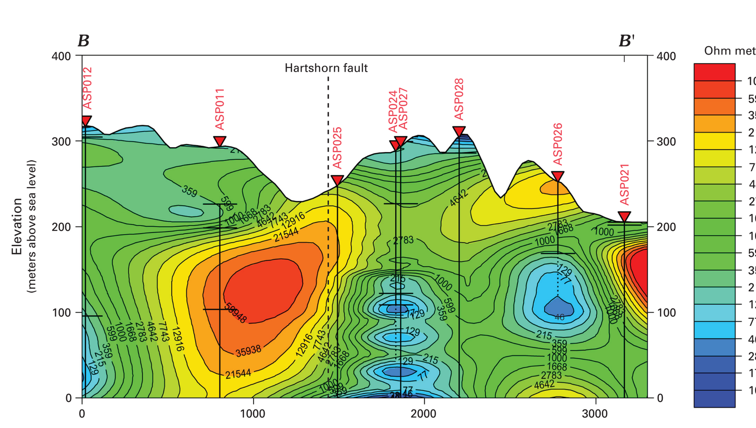
Table 2.—Summary of drill-hole data in the Alley Spring quadrangle, Missouri.

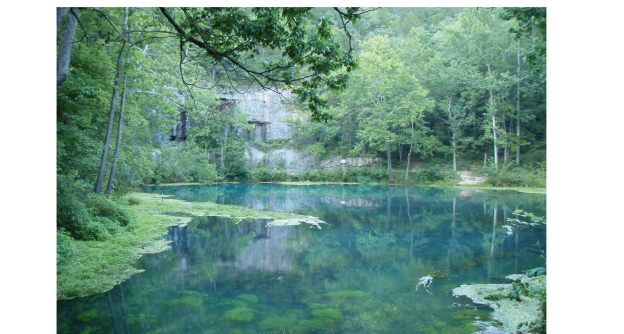
[Or, Roubidoux Formation; Og, Gasconade Dolomite; Ꞓe, Eminence Dolomite; Ꞓp, Potosi Dolomite; Ꞓdd, Derby-Doerun Dolomite. Datum is mean sea level]

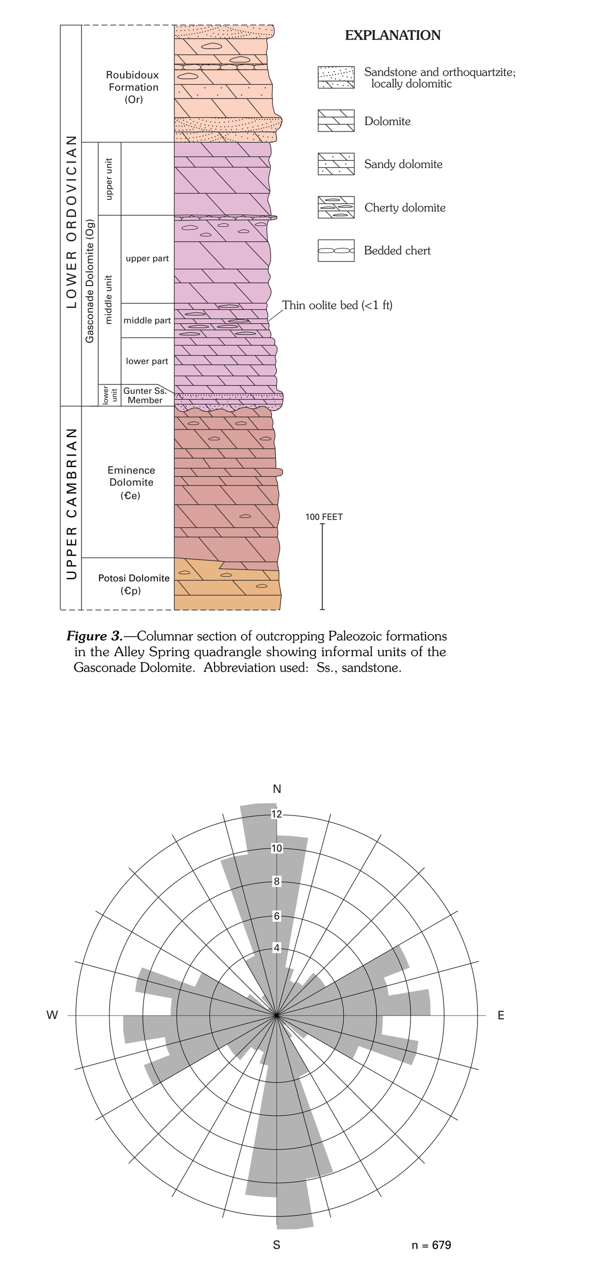
Drill-hole number	Location	Collar elevation, in feet	Contact elevation, in feet	Bottom elevation, in feet
Drill-hole data on file with Missouri Department of Natural Resources, Geological Survey and Resource Assessment Division				
18092	SE1/4 NE1/4 sec. 31 T. 29 N., R. 4 W.	1038	898 Or–Og	635
21242	SE1/4 NE1/4 sec. 20 T. 29 N., R. 4 W.	770	595 Og–Ꞓe 305 Ꞓe–Ꞓp 45 Ꞓp–Ꞓdd	-5
21662	NE1/4 NE1/4 sec. 21 T. 29 N., R. 4 W.	760	675 Og–Ꞓe[1] 295 Ꞓe–Ꞓp	155
26662	SW1/4 NE1/4 sec. 36 T. 29 N., R. 5 W.	750	605 Or–Og[2]	100
28085	SE1/4 NW1/4 sec. 4 T. 28 N., R. 4 W.	720	645 Og–Ꞓe 420 Ꞓe–Ꞓp	120
28153	SE1/4 NE1/4 sec. 5 T. 28 N., R. 4 W.	820	520 Og–Ꞓe 270 Ꞓe–Ꞓp	60
28154	SE1/4 NE1/4 sec. 5 T. 28 N., R. 4 W.	700	550 Og–Ꞓe 270 Ꞓe–Ꞓp	190

[1] Field mapping indicates this well starts below the Og–Ꞓe contact. The contact as shown in this table may actually represent the base of the sandstone-rich interval in the Eminence Dolomite reported in areas to the east of the Alley Spring quadrangle (Bridge, 1930; Weary and Schindler, 2004).

[2] Field mapping indicates this well starts in the lower part of the Gasconade Dolomite. This contact may actually be the Og–Ꞓe contact.







GEOLOGIC MAP OF THE ALLEY SPRING QUADRANGLE, SHANNON COUNTY, MISSOURI

By
David J. Weary and Randall C. Orndorff
2012