

ROUTE LOG 3

Pilot Knob to DeSoto

by

William C. Hayes and James A. Martin

Directions to Starting Point

From the Iron County Courthouse in Ironton, drive north 4.8 miles on Missouri Highway 21 through Pilot Knob to the junction of State Road W. The route log for this portion of Missouri Highway 21 is in Route Log No. 4.

OUTBOUND STARTING POINT: Junction of Missouri Highway 21 and State Road W, Iron County.

INBOUND STARTING POINT: Junction of U. S. Highway 67 and Missouri Highway 110, Jefferson County.

(Total driving distance one way - 43.4 miles)

<u>Outbound</u> <u>Mileage</u>			<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
00.00		From the Outbound Starting Point proceed north on State Road W.	43.35
	0.30		
0.30		CAUTION! Railroad crossing. Missouri Pacific spur to Graniteville.	43.05
	0.25		
0.55		Road on west to Graniteville. Note large blocks of granite along road.	42.80
	0.80		
1.35		Village of Middlebrook to the east. Middlebrook hill, to the west, consists of unassigned felsites of the Middlebrook group. Note the loading spur where lead concentrates from the St. Joseph Lead Company Viburnum mines and mill are loaded on the railroad.	42.00
	0.30		
1.65		Overpass. Missouri Pacific Railroad. Iron-St. Francois county line.	41.70
	2.00		
3.65		South city limits of Iron Mountain.	39.70
	0.50		
4.15		The Midwest Ore Company, Iron Mountain mine, mill, and office on the west. For a description of the deposits at this locality, see the article by Murphy and Mejia in the back of this guidebook.	39.20

<u>Outbound</u> <u>Mileage</u>			<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
	0.50		
4.65		North city limits of Iron Mountain.	38.70
	0.35		
5.00		Road to Iron Mountain Lake on south.	38.35
	0.40		
5.40		Junction of State Roads W and N. Bear north on State Road N.	37.95
	0.30		
5.70		Arkosic Lamotte on west.	37.65
	0.10		
5.80		Small exposure of Buford granite-porphry on west.	37.55
	0.30		
6.10		Lamotte conglomerate on west.	37.25
	0.15		
6.25		Lamotte conglomerate on west. Note the well cemented character of the conglomerate where the fractures extend through individual pebbles and not around them.	37.10
	0.25		
6.50		Lamotte exposure on west. Initial dip is to the south.	36.85
	0.10		
6.60		Small exposure of Buford granite porphyry. The Lamotte basal conglomerate at the north end of the exposure has an initial dip to the north.	36.75
	0.85		
7.45		St. Francis River bridge.	35.90
	1.40		
8.85		South city limits of Bismarck.	34.50
	0.10		
8.95		CAUTION! Railroad crossing. Missouri Pacific Railroad.	34.40
	0.40		
9.35		Junction of State Roads BB and N with Missouri Highway 32. Turn northeast onto Missouri Highway 32.	34.00
		 Bismarck City Well #2 SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 6, T. 35 N., R. 4 E. Curb elevation: 1031 feet. Cambrian Davis 0 - 65 Bonneterre 65 - 520 Lamotte 520 - 555 T.D.	
	0.40		
09.75		East city limits of Bismarck.	33.60
	1.10		
10.85		Bonneterre on north.	32.50
	0.25		
11.10		Bonneterre on north. Note that the pink crystalline dolomite is similar in appearance to Derby-Doerun dolomite.	32.25

<u>Outbound</u> <u>Mileage</u>			<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
	0.40		
11.50		Bonneterre on north.	31.85
	0.05		
11.55		Flat River bridge.	31.80
	0.70		
12.25		Lamotte in creek bed.	31.10
	0.45		
12.70		Exposure of Oak Mountain felsite on southeast. Road to west leads to Irondale.	30.65

Tolman and Robertson (in preparation) describe the Oak Mountain felsite as consisting of a series of nearly black flows (the color actually ranging from dark brown to dark gray) containing small phenocrysts of potash feldspar and quartz. The small percentage of quartz observed in many of the thin sections suggest that these are trachytes, particularly near the base of the unit, areas of devitrified glass are noted. Well defined flow structures and breccias are conspicuous.

Chemical analysis of Oak Mountain felsite; SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 4, T. 34 N., R. 4 E.; University of Minnesota, D. Thaemlitz, Analyst, 1958.

SiO ₂	68.76	H ₂ O+	.60
Al ₂ O ₃	14.16	H ₂ O-	.03
Fe ₂ O ₃	2.02	TiO ₂	.35
FeO	1.91	P ₂ O ₅	.11
MgO	.94	MnO	.11
CaO	1.81	S	.07
Na ₂ O	2.68	Cr ₂ O ₃	.00
K ₂ O	5.89	Total	99.44

	0.40		
13.10		Lamotte in ditch on both sides of road.	30.25
	0.25		
13.35		Labruyere Roadside Park.	30.00
	0.25		
13.60		Lamotte in drive on north.	29.75
	0.20		
13.80		Lamotte sandstone and pebble conglomerate.	29.55
	0.05		
13.85		Crossing Simms Mountain fault zone. The Simms Mountain fault forms the southwest boundary of the northwest trending Farmington anticline and marks the southwest limit of lead mineralization in the Lead Belt.	29.50
	0.15		
14.00		Dry Creek bridge. Davis shale and dolomite in creek bed.	29.35
	0.50		
14.50		CAUTION! Railroad crossing. Missouri Illinois Railroad.	28.85

<u>Outbound</u> <u>Mileage</u>			<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
	0.15		
14.65		Flat River bridge.	28.70
	0.10		
14.75		Derby-Doerun on north.	28.60
	0.20		
14.95		View of Simms Mountain to the south.	28.40
	1.15		
16.10		Derby-Doerun on north.	27.25
	0.45		
16.55		Junction of Missouri Highway 32 and State Road B.	26.80
	0.10		
16.65		South city limits of Elvins.	26.70
	0.30		
16.95		Exposure of Davis in Flat River and on east bank. Park cars and cross river on foot over the railroad bridge behind the service station.	26.40
<p>The Davis formation in the Lead Belt, as measured in numerous drill holes and several surface sections, has an average thickness of about 170 feet. It consists of thin-bedded shale, sandy shale, and calcareous shale as well as dolomite, limestone conglomerate, and limestone. Some of the conglomerate beds are unusual in that they consist chiefly of the "flat pebble" and "edgewise" types. The "flat pebble" type consists of rounded, disc-like pebbles of fine-grained limestone that are imbedded in a matrix of medium-grained limestone. In the edgewise conglomerates, the discs or lenses of fine-grained limestone are arranged with their longer axes perpendicular to or steeply inclined to the bedding planes. In places, groups of "edgewise" pebbles form a radiating or fan-like pattern.</p> <p>"About 60 feet below the top of the formation is the 'central' marble boulder bed. The boulderlike masses consist of fine-grained, white to gray, mottled limestone containing fragmentary fossil shells. According to Buckley (1909, p. 36), the boulders were part of a continuous bed of limestone deposited in shallow water, which became unequally indurated. Subsequent to induration, ocean currents probably scoured out the less indurated portions and left the harder, more resistant, rounded masses. The boulder bed is a good horizon marker in the Lead Belt. The type section of the Elvins group (Davis, Derby, Doerun formations) is in this vicinity." (Muilenburg and Beveridge, 1954, p. 27).</p>			
	0.35		
17.30		CAUTION! Stop sign.	26.05
	0.25		
17.55		North city limits of Elvins. South city limits of River Mines.	25.80

<u>Outbound</u>			<u>Inbound</u>
<u>Mileage</u>			<u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
	0.70		
18.25		North city limits of River Mines. South city limits of Flat River.	25.10
	0.50		
18.75		Junction of Missouri Highway 32 and U. S. Highway 67 (Business Route). Turn north on U. S. Highway 67. Large chat pile of St. Joseph Lead Company to the south.	24.60
<p>Flat River, the "lead capital of the world" is in the center of the famous southeast Missouri Lead Belt. The first shaft was sunk in 1870, and it was not until 1890 that the mining boom began. The Flat River Junior College, in the southeast part of town, was established in 1922.</p> <p>The log of the St. Louis S. & R. Company Shaft #2 is typical of the stratigraphic section in the Lead Belt.</p> <p style="padding-left: 40px;">St. Louis S. & R. Co. #2 Shaft NE$\frac{1}{4}$ sec. 6, T. 36 N., R. 5 E.</p> <p style="padding-left: 40px;">Curb elevation: 791 feet.</p> <p>Cambrian</p> <p style="padding-left: 40px;">Davis 0 - 37</p> <p style="padding-left: 40px;">Bonneterre 37 - 415</p> <p style="padding-left: 40px;">Lamotte. 415 - 850</p> <p>Precambrian 850 - 853 T.D.</p>			
	0.10		
18.85		Turn east on U. S. Highway 67 (Business Route).	24.50
	1.00		
19.85		Junction of U. S. Highway 67 (Business Route) and Missouri Highway 8. Lead Belt Mineral Museum on southwest corner of junction. North city limits of Flat River. South city limits of Desloge. Continue north on U. S. Highway 67 (Business Route) and Missouri Highway 8.	23.50
	1.35		
21.20		North city limits of Desloge.	22.15
	0.75		
21.95		Junction of U. S. Highway 67 (Business Route) and Missouri Highway 8 with U. S. Highway 67. Lead Belt area exit. Go under overpass and turn north on U. S. Highway 67. Cuts in underpass are in upper part of the Bonneterre.	21.40
<p style="padding-left: 40px;">Midwest Radiant Company #1 Well. 200' N and 100' W of SE cor. sec. 31, T. 37 N., R. 5 E.</p>			

<u>Outbound</u>			<u>Inbound</u>
<u>Mileage</u>			<u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
		Curb elevation: 758.8 feet.	
		Cambrian	
		Bonneterre 15 - 295	
		Lamotte.295 - 320 T. D.	
	0.65		
22.60		Big River bridge. Intermittent Bonneterre exposures are to be seen along the highway for the next 2 miles north.	20.75
	2.80		
25.40		Davis outcrop.	17.95
	0.30		
25.70		Bonne Terre exit. Junction of U. S. Highway 67 with Missouri Highway 47 and State Road K.	17.65
		Bonne Terre is the oldest of the closely grouped lead mining towns in the Lead Belt. It is the home of the St. Joseph Lead Company, founded in 1864. St. Joe introduced the diamond drill for exploration in 1869. After numerous consolidations, St. Joe emerged in 1900 as the largest of four principal lead mining companies in the Lead Belt. During recent years, it has been the only company active in the area. In July 1960, the mines of Bonne Terre were abandoned, and most of the operations were transferred to the Viburnum area of Crawford, Washington, and Iron Counties.	
	0.50		
26.20		Large tailing pond to the east. To the west is one of the many large chat piles - the waste product of milling of the lead ores. In general, the chat piles contain less than 1 percent galena, but some material has been remilled. Other uses for chat are railroad ballast, road metal, and concrete aggregate.	17.15
	0.50		
26.70		Davis outcrop.	16.65
	0.90		
27.60		Davis above the Bonneterre.	15.75
	0.30		
27.90		Bonneterre on east. Fault.	15.45
	0.05		
27.95		Davis on east.	15.40
	0.25		
28.20		Davis formation. Small fault in the Davis on east side of road; 18 to 24 inches of displacement. <u>Eoorthis</u> bed on east side at south end of bridge about 5 feet below road level.	15.15
	0.10		
28.30		Center of bridge over Big River	15.05
	0.50		
28.80		Derby-Doerun formation in roadcut. A small fault (Davis	14.55

<u>Outbound</u> <u>Mileage</u>			<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
		against Derby-Doerun) can be seen at the north end of this roadcut in the valley on the west side of the road. The north side (Davis) is the upthrown side.	
29.05	0.25	Davis below road level on west.	14.30
29.35	0.30	Roadcut in the Derby-Doerun and Potosi formations. The beds show a slight north-northwest dip. The base of the Potosi is near the top of the cut.	14.00
30.25	9.90	Potosi formation on both sides of the road. Solution cavities and joints filled with red clay and quartz druse are near the south end of the roadcut. Chert bands can be traced through the clay residuum in the solution cavities and joints. Quartz druse is quite prominent in the dolomite beds.	13.10
31.55	1.30	Roadcut in Potosi residuum. This exposure shows the typical, deep red color of the clay residuum and the quartz druse on the chert.	11.80
32.15	0.60	Potosi on west. Note the quartz druse.	11.20
33.45	1.30	Eminence formation on both sides of highway.	9.90
34.00	0.55	Junction of U. S. Highway 67 and State Road Y.	9.35
34.45	0.45	Junction of U. S. Highway 67 and State Road JJ.	8.90
35.00	0.55	St. Francois-Jefferson county line.	8.35
36.10	1.10	Fault. Eminence on south against Jefferson City on north; Eminence dips north, Jefferson City dips south.	7.25
36.35	0.25	Junction of U. S. Highway 67 and State Road V. Jefferson City on east; beds dip south-southwest. Valle Mines to the west.	7.00

"The lead smelter at Valle Mines began operation more than 100 years ago. The last period of activity was from 1890-1900. Farther south in the hills are the old Valle Mines, which from the date of discovery in 1824 to 1892 produced more than 40,000 tons of lead and 60,000 tons of zinc. The presence of so much zinc is noteworthy because zinc is a relatively minor constituent of the ore in the Lead Belt, a few miles to the south. The ore in the Valle Mines was chiefly galena and zinc carbonate - smithsonite. Zinc silicote - calamine, and the sulphide - sphalerite were relatively rare. The ore was found in a series of solution channels and caves. Galena and sphalerite were associated with barite, drusy quartz, chert, and clay. Smith-

Outbound
Mileage
Cum. Diff.

Inbound
Mileage
Cum.

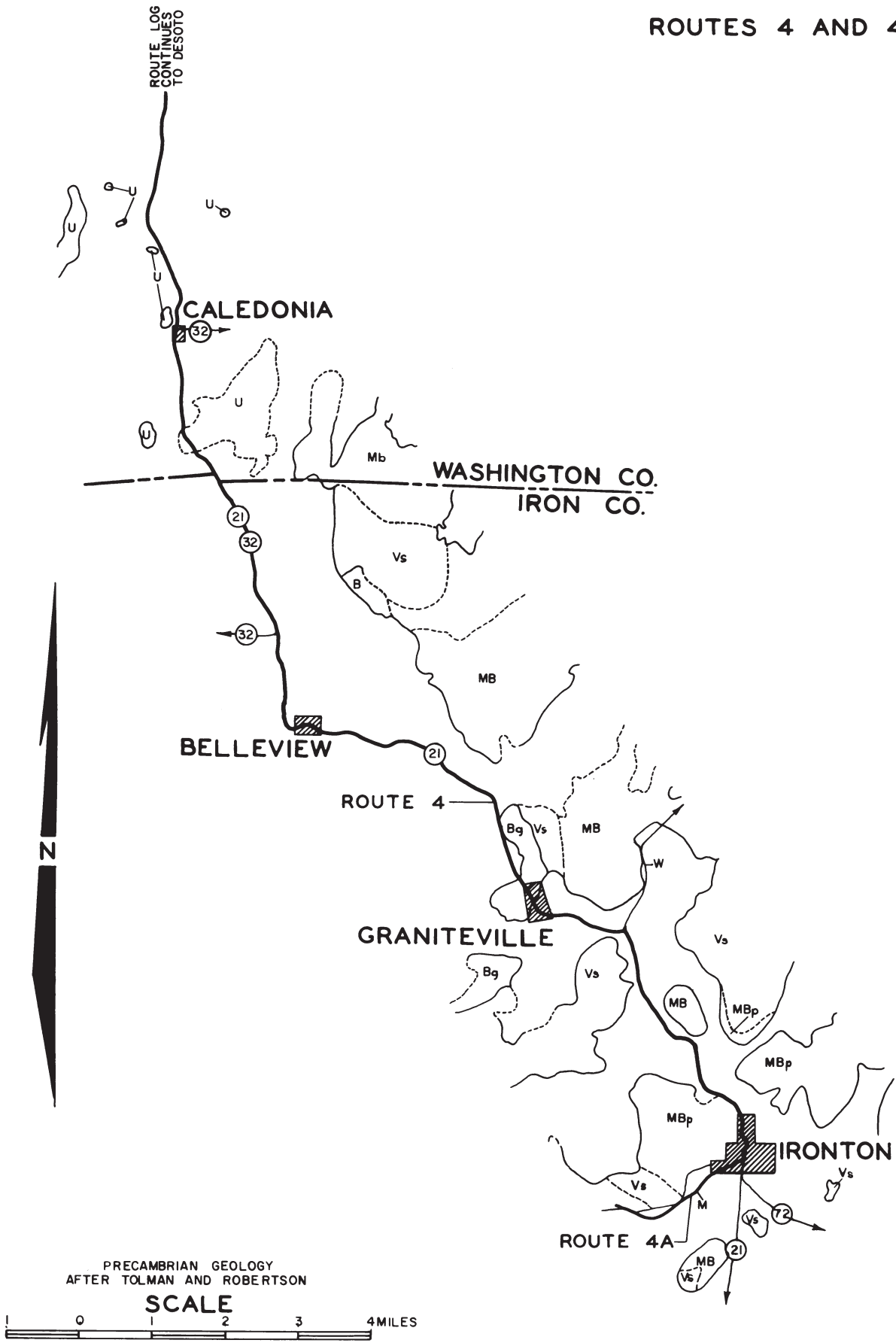
sonite occurred in large and small botryoidal masses in the clay. Mining operations consisted entirely of cleaning out the clay-filled joints and cavities. Very little ore was found in solid rock." (Muilenburg and Beveridge, 1954, pp. 24-25).

	0.30		
36.65		Small fault in Jefferson City formation on east; beds dip south-southwest.	6.70
	0.20		
36.85		Fault at south end of roadcut. Roubidoux on north; Jefferson City on south.	6.50
	0.25		
27.10		Missouri Pacific Railroad overpass. Roubidoux in cut along east side of highway.	6.25
	0.40		
37.50		Gasconade? formation on both sides of highway. Sandstone (Roubidoux?) is at the top of the cut on the east side. South end of cut, west side, Jefferson City is faulted against the Gasconade.	5.85
	2.55		
40.05		Junction of U. S. Highway 67 and State Road JJ. Jefferson City in roadcut north of junction.	3.30
	0.60		
40.65		Jefferson City on both sides of highway.	2.70
	0.80		
41.45		Jefferson City on both sides of highway.	1.90
	1.10		
43.55		Jefferson City in roadcut. Note sandstone at top of cut.	0.80
	0.50		
43.05		Jefferson City on west side of highway.	0.30
	0.30		
43.35		Junction of U. S. Highway 67 and Missouri Highway 110 east of DeSoto.	00.00

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ROUTES 4 AND 4A



PRECAMBRIAN GEOLOGY
AFTER TOLMAN AND ROBERTSON

SCALE

1 0 1 2 3 4 MILES

ROUTE LOG 4

Ironton to DeSoto

by

James A. Martin and Donald K. Knapp

OUTBOUND STARTING POINT: Junction of Mo. Hwy. 21 and State Rd. M, Iron County.

INBOUND STARTING POINT: Junction of Mo. Hwys. 21 and 110, Jefferson County.

(Total driving distance one way - 62.10 miles)

<u>Outbound</u> <u>Mileage</u>		<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>	<u>Cum.</u>
00.00	From the Outbound Starting Point at the Iron County Courthouse in Ironton, proceed north on Mo. Hwy. 21.	62.10
	Shepherd Mountain (elevation 1612 ft.) to the west of Ironton rises nearly 700 feet above the valley and is composed of unassigned felsites of the Middlebrook group. Three nearly vertical veins, near the crest of the mountain and consisting chiefly of specular hematite cementing a brecciated porphyry and ranging in width from 2 to 30 feet, were worked intermittently between 1815 and 1850. Magnetite of the lodestone variety was abundant in some of the veins. Little or no work has been done on these deposits since the end of the Civil War. Some exploratory diamond drilling was done in 1888, 1930, and in 1955.	
1.00	1.00 North city limits of Ironton.	61.10
	A storm cellar, which can be seen from the highway in the hillside on the west, was used as a refuge by a number of women and children during the 1864 Confederate attack on Fort Davidson.	
1.80	0.80 Knob Creek bridge.	60.30
2.00	0.20 Fort Davidson and Pilot Knob to the east.	60.10
	Fort Davidson, which consisted of an earthworks surrounded by a narrow moat, was erected by the Union army to protect the iron mines on Pilot Knob and Iron Mountain. On September 27, 1864, with a force of approximately 1,000 men, General Thomas Ewing repulsed an attack of between 12,000 and 20,000 Confederates under the command of General	

Outbound
Mileage
Cum. Diff.

Inbound
Mileage
Cum.

Sterling Price. Sustaining considerable losses, about 1,500 men, Price retired that evening to regroup his forces for a renewed attack at day-break. Outnumbered and realizing the hopelessness of further attempts to hold his position under heavy assault, Ewing spiked his cannon, destroyed his powder magazine, and under cover of darkness retreated southward through Ironton. Price spent three days in futile pursuit and, thus, lost the advantage of an attack on St. Louis before the city had time to be reinforced.

Though overgrown with trees and brush, the outline of the fort is still visible. A footpath leads around the breastworks.

The primary iron deposits on Pilot Knob occur near the crest where they were mined by open pit methods, and on the southwest flank where the ore was mined on an incline room and pillar system. Conglomerate ore, which rests on the Precambrian surface, and surface boulder ore have also been mined. According to Crane (1912, p. 124), the ore deposit was divided into a lower ore bed (30 feet thick) and an upper ore bed (20-30 feet thick). The total area mined is reported to have been approximately 900 feet by 1500 feet. Hematite occurs in the cementing material and as replacements in volcanic breccia and tuff.

Mining operations began at Pilot Knob in 1847, and a year later the Madison Iron Mining Company was formed. It was reorganized in 1853 as the Pilot Knob Iron Company. In 1882 it was consolidated with the Vulcan Iron and Steel Works and the Grand Tower Coal Company to form the St. Louis Ore and Steel Company. All records were destroyed by fire in 1882, but production continued until 1892. In 1910, operations were resumed by the Puxico Iron Company. About 1921, the Big Muddy Coal and Iron Company operated the mine for a short time. (Additional information on Pilot Knob may be found in Johnson's article in the back of the guidebook).

	0.10		
2.10		Junction of Mo. Hwy. 21 and State Rd. V.	60.00
	0.40		
2.50		CAUTION! Sharp curve. Cedar Hill to the north.	59.60

Two tabular bodies of iron ore, separated by approximately 10 feet of a brecciated rhyolite porphyry, occur

Outbound
Mileage
Cum. Diff.

Inbound
Mileage
Cum.

high on the west slope of Cedar Hill. The southern bed is about 18 inches thick and the northern one over 2 feet thick. The trend of the ore bodies is about N. 45° W., and they dip 50 degrees to the southwest. The ore is a replaced tuff similar to that at Pilot Knob except that at Cedar Hill red jasper is an abundant gangue. Nason (1892, p. 307) reported that a total of 25,000 tons of ore had been mined from the deposit.

	0.40		
2.90		North city limits of Pilot Knob.	59.20
	0.50		
3.40		The Bonneterre formation underlies most of the valleys in this area.	58.70
	0.30		
3.70		Unassigned Middlebrook felsite exposure on west.	58.40
	0.40		
4.10		Unassigned Middlebrook felsite on both sides of road.	58.00
	0.40		
4.50		Unassigned Middlebrook felsite residuum.	57.60
	0.30		
4.80		Junction of Mo. Hwy. 21 and State Rd. W. (Starting Point of Route Log 3).	57.30
	0.50		
5.30		Junction of Mo. Hwy. 21 and State Rd. H. State Rd. H leads to Johnson Shut-ins State Park. The valley here is underlain by the Bonneterre formation.	56.80
	0.20		
5.50		South city limits of Graniteville.	56.60

Granite quarrying in Missouri was begun here in 1869 by Phillip W. Schneider. The early quarries produced rough building and monumental stone, but in the latter part of the century the use of granite blocks as paving and curbing stone in the St. Louis area became increasingly important and resulted in the opening of a large number of small quarry operations. When paving blocks became outmoded at the turn of the century, only a few of the larger quarries remained in operation. During this period, crushed granite for concrete aggregate and paving became the chief product of several of the quarries. The present use of Missouri granite is, in order of decreasing value; dressed and rough monumental stone, rough architectural stone, and riprap.

The Sheahan Granite Company, established as the Sheahan Brothers Quarry in 1889, was the major granite producer in Missouri, having operated continuously until 1953 when it was purchased by the Heyward Granite Company who is presently the only active producer in the state.

<u>Outbound</u> <u>Mileage</u>			<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
	0.85		
6.35		The road to the east leads to the Heyward Quarry.	55.75
		The so-called Elephant Rocks to the west are picturesque, large, residual granite boulders which illustrate spheroidal weathering along joint planes in a most striking manner. Examples of all stages of weathering from narrow open joints to large, isolated, rounded blocks may be seen in the area.	
		The granite in the Graniteville area has a uniform medium-grained groundmass. Occasional phenocrysts of potash feldspar give the rock a slight porphyritic texture. The color, a deep pink to red, is uniform throughout. The granite forms a rather restricted elongate body which is in vertical contact with felsites to the east. To the northwest and southwest, it is overlapped by the Bonneterre formation. The name Graniteville granite has been proposed for this and similar granites that appear to be related to it by Tolman (1933).	
	0.05		
6.40		North city limits of Graniteville.	55.70
	0.55		
6.95		Spheroidal weathering of the granite to the east. An abandoned quarry is located just to the northeast of this point.	55.15
	0.45		
7.40		Graniteville granite on east. The valley to the west is underlain by the Bonneterre formation.	54.70
	0.20		
7.60		Bonneterre formation in creek bed on west. The creek is one of headwater tributaries of the St. Francis River. Entering Bellview Valley.	54.50
		This wide, rather elongate valley, which is underlain by Cambrian sediments and is bounded by the nearly straight alignment of the southwest flank of Buford Mountain to the northeast and by the southeast flank of Logan Mountain to the northwest, has the suggested appearance of a down-dropped block with the greatest movement having occurred to the northeast along Buford Mountain (Dake, 1930, p. 184; Graves, 1938, pp. 133 and 138). Dake (1930, pp. 184-185) gave two lines of indirect evidence that imply Precambrian faulting in the area: 1) the topographic alignment of the Precambrian felsite ridges, and 2) the peculiar termination or offsetting of basic dikes in the northeastern part of the Edgemoor Quadrangle. Other lines of evidence to support a fault scarp or structural line along the southwest base of	

Outbound
Mileage
Cum. Diff.

Inbound
Mileage
Cum.

Buford Mountain as suggested by Graves (1938, pp. 133, 134, and 138) are: 1) the inclination of the felsites on Shepherd Mountain, Pilot Knob, and at Stouts Creek Shut-ins, 2) the difference in lithologies of the felsites on the two sides of the valley but which could be accounted for by dip, 3) the location and altitude of iron deposits on Buford, Shepherd, Pilot Knob, Cedar Hill, and Shut-in Mountains, and 4) the nearly straight boundaries along the eastern side of the broad Belleview Valley which probably could not be duplicated by erosion along joint planes but rather implies erosion along nearly vertical faults.

Buford Mountain to the northeast is the most prominent feature of the scarp that can be seen along the route. The alignment of the other mountains are clearly shown on the maps of the Ironton and Edgehill Quadrangles. Graves proposed the name Ironton fault for the Buford Mountain scarp and extended the fault line southward to Ironton where the fault scarp becomes obscure in the Arcadia Valley.

8.30	0.70	Junction of Mo. Hwy. 21 and State Rd. U. Intermittent exposures of Bonneterre are to be seen for the next 4 miles.	53.80
		The large elongate northwest trending hill to the northeast is Buford Mountain (elevation 1,740 feet). It is the second highest hill in the state.	
10.15	1.85	South city limits of Belleview.	51.95
10.35	0.20	Bonneterre formation in creek bed on south side of road.	51.75
10.70	0.35	SLOW! Sharp turn. Junction of Mo. Hwy. 21 and State Rd. O.	51.40
10.75	0.05	North city limits of Belleview.	51.35
12.30	1.55	Junction of Mo. Hwy. 21 and Mo. Hwy. 32. Continue north on Mo. Hwy. 21. Buford Mountain to the east. The Bonneterre formation is intermittently exposed along the road for the next 2½ miles.	49.80

Belleview School #1 Well
SE¼ SW¼ sec. 30, T. 35 N., R. 3 E.
Approximate curb elevation 1010 feet (T.M.)

Cambrian
Bonneterre 0 - 65
Lamotte 65-185 T.D.

<u>Outbound</u> <u>Mileage</u>			<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
	2.45		
14.75		Lamotte sandstone in ditch on west.	47.35
	0.10		
14.85		Unassigned felsite on west.	47.25
	0.10		
14.95		Cedar Creek bridge.	47.15
	0.25		
15.20		Lamotte sandstone in roadcut on west. Note initial dip.	46.90
	1.00		
16.20		Dolomitic sandstone (Lamotte-Bonneterre transition zone) in ditch on the west.	45.90
	0.40		
16.60		Junction of Mo. Hwy. 21 and Mo. Hwy. 32 within the city limits of Caledonia.	45.50
		<p>Caledonia was founded in 1819 by Alexander Craighead. On December 1, 1807, the first Presbyterian service held west of the Mississippi River was conducted at the Presbyterian Cemetery located about 0.7 mile northeast of this junction.</p>	
		<p>In the gully to the northeast of the junction, the transition zone of the Lamotte and Bonneterre formations is exposed. The beds grade both laterally and vertically from sandstone to dolomite.</p>	
	0.10		
16.70		North city limits of Caledonia.	45.40
	0.15		
16.85		Arkosic Lamotte sandstone on the east. Note initial dip. The cedar covered knob on the west is a Precambrian, unassigned felsite.	45.25
	0.35		
17.20		Bonneterre dolomite on both sides of road.	44.90
	0.20		
17.40		Junction of Mo. Hwy. 21 and State Rd. C.	44.70
	0.80		
18.20		Lamotte sandstone in ditches on both sides of road.	43.90
	0.20		
18.40		Bonneterre exposed along hillside to the west.	43.70
	0.55		
18.95		Junction of Mo. Hwy. 21 and State Rd. M. Bonneterre crops out on the hillside to the west, and the Lamotte formation is exposed along State Rd. M. for a short distance to the east.	43.15
	0.30		
19.25		Lamotte sandstone exposed on both sides of road; crossing fault onto Bonneterre formation.	42.85

<u>Outbound</u> <u>Mileage</u>			<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
	0.10		
19.35		Bonneterre dolomite on west side of road; crossing fault onto Davis formation in covered interval.	42.75
	0.15		
19.50		Davis exposed on east.	42.60
	0.30		
19.80		Big River bridge. The Big River fault is in the creek bed; crossing fault onto Eminence formation.	42.30
	0.15		
19.95		Brecciated Eminence on east.	42.15
	0.05		
20.00		Small fault in gully to the east. Potosi residuum to north. Eminence to south; crossing fault onto Potosi formation.	42.10
	0.05		
20.05		Potosi on east.	42.05
	0.30		
20.35		Potosi on east.	41.75
	0.40		
20.75		Springfield furnace.	41.35
		<p>The gravel road to the northwest follows along Furnace Creek. About 1 mile north, the Springfield furnace, the third iron works established in Missouri, was built on the creek in 1823. It consisted of a blast furnace and machine shop. Iron was hauled from the furnace to the forge at Caledonia, about 5 miles south. In May 1825, the Springfield furnace was the first west of the Mississippi River to produce an iron bar from pig metal. Following the 1837 depression, sales declined steadily, and in November 1842 the furnace closed down. Only the slag heaps indicate its former presence.</p>	
	1.50		
22.25		Eminence formation on west.	39.85
	1.90		
24.15		Large boulders of residual Gasconade chert on west.	37.95
	1.50		
25.65		Eminence on west. The dolomite contains calcite crystals, chert, and stromatolitic-like structures. The residual cherts on the hilltop show banded algal (<u>Cryptozoon</u>) structures typical of the Gasconade.	36.45
	2.50		
28.15		Eminence formation in roadcut contains coarse-grained dolomite with green shale seams, chert nodules and bands, and a small amount of quartz druse.	33.95
	0.35		
28.50		Potosi-Eminence contact in covered interval. Note color change of soil from deep red to buff.	33.60
	0.10		
28.60		Potosi dolomite and residuum on east.	33.50

<u>Outbound</u>			<u>Inbound</u>
<u>Mileage</u>			<u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
	0.30		
28.90		Junction of Missouri Highway 21 and Missouri Highway 8. Potosi dolomite on both sides of road at intersection. Barite is mixed with the chert residuum. Note the deep red color of the clayey soil and chert.	33.20
		To the west of the junction is the town of Potosi which was established as the county seat of Washington County in 1813. Lead was discovered in the area about 1763 by Francis Azor, who was locally known as LeBreton. In 1797, Moses Austin, organizer of the Missouri lead industry, received a grant which included most of the town of Mine a Burton which in 1826 merged with Potosi. Under Austin's direction, lead production increased. A shot tower, a plant for making sheet lead, and the first reverberatory furnace west of the Alleghenies were constructed. With the depletion of the deposits and the drop in lead prices, mining steadily declined during the latter part of the 1800's. With the decline, however, came the discovery of uses for barite, previously considered gangue, and the old lead diggings were reopened and new barite deposits developed.	
		City of Potosi #3 Well C. NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 11, T. 37 N., R. 2 E.	
		Curb elevation: 964 feet.	
		Cambrian	
		Potosi 0 - 300	
		Derby-Doerun 300 - 375	
		Davis 375 - 525	
		Bonneterre 525 - 910	
		Lamotte. 910 - 1100 T.D.	
	0.25		
29.15		CAUTION! Missouri-Pacific Railroad crossing. The Potosi-Eminence contact was crossed in the covered interval between here and the junction with Missouri Highway 8.	32.95
	0.40		
29.55		Roadcuts in Eminence.	33.25
	0.70		
30.25		Roadcut in Eminence. Note the algal-like (Cryptozoon?) structures in the dolomite and the barite in the chert residuum.	
	0.20		
30.45		Junction of Missouri Highway 21 and State Road E.	31.65
	0.70		
31.15		Eminence on east.	30.95

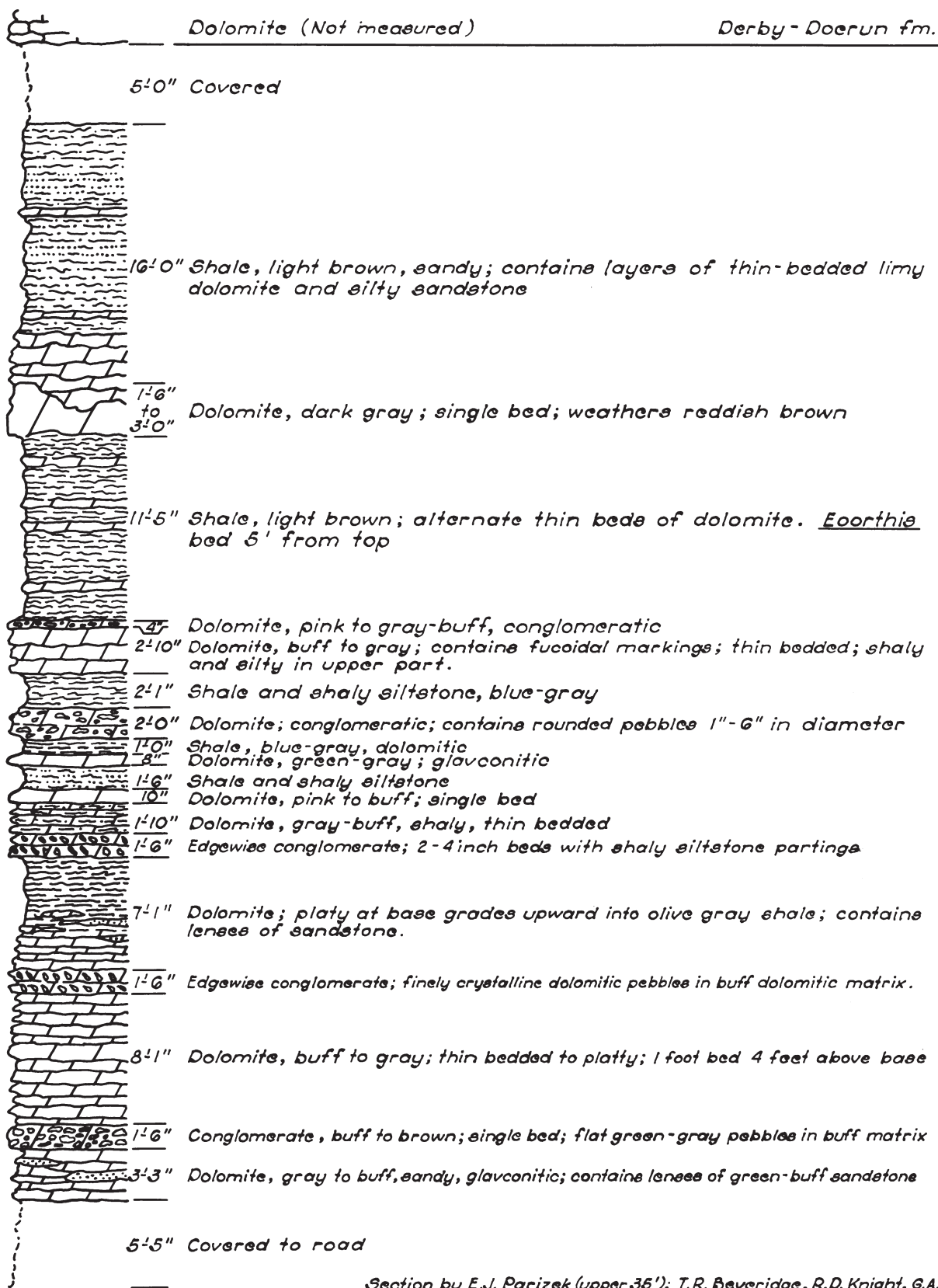
<u>Outbound</u> <u>Mileage</u>			<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
	1.40		
32.55		Overpass. Missouri-Pacific Railroad spur to the St. Joseph Lead Company, Indian Creek mine and the Meramec Mining Company, Pea Ridge mine. Eminence in railroad cut.	29.55
		Lead production from the Indian Creek Mine (NW $\frac{1}{4}$ sec. 10, T. 38 N., R. 1 E., Washington County) of the St. Joseph Lead Company began in 1954. Bain (1953) reports that the ore body is about 4,000 feet long, 500-600 feet wide, and up to 150 feet thick in some places. Galena is disseminated in the Bonneterre formation at a depth of 900 feet below the surface.	
	1.75		
34.30		Crossing Potosi-Eminence contact in covered interval.	27.80
	0.80		
35.10		Potosi in creek bed on west. Old lead and barite diggings can be seen along both sides of the road for the next several miles.	27.00
	0.30		
35.40		Junction Missouri Highway 21 and Missouri Highway 47. South city limits of Old Mines.	26.70
		This small French community, founded in 1802 and surrounded by lead and barite diggings, is in the center of one of the earliest lead mining areas in the state. Mining was begun around 1720 with the arrival of Philippe Francois Renault who established lead mining as one of Missouri's first industries, and who directed the activities of the Company of the West in this area till about 1744. Lead was recovered from the residual clay. With the discovery of the Mine a Breton (Potosi) deposit by Francis Azor, a former employee of Renault's, the "old mines" were abandoned. Many of these diggings were later reworked for barite.	
	0.35		
35.75		St. Joachim's Catholic Church to the west. The cruciform church was constructed in 1830 to replace an earlier log structure. Wrought-iron crosses of early French origin mark many of the graves in the adjoining cemetery.	26.35
	0.30		
36.05		North city limits of Old Mines. Intermittent exposures of the Potosi formation and barite diggings and tailings along both sides of the road for the next 5 miles.	26.05
	3.85		
39.90		Old Mines Creek bridge.	22.20
	0.10		
40.00		New Cruise School #1 Well NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 39 N., R. 3 E.	22.10
		Curb elevation: 655 feet.	

Outbound
Mileage
Cum. Diff.

Inbound
Mileage
Cum.

		Cambrian	
		Potosi	0 - 185
		Derby-Doerun	185 - 225 T. D.
	0.65		
40.65		Junction of Missouri Highway 21 and Missouri Highway 47.	21.45
		<p>Barite mining was first recorded as a profitable enterprise in Missouri in about 1855. Until the 1930's, barite was mined entirely by hand from open diggings in the residuum overlying the Potosi formation. A narrow circular shaft was dug to bedrock and then enlarged laterally and upwards to make a jug-shaped opening. The miner stood on the caved material and worked upward until he literally dug himself to the surface. Barite was raised to the surface, dried and freed from the clay gangue, and hauled to loading sheds in Potosi or DeSoto. Later years have seen mechanized methods of mining employed to work new deposits and to rework the old. Power shovels strip the barite-rich overburden from the bedrock surface. Then the stripped material is washed in log washers and run over jig separators.</p> <p>To the north on a hill southeast of the junction of Missouri Highway 47 and State Road H lies the famous Paw-Paw patch, one of the richest barite areas in Washington County. On this 15 acre tract, 175,000 tons of crude barite were mined.</p> <p>For many years, this area was the nation's largest producer of barite. Barite is the only barium mineral found in abundance, and it is of great value to industry as a constituent of drilling mud, as lithopone, and as a constituent of chemicals, fillers, and glass.</p>	
	0.15		
40.80		Potosi formation on southeast side of road exhibits the columnar drusy quartz so typical of this formation.	21.30
	0.20		
41.00		Barite diggings and crusher of the Whaley & Scott Company to the southeast.	21.10
	0.10		
41.10		Potosi-Eminence contact in ditch on the southeast side of the road. Roadcuts in Eminence for the next mile.	21.00
	1.10		
42.20		Potosi-Eminence contact in covered interval. Note color change in chert and soil from buff (Eminence) to deep red (Potosi).	19.90
	0.15		
42.35		Cannon Mines Creek bridge. Potosi formation in creek bed.	19.75
	0.35		
42.70		Potosi-Eminence contact in covered interval. Note the heavy quartz druse and barite fragments in the deep red	19.40

<u>Outbound</u> Mileage			<u>Inbound</u> Mileage
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
		clay and chert residuum.	
	0.20		
42.90		Eminence formation on south.	19.20
	0.20		
43.10		Roadcut in Eminence residuum.	19.00
	0.20		
43.30		Junction of Missouri Highway 21 and Missouri Highway 104. West entrance of Washington State Park. Turn north on Missouri Highway 104.	18.80
		<p>On the northeast corner of the junction is mixed Potosi and Eminence residuum. Parizek (1949, p. 187 & pl. 3) has mapped a northwest-southeast trending, high-angle normal fault (Cruise Mill - Fertile fault zone) which crosses the intersection at this point. The north side is upthrown. The fault is difficult to follow as there is no topographic expression of its trace, and over much of its extent the amount of throw is within the Potosi formation.</p>	
		<p>Washington State Park consists of 1,011 acres of heavily wooded rugged terrain along the south bank of Big River. The park provides both recreational (fishing, swimming, hiking, and picnicking) and camping facilities. The park originally was a Civilian Conservation Corps camp, and many of the roads and the log and stone buildings were constructed during the period when the camp was active. Within the park, there are several well preserved Indian petroglyph sites. They have been studied, and a short interpretive pamphlet published by the Missouri Park Board is available at the park museum.</p>	
		<p>Rocks exposed in the park area belong to the Davis, Derby-Doerun, and Potosi formations. A noticeable and rather unusual feature on the Derby-Doerun surfaces is the fluted solution potholes which are especially well developed and readily accessible in the park. These shallow depressions are generally oval to round in outline, flat bottomed, and almost always fluted or scored around the sloping sides. Similar features in the southwest were described by Udden (1925) who used the local Spanish name "tinajitas" (little water pots) for them. These and other solution features of the Derby-Doerun and the other formations in the area are discussed in detail by Parizek (1949).</p>	
	0.95		
44.25		Water tower, This was the former site of the Thunderbolt C.C.C. Camp.	17.85
	0.55		
		C.C.C. Camp #1 Well SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 22, T. 39 N., R. 3 E.	



Section by E.J. Parizek (upper 35'); T.R. Beveridge, R.D. Knight, G.A. Muilenburg

Figure 1

Davis section on east side of Mo. Hwy. 104, E 1/2 NW 1/4 NE 1/4 sec. 27, T. 39 N., R. 3 E., Washington State Park, Washington County.

Outbound
Mileage
Cum. Diff.

Inbound
Mileage
Cum.

Curb elevation: 872 feet.

No samples 0 - 65
Cambrian
Potosi 65 - 130
Derby-Doerun 130 - 230
Davis 230 - 375
Bonneterre (limestone). 375 - 770
Lamotte. 770 - 775 T. D.

44.80		Lookout and shelter on north side of road. Note the nearly vertical bluff overlooking Big River. The dolomite is Derby-Doerun. The Davis formation is exposed toward the base of the bluff.	17.30
	0.30		
45.10		Davis - Derby-Doerun contact.	17.00
	0.35		
45.45		Entrance to Parking area, dining lodge, and picnic area.	16.65
	0.20		
45.65		Davis - Derby-Doerun contact? in covered interval. Note the fault and the algal beds in the Derby-Doerun formation (Figure 1).	16.45
	0.25		
45.90		Derby-Doerun on north side of road. Trail to petroglyph site and explanatory sign on south side of road. Note "tinajitas" depressions on the surface of the Derby-Doerun along the trail and at the site. There are a number of rock and cedar glades, similar to the one at the petroglyph site, throughout this area where the Derby-Doerun is the surface formation.	16.20
	0.40		
46.30		Potosi residuum with characteristic red color on backslope on north side of road. The road is approximately at the Derby-Doerun - Potosi contact.	15.80
	0.15		
46.45		Park museum, petroglyph site, and superintendent's residence on northeast side of road. The Derby-Doerun formation is exposed in the cut along the road to the east park entrance (Figure 2).	15.65
	0.20		
46.65		East entrance of Washington State Park. Junction of Missouri Highway 104 and Missouri Highway 21. Turn east on Missouri Highway 21. Intermittent exposures of Derby-Doerun along the north side of road for next one-half mile.	15.45
	0.55		
47.20		Top of the Davis formation on north.	14.90
	0.25		
47.45		Center of Big River bridge.	14.65
	0.20		
47.65		Residual red soil of the Potosi.	14.45
	2.50		

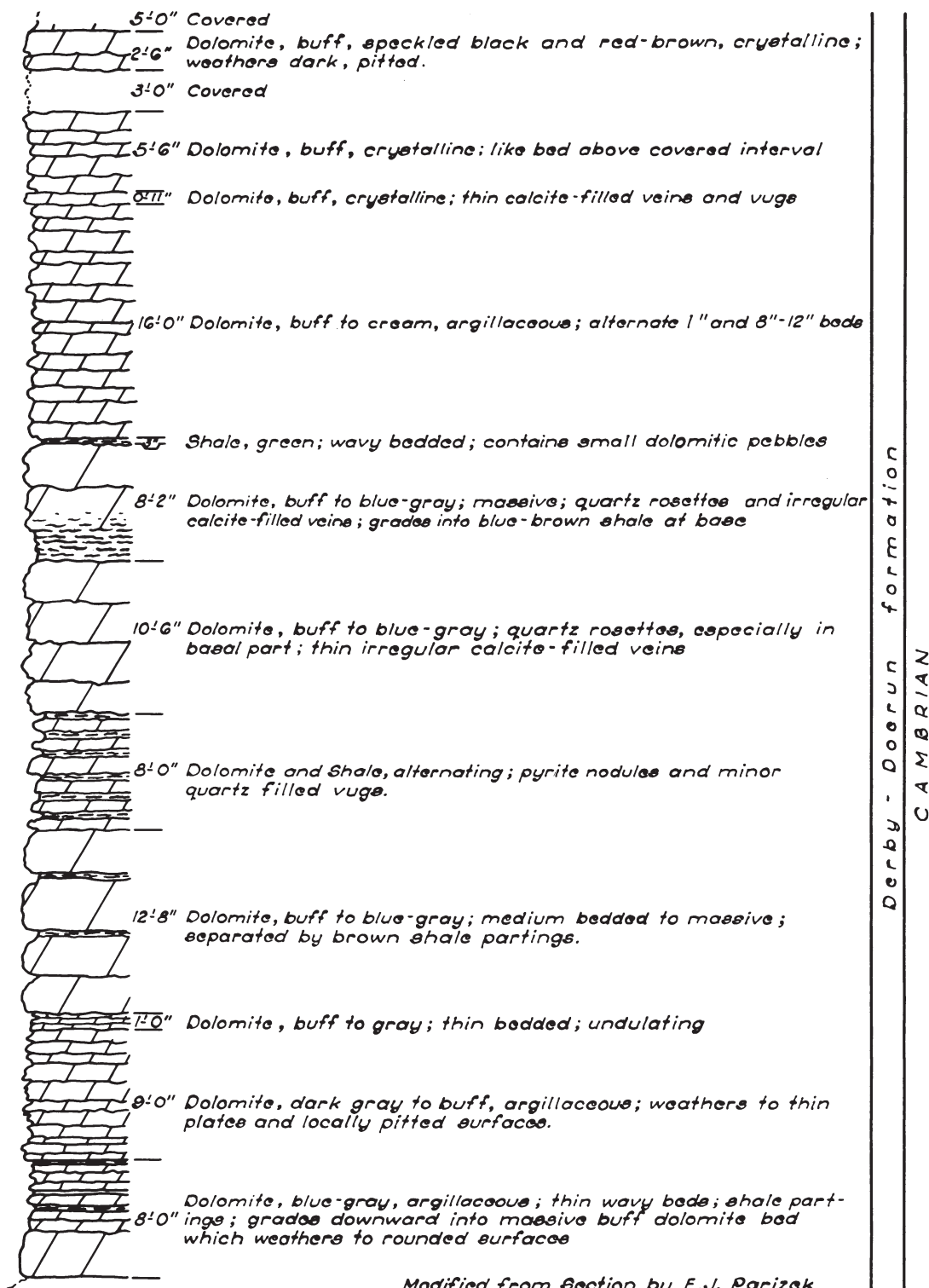


Figure 2

Derby-Doerun section along west side of Mo. Hwy. 104 at east entrance to Washington State Park, E 1/2 NW 1/4 sec. 26, T. 39 N., R. 3 E., Washington County.

<u>Outbound</u> <u>Mileage</u>			<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
50.15		Crossing the Vineland fault zone. The Eminence, Gasconade, Roubidoux, and Jefferson City formations are downthrown on the northeast.	11.95
	0.45		
50.60		Jefferson City formation.	11.50
	2.05		
52.65		Junction of Missouri Highway 21 and gravel road leading south; filling station on southeast corner. Turn south on gravel road to Vineland fault zone along the Missouri Pacific Railroad tracks.	9.45
	2.10		
54.75		Abandoned red-roofed school on west side of road.	7.35
	0.10		
54.85		Turn east.	7.25
	0.05		
54.90		Missouri Pacific Railroad crossing. Vineland. Walk southwest along tracks to fault zone. (Figure 3).	7.20

"Vineland fault zone. The fault zone extends from the railroad cut in Jefferson City dolomite, northeast to Vineland, southwest to Big River, a distance of about one and one-half miles. The dislocation is along a series of normal faults which together make up a complex fault zone. The total displacement may reach a maximum of 1,100 feet. Near the dairy farm north of the track, a water well starting in horizontally lying Jefferson City encountered the Roubidoux at 85 feet. Just north of the entrance to the railroad cut south of Vineland a few hundred yards distant, the Jefferson City is exposed in the creek bed 25 feet below track level, dipping 70 to 75 degrees northeast. On the hillside above are dislocated blocks of Roubidoux sandstone, some of which are much brecciated and recemented with silica. At the entrance to the cut the contact between the lower part of the Gasconade (Gunter member) with the Eminence can be seen. Farther south the Potosi appears. These formations dip strongly to the northeast. Farther along, near the bottom of a deep valley, on the east side of the track, massive ledges of Derby-Doerun crop out in essentially horizontal position. A little farther on is the Davis. Beginning at track level 30 feet of Davis and 45 feet of Derby-Doerun are exposed near the south end of the cut. The contact between the Davis and Derby-Doerun is conspicuous in wet weather, being marked by a horizontal line of seepage . . . The railroad cut is approximately parallel to the strike of the beds at this point so that they appear to be horizontal, but there is an appreciable dip to the northwest, at a right angle to the railroad. Several small dip faults cut the Davis and Derby-Doerun near the south end of the cut." (Muilenburg and Beveridge, 1954, p. 22).

Retrace route to Missouri Highway 21.

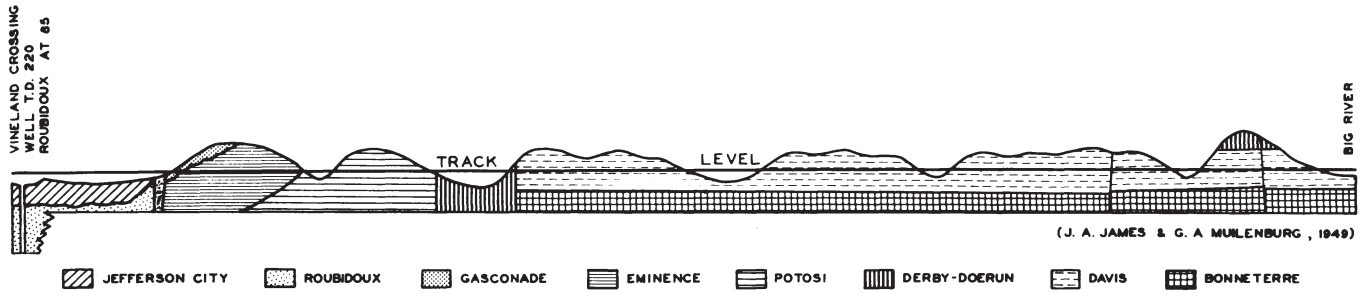


Figure 3

Diagrammatic NE-SW cross section of the Vineland fault zone along the Missouri Pacific Railroad from Vineland Station to Big River.

<u>Outbound</u> <u>Mileage</u>			<u>Inbound</u> <u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
57.15	0.25	Junction of gravel road and Missouri Highway 21. Turn east on Missouri Highway 21.	4.95
57.80	0.65	Cut in Jefferson City formation.	4.30

"The section at this point consists of two feet of cotton rock at the base on the edge of the highway, which grades upward into 2½ feet of brown to buff, mottled, crystalline dolomite. Above this is 10 feet of cotton rock (fine-grained argillaceous dolomite) with calcite-filled vugs and small quartz rosettes. A two-inch layer of white, dead appearing chert separates five feet of brown to gray, mottled dolomite containing large calcite filled vugs, from the cotton rock below. Above this is soil and residual chert.

This section is estimated to be about 140 feet above the Roubidoux. Beds of more massive, coarsely crystalline dolomite are exposed in nearby valleys, below the level of the road. These may be equivalent to the pitted dolomite which is common in the lower part of the formation in numerous other localities.

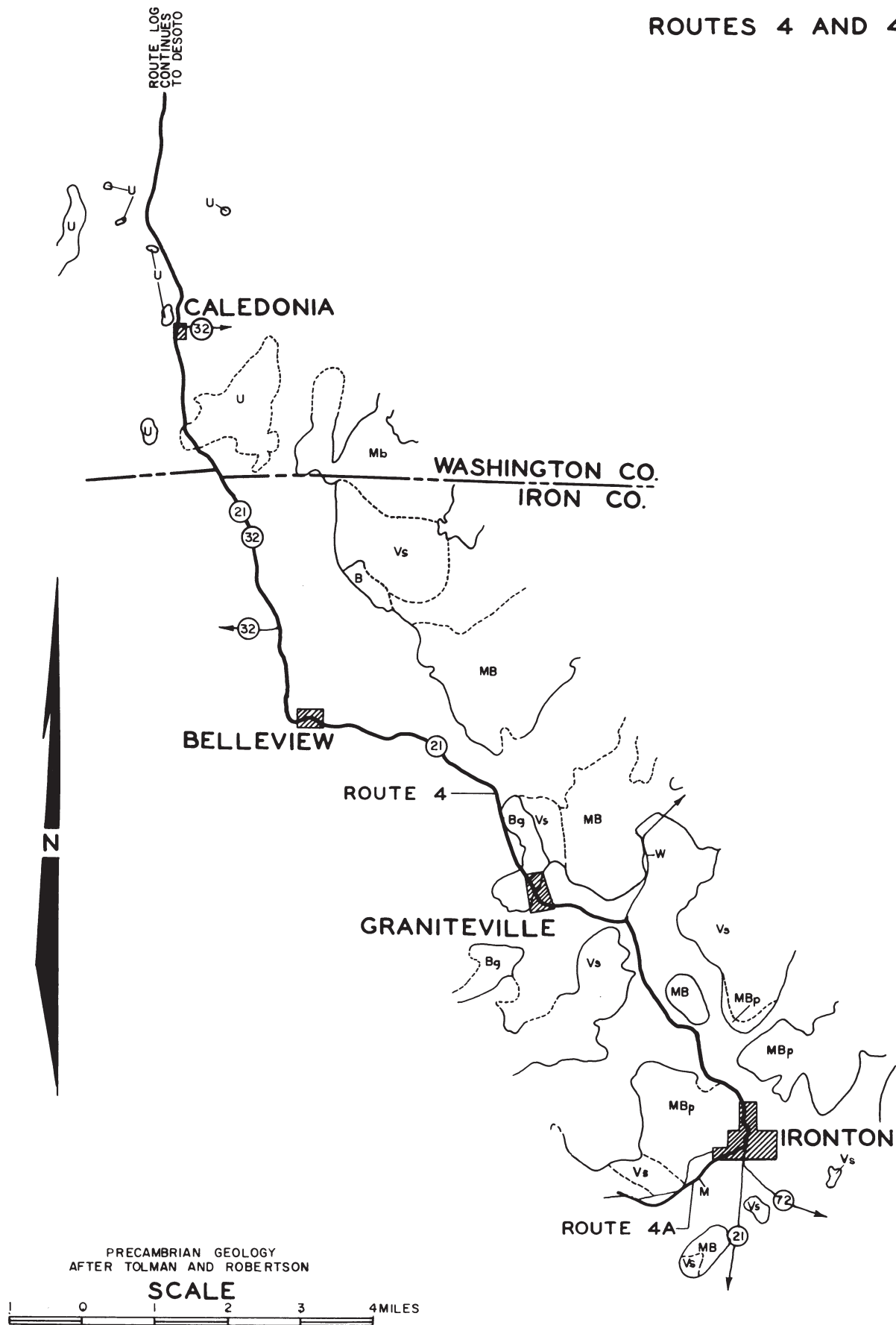
The Jefferson City is very heterogeneous and irregular in its lithologic constitution. Dolomite, argillaceous dolomite, cotton rock, sandstone, chert, and small amounts of quartzite, oolite, conglomerate and shale are found in the formation. A section of the formation in one locality is rarely duplicated by the succession of beds in another locality, although in a general way there is a recognizable relation between them. While easily recognized "cotton rock" horizons are extremely useful in determining the stratigraphic contacts in some places, they

<u>Outbound</u>			<u>Inbound</u>
<u>Mileage</u>			<u>Mileage</u>
<u>Cum.</u>	<u>Diff.</u>		<u>Cum.</u>
		cannot be entirely relied upon in even small areas, for similar horizons also occur at different stratigraphic positions within the formation." (Muilenburg and Beveridge, 1954, p. 22).	
59.65	1.85	Junction of Missouri Highway 21 and State Road H.	2.45
		Outcrops and roadcuts from here to end of the route are in the upper part of the Jefferson City formation. Many of the beds are the "cotton rock" variety.	
60.55	0.90	Junction of Missouri Highway 21 and State Road Y.	1.55
61.50	0.95	Quarry in the Jefferson City formation on hillside to east of road.	0.60
62.10	0.60	Junction of Missouri Highway 21 and Missouri Highway 110. Jefferson City formation in cuts at junction.	00.00

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ROUTES 4 AND 4A



ROUTE LOG 4A

Ironton-west

by

William C. Hayes and James A. Martin

STARTING POINT: Junction of Missouri Highway 21 and State Road M, Iron County.

(Total driving distance - 3.9 miles)

Mileage
Cum. Diff.

0.00 From the Starting Point at the Iron County Courthouse in Ironton, proceed west on State Road M from junction of Missouri Highway 21.

0.40 Bear south on State Road M.

0.80 West city limits of Ironton.

1.75 Road on north leads to Shepherd Mountain Lake which is the Ironton City reservoir. About 0.2 mile along this road on the east side of the reservoir, there is a thick residuum of granite-porphphyry that shows deep weathering not usually observed in the outcrop areas of the granite and felsite. The ferromagnesian minerals are altered to chloritic material and hematite. A thin seam of actinolite is present in the cut.



Fig. 1
SHEPHERD LAKE GRANITE PORPHYRY
(WEATHERED)
(SKETCH BY P. D. PROCTOR)

QUARTZ

ORTHOCLASE, HEMATITE DUSTING AND CHLORITIC ALTERATION

HEMATITE

GROUNDMASS VERY FINE-GRAINED FELDSPAR-QUARTZ



Fig. 2
STOUT'S CREEK RHYOLITE
SHEPHERD LAKE DAM
(SKETCH BY P. D. PROCTOR)

QUARTZ

ORTHOCLASE, SOME SERICITIZED AND CALCITIZED

ALBITE

HEMATITE/MAGNETITE

GROUNDMASS VERY FINE-GRAINED FELDSPAR-QUARTZ

0.15

1.90 Shepherd Mountain Lake, dam and spillway. On the north side of the road, the Stouts Creek rhyolite is well exposed.

<u>Mileage</u>		
<u>Cum.</u>	<u>Diff.</u>	
	0.70	
2.60		Unassigned Middlebrook felsite on north. Russell Mountain to the southwest.
	1.20	
3.80		Exposures of Taum Sauk marble on the south side of the creek south of the road. Footbridge 0.1 mile downstream.
	0.10	
3.90		End of State Road M.

PRECAMBRIAN ROCK UNITS IN MISSOURI

by

William C. Hayes¹

In 1931 the Missouri Geological Survey under the direction of Dr. H. A. Buehler, then Director of the Survey, initiated an investigation of the Missouri Precambrian in cooperation with Dr. Carl Tolman who at that time was the Chairman of the Department of Geology at Washington University in St. Louis. Much of the early work in the form of graduate theses on various phases of the Missouri Precambrian was completed under the direction and supervision of Dr. Tolman. Some of this early work was published in a report on the geology of the Silver Mine area in Madison County (Tolman, 1933) where the granites of that area were divided into types on the basis of their suites of accessory minerals. Forbes Robertson studied the igneous geology of the eastern part of the Ironton and western part of the Fredericktown quadrangles and distinguished the flow sequence of the felsite rocks in the eastern Ironton quadrangle (Robertson, 1940). In 1948 Robertson and Tolman published a paper concerning the high-potash volcanic rocks in the St. Francois Mountains.

Robertson continued his field work in 1946 and 1947 while on the staff of the Missouri Geological Survey and during the field seasons of 1948 and 1949. The work of Tolman, Robertson, and many others was compiled into a manuscript by Tolman and Robertson, and submitted to the Survey in 1952. Continuous revision of this work has ensued, and subsequent mapping and studies of the Precambrian area in the state have been compiled in a manuscript map completed in 1960.

A report, which is now in progress on the Precambrian rocks of Missouri, includes several new stratigraphic names applicable to the Precambrian in the St. Francois Mountain area. Because it is anticipated that the report will be published in the near future and will formally name several of the Precambrian rock units, the names are introduced here so that this guidebook may be used as a companion publication with the report.

The igneous rocks of the St. Francois Mountains are composed of a thick series of extrusive felsitic flows which are intruded by a granitic batholith with its associated intrusive masses of felsitic rocks. Basic dikes and sills and irregular stocks or bosses are intruded into the granites and felsites. Age determinations indicate that some of the Precambrian rocks are between 1.2 to 1.4 billion years old.

The felsites of the St. Francois Mountains are divided into two groups. The older felsite unit, the Middlebrook group, is composed mainly of rhyolite flows which have a high potash-soda ratio in which the potash content ranges to a maximum of 9.76 percent. A tuff is present above many of the flows that have been assigned to the Middlebrook group, and it separates them from the younger flows of the Van East group. Rocks of the Van East group are also dominantly composed of rhyolite and in general are indistinguishable from rocks of the Middlebrook. However, the potash-soda ratio is of normal proportions in these younger flows. The stratigraphic position of many flows may be determined by their relation to either the Ketcherside tuff or to other flows. However, there are many flows which appear to belong to the Middlebrook or to the Van East, but whose position within either group is not known. Because of this they are described as miscellaneous units. There are also isolated occurrences of felsitic rocks which cannot as yet be placed in either group. These pre-batholithic rocks are designated as unassigned units.

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The batholithic intrusion is thought to represent a large essentially concordant, sill-like body which intruded between and into the extrusive felsitic flows. The granites are dominantly pink to red granophyres that are massive, coarse grained, and have very little internal structure.

The granites represent two distinct stages of emplacement. Rocks of the first stage, designated as the Muscogroup, commonly occupy the position between the felsites of the Middlebrook and the Van East group. Rocks of the second stage of emplacement comprise the Bevos group. This group also contains several granite porphyry intrusives that are genetically related to the granites of this group. Granite types within both groups seem to be differentiates of a main mass, but in some places rocks of the Bevos are intrusive into the earlier formed granites. Some isolated granite exposures are unassigned, because their relation to rocks of either group have not been determined.

Intrusive into the felsites and granites are basic rocks which occur as dikes, sills, and irregularly shaped stocks or bosses. There are many varieties of these basic rocks such as: 1) dikes of fine-grained, nearly black basalt; 2) dikes of quartz basalt; 3) dikes and stocks of diabase; and 4) basalt and diabase that contain unusually large feldspar phenocrysts.

The accompanying table is a modification of the explanation which will appear on the map that is to accompany the forthcoming Precambrian report. The various felsite or porphyry units within the Middlebrook and the Van East groups are not arranged in stratigraphic order. The granitic rocks, thought to be differentiates of a single mass, are likewise not arranged in stratigraphic order except that it is believed that rocks of the Musco were emplaced in the first stage and rocks of the Bevos in a later stage.

REFERENCES CITED

- Tolman, Carl, 1933, The geology of the Silver Mine area, Madison County, Missouri: Missouri Bur. Geology and Mines, Bienn. Rept. of the State Geologist to the 57th General Assembly, 1931-32, app. 1, 39 pp., 6 pls.
- Robertson, Forbes, 1940, Flow sequence in the felsite rocks in the eastern Ironton quadrangle (abstract): Missouri Acad. Sci. Proc., vol. 6, no. 4, pp. 83-84.
- , and Tolman, Carl, 1948, High-potash volcanic rocks, St. Francois Mountains, Missouri (abstract): Geol. Soc. America Bull., vol. 59, no. 12, pt. 2, p. 1347.

Table 1

Precambrian Rock Units in Missouri

(Modified after Robertson and Tolman, 1960)

POST-BATHOLITHIC BASIC ROCKS

Skrainka diabase SD

BATHOLITHIC ROCKS

Mudlick latite L

Bevos group (misc. units) B

Silvermine granite Bs

Graniteville granite Bg

Brown Mt. rhyolite porphyry . . Bb

Musco group (misc. units) M

Stono granite Ms

Slabtown granite Mw

Breadtray granite Bm

Butler Hill granite Bh

Knoblick granite Bk

Buford granite porphyry Mb

Munger granite porphyry Mm

Carver Creek granite porphyry Mc

PRE-BATHOLITHIC ROCKS (Unassigned-U)

Van East group (misc. units) . . . V

Hogan Mt. rhyolite Vh

Stouts Creek rhyolite Vs

Ketcherside tuff K

Middlebrook group (misc. units). . MB

Pilot Knob felsite MBp

Royal Gorge rhyolite MBr

Annapolis rhyolite Va

French Mills felsite Vf

Oak Mt. felsite MBo

Marlow Mt. rhyolite MBm

Clark Mt. rhyolite MBc

PRECAMBRIAN OF SOUTHEAST MISSOURI: STATUS AND PROBLEMS

by

Frank G. Snyder¹ and Richard E. Wagner²

INTRODUCTION

This summary of the geology of the Precambrian rocks of southeast Missouri is written primarily as background information for the Association of Missouri Geologists field trip and for those geologists not working directly with Missouri Precambrian. It reviews the major rock types, the status of correlation and study, and the major problems in the area needing further attention. It is concerned particularly with relationships of the igneous rock units that will be seen on the field trip.

It may not be known to all members of the Association that for many years Carl Tolman made extensive studies of southeast Missouri Precambrian and, by means of Master's thesis field studies, mapped a large part of the exposed Precambrian. For a number of years, maps contained in individual theses represented the only detailed maps available. These, as is to be expected, varied in degree of excellence. Generally, the work is good and the maps stand up in the field. The chief drawback in using these maps is the lack of correlation of units from one thesis area to another - or at least a lack of correlation available to the profession.

Recently, stimulated by the interest of the mining industry in Precambrian rocks, the Missouri Geological Survey released a preliminary copy of a Precambrian geologic map compiled by Tolman and Robertson. This map, presumably not yet in the final stage of correlation and interpretation, is the basis for the Association field trip. It provides order and continuity to observation and discussion of geology of Missouri Precambrian. Without it, this field trip with its review of rock types and discussion of problems of the Precambrian would not be possible.

Numerous written contributions to knowledge of the Precambrian have been made by staff members of the universities of the area, by their students, and by State and Federal Survey geologists. A list of some of the theses and publications is appended to this review.

The writers of this paper have done little extensive areal mapping of the exposed Precambrian. By means of student thesis maps and more recently by the Tolman-Robertson compilation, they have become familiar with the named units and their relationships. Critical outcrop areas have been examined, some of them many times. In the course of their geological duties with the St. Joseph Lead Company, the writers have given considerable attention to the buried Precambrian. Extensive diamond drilling, geophysical studies, and exposures of Precambrian rocks in mine workings have made possible delineation of the major features of the Precambrian subsurface of a large part of southeast Missouri.

THE SOUTHEAST MISSOURI PRECAMBRIAN SEQUENCE

The exposed Precambrian includes one or more series of acid to intermediate volcanic rocks cut by one or more periods of granite intrusives. The sequence, as defined on the Tolman-Robertson preliminary map is shown in Table 1 of Hayes' article on the "Precambrian Rock Units

¹Chief Geologist, St. Joseph Lead Company

²Geologist, St. Joseph Lead Company

in Missouri'' included in this guidebook.

Basic Rocks

Small diabase dikes are common throughout much of the area. They are rarely seen in outcrop but are readily apparent from well-rounded residual boulders.

A few larger bodies, up to several hundred feet in width and 2 to 3 miles in length, crop out along an east-west zone in the Fredericktown-Ironton area. Some of these are coarse-grained gabbros and could well be layered, sill-like bodies. One of the larger exposed bodies, probably a sill, may be seen on Route 1.

Several occurrences of diorite and gabbro are known from subsurface information. Judging from the size of magnetic anomalies and the character of rock in drill core, these may represent large bosses or stocks. The relationship of these bodies to the exposed basic rocks is undetermined.

Granites

Two main areas of granite outcrop are mapped. One, which embraces several different named granites in an area of about 150 square miles, lies some 20 miles east and northeast of Ironton. This outcrop area includes the Magee, Butler Hill, Knoblick, Silvermine, and Wills granites. The other granite area, which encompasses approximately 50 square miles, lies northwest of Ironton. Only a small part of this granite can be seen in outcrop, with most of what can be seen being in the vicinity of Graniteville. North of the exposed Precambrian, these two granite areas appear to merge in the subsurface and to continue to the north for many miles.

Although the granites vary somewhat in grain size, in texture, and in mineralogy, they have a great deal of similarity. Most of them are exceptionally high in silica, low in plagioclase, relatively free of mafics, and contain appreciable amounts of fluorite.

Granite Porphyries

The four units designated as granite porphyry appear to be distinctive types and here are treated separately from the granites, although they have been assigned to the earlier granite group. They differ from the granites in texture and grain size. Generally, they are composed of potash feldspar phenocrysts and hornblende aggregates set in a fine-grained matrix. Without the phenocrysts the texture would be termed aplitic.

Two of the units, the Stono granite (granite porphyry) and the Buford granite porphyry, apparently lie on the granite and are at the position of the granite-roof rock contact. Their position and their composition suggest that they are hypabyssal equivalents of the underlying granites, probably modified somewhat by assimilation of roof rock, rather than distinct intrusives of a different age.

Felsites

The main outcrop area of volcanic rock is a 6-mile belt along the Iron Mountain-Ironton axis that widens south of Ironton and the granite outcrop area to some 40 miles in width and continues as a strip of scattered outliers southward to Piedmont. The volcanics form the higher hills and

the more rugged topography of the St. Francois Mountains.

The felsites have received far less study than the granites. As noted earlier, they are divided into two major groups (excluding the latites and Ketcherside tuff). Except for a small area south of Silver Mine, the older group is restricted largely to a central zone along the Iron Mountain-Ironton axis. Named units of the older group represent disconnected areas where relationships to other outcrop areas are undetermined.

The younger volcanics make up the larger part of the exposed volcanic area. With only a very few exceptions, the volcanics in direct contact with granite intrusives belong to the younger series. The Hogan rhyolite rests on and is younger than the Stouts Creek rhyolite. Relationship of these to other members of the younger volcanic group is unknown.

It can be demonstrated in many places that the felsites represent only a thin erosional remnant resting on granite. However, along the Iron Mountain-Ironton axis the volcanics appear to be very thick. This area represents a roof pendant, probably of complex structure, in the Graniteville-Magee granite complex.

To the west and northwest felsites appear to make up a much larger part of the subsurface Precambrian than do the granites. Although these have not been classified, much of the rock appears to be more similar chemically and mineralogically to the older volcanic group than to the younger.

STATUS OF STUDY AND CORRELATION

Correlation of units and rock types in an area of discontinuous outcrop is a major problem in Precambrian geology. Even where nearly continuous exposures are present, minor differences in composition, mineralogy, and texture — particularly in fine-grained rocks — make correlations difficult. Where outcrops are scattered or complex faulting is present, the problem is compounded.

Methods of Correlation

Preliminary correlations of the Precambrian commonly are made on the basis of field relationships. Specific features used include lithologic similarity, similarity in sequence, topographic expression, relation to unconformities, relation of units to known horizons, and degree of metamorphism and deformation. In the Missouri Precambrian, units cannot be related to an unconformity or to any known horizon, and they show no distinctive differences in degree of metamorphism and deformation. Granites and volcanics show marked differences in topographic expression, but individual members within a type do not vary appreciably. Lithologic similarity and similarity of sequence represent the main criteria used in field mapping.

Greater refinements in correlation and classification are obtained by detailed petrographic studies, chemical analyses, heavy mineral studies, trace element studies, and isotopic analyses.

Studies of the Granites and Granite Porphyries

Petrography. — Numerous petrographic studies have been made of the granites. Many of these are restricted to a particular area or problem. In an excellent and recent study, Kisvarsanyi (1960) described most of the granite types and classified them according to the methods of Johannsen and of Niggli. (A summary of Mrs. Kisvarsanyi's work is given elsewhere in this guidebook). Other useful studies, dealing with limited areas, include those of Bonham

(1948), French (1956), Koch (1932), Myers (1939), Robertson (1940), Tolman (1933), and Walker (1942).

Most of the granites are classed as normal granite, leucogranite, and alaskite in the Johannsen system. An exception to this is the Knoblick granite which is classed as an adamellite, a member of the quartz-monzonite family.

It appears that sufficient work has been done to establish the character of the Graniteville, Magee, Butler Hill, Silvermine, and Wills granites. Additional study is needed of the Knoblick granite and of the granite porphyries.

Chemical analyses. — Analyses of 93 rocks are reported by Hayes (1959) of which 32 are granites and 3 are granite porphyries. The analyses include 5 from Graniteville granite, 2 from Silvermine, 2 from Magee, 7 from Butler Hill, 4 from Wills, and 1 from Knoblick. The others are from undifferentiated areas and the subsurface.

The striking feature of most of the granites is the high SiO_2 content. Generally, the Graniteville, Butler Hill, and Magee granites contain about 76 percent SiO_2 as compared with 71 percent in Daly's average for all Precambrian granites. The Wills and Silvermine granites contain the normal amount of SiO_2 . In most of the granites, CaO is low, Na_2O and K_2O are normal with potash usually slightly in excess of soda.

Additional analyses are needed for Knoblick and Silvermine granites and the granite porphyries.

Heavy mineral studies. — Study of heavy accessory minerals is a widely used tool in correlation of granites. Some determinations of scattered samples have been made, but the only comprehensive study known to the writers is that of Tolman and Koch (1936). This study embraced all the major granite units. Six types of heavy mineral assemblages were defined, based on occurrence and abundance of fluorite, zircon, apatite, titanite, and epidote-zoisite. In general, all the major granites are quite similar except for the Silvermine granite which contains very little fluorite and zircon but is the only one that contains significant amounts of titanite. The authors postulated the Silvermine granite as being a different, and older, granite than the Graniteville-Magee-Butler Hill types.

On the basis of Tolman and Koch's study as well as petrographic and chemical classifications, the Graniteville, Magee, and Butler Hill granites must be regarded as products of a single granite magma.

One additional point from Tolman and Koch's paper merits attention. They show (Plate I) that the heavy mineral suite found in the Silvermine granite also occurs in granites north of Fredericktown that are mapped as Wills granite. It is interesting to note that in Kisvarsanyi's petrographic classification (1960, p. 47) that the Wills granite (called Fredericktown granite) and the Silvermine granite are the only major granites that do not include alaskite. These two granites contain appreciably less SiO_2 than the Graniteville-Magee-Butler Hill group (Hayes, 1959).

Trace element studies. — The Kisvarsanyi paper (1960) includes analyses of trace elements from a number of the granites studied petrographically. From the data presented, it appears that the granites are essentially similar in trace metal content, and the method cannot be used to distinguish between them.

Isotopic determinations. — The degree of accuracy of isotopic determinations on Precambrian rocks is not sufficient to permit dating of closely spaced events such as distinguishing the relative

order of emplacement of units of a composite batholith. However, a number of measurements on record are useful in placing the relative order of events.

Allen and others (1959) report five age determinations made on micas by the A^{40}/K^{40} method in MIT laboratories. Granites and pegmatites from Graniteville and Silvermine granites gave values of 1,200, 1,210, and 1,220 m.y. Zinnwaldite, a lithium mica, from Silver Mine (locality not granite) gave a value of 1,350 m.y. Biotite from a diorite body near Lebanon, Missouri, drilled by the St. Joseph Lead Company, gave a value of 1,150 m.y. These data suggest that the Graniteville and Silvermine granites are approximately the same age (all within the limit of error of the method) and that the diorite body is only slightly younger.

Determinations made in the Lamont Observatory (Eckelmann, et al, 1961) include a Rb/Sr determination on feldspar that gave an age of $1,300 \pm 100$ m.y. Determinations of Pb/Pb ratios on two galenas from Silver Mine (locality) and one from the Fredericktown area gave values of 1,300 m.y.

It is interesting to note that the vein minerals, zinnwaldite and galena, gave slightly older ages than the host rock. In this case, age of the vein minerals must be that of the source from which they were derived. Although it is beside the point, it may be mentioned that galena in the Bonnetterre formation also gives an age of 1,300 m.y.

Studies of the Felsites

Field relationships. — The volcanic rocks present a difficult problem in the field as well as in the laboratory. Flows thin outward from the vent or fissure, they interfinger with material from other sources, and they vary in texture, in presence of flow structures, and in degree of brecciation. Structural patterns of flow lines may represent original position or may be modified by deformation. Thin hypabyssal intrusives may differ little in grain size and textural features from thick surface flows.

Petrography. — A considerable amount of petrographic work has been done on the felsites, but much of this represents studies of specific problems or areas. No systematic study or classification has been published, although such studies are in progress. Most of the presently available petrographic descriptions are in student theses.

The felsites include various types of rhyolites, trachyte, andesite, and latite. Agglomerates and tuffs are common.

Chemical analyses. — In the Hayes compilation (1959), analyses of 39 volcanic rocks are reported. These include 2 from the Brown Mountain rhyolite, 2 from the Hogan rhyolite, 9 from the Stouts Creek rhyolite, of which 4 are near a granite contact, 2 from the French Mills felsite, and 6 from the Iron Mountain area - presumably from the older volcanic sequence. The others represent isolated or undifferentiated occurrences. Three analyses are given for the latite.

The older volcanic group differs appreciably from the younger group. The Stegall, Clark Mountain, Marlow Mountain, and Royal Gorge rhyolites, each represented by one analysis, are similar in that they contain virtually no CaO, very little Na₂O, and an exceptionally large amount of K₂O. Samples from near Iron Mountain, classified as Oak Mountain felsite, contain 63 to 68 percent SiO₂ and 1.5 to 2.0 percent CaO. Potash is usually slightly in excess of soda.

The French Mills felsite is the only member of the younger group similar in composition to the Oak Mountain felsite. The other younger volcanics contain much more silica and less CaO than the Oak Mountain felsite. Analyses of Stouts Creek rhyolite are similar in composition to

the high silica granites. Four samples of Stouts Creek rhyolite from near intrusive granite contacts are variable in composition, showing less silica and more lime than normal Stouts Creek.

Magnetic Studies of the Precambrian

The magnetic character of igneous rocks has been proved useful in interpreting the geology of the Precambrian both in subsurface and in areas where outcrops are lacking. Frank (1958) studied basement-rock cores for determination of magnetic susceptibility and remanent magnetism. He concluded that high susceptibility and high remanent magnetization are indicative of magnetite, that high susceptibility and low remanent magnetization are indicative of hematite, and that low susceptibility and negligible remanent magnetization are indicative of very little contained hematite.

Allingham (1960) employed aeromagnetic data to interpret granite/felsite relationships in the subsurface, using subsurface information supplied by the St. Joseph Lead Company. Most of the granites show a relatively flat magnetic pattern, while broad high anomalies may be due to magnetite-bearing felsites or to magnetite bodies such as Pea Ridge. Broad anomalies of low amplitude are due to shallow roof pendants in granite. Allingham also used the shape and magnitude of the anomalies to interpret the dip of the granite/felsite contact and to recognize faulting.

Comparison of the Tolman-Robertson map with the U. S. Geological Survey aeromagnetic map confirms the close correlation of magnetic character and rock type. The Magee and Butler Hill granites are low compared to the adjacent felsites. The shape and extent of the area of the Graniteville granite are indicated, although actual outcrop of this granite is restricted. The Silvermine granite area is a magnetic low.

One exception in the granite types is the Wills granite in the Fredericktown area. This is high for a granite, virtually as strong magnetically as many felsite areas. Earlier, the present authors cited evidence suggestive of kinship between the Wills and Silvermine granites, but magnetically they appear to be distinctly different.

Generally, the felsites give a strong magnetic pattern. It appears also from the Ironton area as well as the subsurface to the northwest that the older felsites give a stronger magnetic pattern than the younger ones. However, this could be due to greater thickness instead of greater susceptibility.

The magnetic pattern also suggests the possibility of a large granite area in the region east of Lesterville, north of Annapolis, and south of the Royal Gorge-Ketcherside Mountain felsites. This area shows a broad low magnetic pattern, similar to, but not so intense as the Graniteville, low. At the north end of this magnetic low, the southernmost igneous outcrops are the Carver Creek granite porphyry. A number of holes drilled in this area were bottomed in Lamotte sandstone and did not reach the Precambrian, so confirmation of this interpretation cannot be made at this time.

The entire area shows a marked gradient of the magnetic pattern to the southwest. Allingham interpreted this as indicating a southwestward tilt to faulted granite blocks.

SUMMARY OF PRECAMBRIAN HISTORY

The major events in the geologic history of the Precambrian of southeast Missouri can be

outlined. The age of the oldest rocks in the area is unknown, and the time duration of each of the major events is uncertain, but the relative order seems fairly well established.

The sequence of events, starting with early Paleozoic and continuing downward through Precambrian time includes:

- Regional tilting and continued deposition.
- Deposition of Upper Cambrian Lamotte formation.
- Erosion.
- Regional tilting, accompanied by faulting
- Hypothermal vein-type mineralization.
- Intrusion of basic rocks.
- Iron mineralization (?)
- Intrusion of granites.
- Folding and faulting.
- Extrusion of younger felsites.
- Erosion (?)
- Extrusion of older felsites.

} Probably contemporaneous.

The Older Felsites

The older felsites represent the oldest exposed rocks in Missouri. The time at which they were deposited is unknown. As stated, the earlier felsites are most widely exposed along the Iron Mountain-Ironton axis. The group includes also the exposed Precambrian of the Shannon-Carter County area and probably much of the subsurface Precambrian northwest of the St. Francois Mountains.

One intriguing question is the nature of the surface on which these older volcanics were extruded. Possibly, some of the rocks, in outcrop or in subsurface, now lumped with the felsites may be part of that surface. The nature of this original surface eventually will be solved, we believe, from the subsurface information.

Erosion

Assuming the outcrop pattern of older versus younger felsites is essentially correct as mapped, we find it necessary to postulate a period of erosion between the two groups. The outcrop pattern cannot be explained by faulting alone. It seems likely that the surface of the older felsite group was strongly eroded, even maturely dissected, before extrusion of the younger volcanics.

Admittedly, the possibility of an erosional interval between the two volcanic episodes is based on tenuous evidence. We believe it merits further study.

Extrusion of the Younger Felsites

The younger volcanics make up a larger outcrop area but probably less total volume than the older felsites. The age of this younger group is unknown. We are inclined to regard the group as only slightly older than the granites, with the volcanics being the forerunner of the deeper-seated intrusives and probably derived from the same magma source.

The pyroclastics appear to be more abundant in the younger volcanic group than in the older, although this apparent difference could be due to accident of initial preservation and later ex-

posure by erosion. Robertson (1940) suggested, on the basis of size and abundance of fragments, that the area north of Stouts Creek Shut-ins at the west of Lake Killarney may have been the site of the vent from which much of the younger pyroclastics were erupted.

Folding and Faulting

The volcanic rocks appear to be folded on an approximate north-south axis. Some of the dips shown by flow banding may be at or near original positions, but the vertical flow banding seen in some exposures and contacts between flows cross-cutting topography indicate deformation. Steeply dipping structures also are seen in drill cores and have been mapped underground. So far as we know, the older and younger felsites were folded as a unit.

In many orogenic areas, granite intrusion accompanies folding. In such cases, the granites show the effect of intrusion and crystallization under stress by the development of strong foliation and lineation and by cataclastic textures. The Missouri granites do not contain evidence of syntectonic intrusion. Foliation is developed in places but is not strong. The intrusives lack the rift and grain found useful by quarrymen in syntectonic granites. Granulation of feldspar and quartz is rare.

We suggested earlier that the Stouts Creek rhyolite may be genetically related to the granites. If this is true, the intervening period of deformation must have been short, possibly continuing into the period of granite intrusion but terminating prior to the late stages of granite crystallization.

Considerable faulting mapped in the felsites may have been initiated during this period. Many of the faults mapped in southeast Missouri show recurring periods of movement which could have begun well back in Precambrian time.

Intrusion of the Granites

The petrographic and chemical similarity of the granite types has been cited. Possibly the Silvermine and Wills granites were distinct plutons and may have originated from a different magmatic source, but the Graniteville, Magee, and Butler Hill units were emplaced as phases of a composite batholith, either at the same time or closely following one another.

The exposed Precambrian is an area in which erosion has intersected the undulating, irregular roof of the batholith. The Graniteville and Magee granites represent cupolas in which magma rose higher than in adjacent areas. The erosional surface has cut deeply into these cupolas exposing a broad expanse of granite charged with silica and the products of mineralizers. The Iron Mountain-Ironton roof pendant between these cupolas is large and probably thick. Other roof pendants, like those at Knoblick and Evans Mountains, are shallow, amounting to little more than thin erosional remnants.

The variety of rock types found in an intrusive area is a function of the type of rock invaded and the conditions of cooling and crystallization of the magma. In the southeast Missouri region, the uniformity in composition, texture, and the rock type of the granites attests to a simple intrusive history. The intruded rocks were felsites similar in composition to the magma and offering little possibility for chemical reactions resulting in exotic rock types. Unusual minerals and textures and prominent development of schlieren, so common when magma intrudes a rock of different composition, are almost entirely lacking in the granites.

Differences in crystallization history of the various granite types also were slight. The only

difference regarded as significant by the writers is the mineralogical state of iron in the Wills granite as compared with the others. In the Wills granite, enough iron crystallized in oxide form to make the granite moderately magnetic. In the other granites, which contain approximately the same amount of total iron, the iron went into hornblende and biotite resulting in a weakly magnetic rock.

The Knoblick granite and the latite occurring in the southern part of the area represent an interesting problem. The Knoblick unit has been classified on the basis of very limited sampling as adamellite, a quartz-monzonite type. The latite, actually a quartz latite, is the effusive equivalent of a quartz monzonite. Are these relatively unusual rock types related parts of a different phase of igneous history? Both units have received little attention and demand more detailed study.

Iron Mineralization (?)

Iron mineralization in Precambrian felsites is definitely Precambrian in age because ore bodies are truncated by the Precambrian erosional surface and basal conglomerates of hematite boulders are known.

At Pea Ridge the magnetite ore body is cut by diabase dikes. Iron Mountain ore body also is reportedly cut by basic dikes. Presumably these dikes were intruded at the same time as other basic dikes in the exposed Precambrian. The iron could have been introduced anytime during the long period between extrusion of the felsites and intrusion of the basic dikes. From preliminary study, there is some suggestion that iron mineralization and basic dikes may be closely related in time, so this phase of activity is tentatively assigned a place between the granites and the basic rocks.

Intrusion of Basic Rocks

Following the emplacement and crystallization of the granites and apparently soon after formation of the iron deposits, the region was intruded by basic dikes and sills, while outlying parts of the subsurface Precambrian were intruded by larger bodies of basic and intermediate rocks.

The latter part of Precambrian time is recognized worldwide as a period of intrusion of diabases, gabbros, and norites. The large basic rock bodies in Missouri subsurface appear to represent the midcontinent phase of this intrusive period.

Hypothermal Vein-type Mineralization

The silver-lead-tungsten mineralization of the Silver Mine area has been dated by Tolman (1933) as younger than the basic dikes of the area. A terminal date for mineralization cannot be given because of the absence of rocks younger than the Precambrian. However, Tolman cites evidence on temperature of formation of vein minerals and depth of cover required to achieve such conditions that precludes the mineralization being younger than Precambrian.

Regional Tilting and Erosion

It is apparent that during the long period intervening between the last phase of intrusion and the beginning of Upper Cambrian deposition the area was tilted to the southwest and deeply eroded.

Granites that had crystallized at depth were deroofed prior to Lamotte time. From the Magee-Butler Hill granite area to the north and northeast, the volcanics which the granites intruded were almost completely stripped away and great expanses of granite formed the floor for the Lamotte sandstone.

West and southwest of the Magee-Silvermine granite area, felsites make up a large part of the exposed Precambrian. Granites and granite porphyry are exposed, and farther southwest they are occasionally encountered in the subsurface, but no great expanse of granite like that to the northeast is known. In the Shannon-Carter County area, there also are great thicknesses of felsite, but, to our knowledge, no granite is deroofed.

The truncation of granite and felsite indicate that tilting was initiated long before the beginning of Lamotte deposition. Undoubtedly, the tilting was accompanied by and may have resulted from intermittent faulting.

The Lamotte formation provides a datum to which pre-Upper Cambrian topography can be related. At the Lamotte/Butler Hill contact a mile northwest of Knoblick Mountain, the contact is at approximately 900 feet elevation. Knoblick Mountain has an elevation of 1,331 feet, and formed a peak some 400 feet (plus later erosion) above the Lamotte sea. To the southwest, Taum Sauk Mountain at 1,759 feet elevation is not far distant from Lamotte sandstone at 400 feet elevation, making Taum Sauk 1,300 to 1,400 feet above the Lamotte sea. Stegall Mountain in Carter County at an elevation of 1,341 feet is not far from Lamotte formation at -800 feet elevation. Stegall Mountain and surrounding peaks towered some 2,200 feet above the Lamotte sea and represented the highest peaks during Lamotte time.

The present difference in elevation of Lamotte, some 1,700 feet, represents regional tilting and faulting after Lamotte deposition. The amount of pre-Lamotte tilting necessary to deroof the granites must have been considerably greater.

Summary and Acknowledgments

The Precambrian outcrop area embraces over 1,000 square miles, most of it rugged and inaccessible terrain. The physical task of mapping this area in considerable detail, establishing rock units, making correlations, and deciphering structure is an immense one. Those who did the field work and produced the Precambrian map can rightfully be proud of their accomplishment. Those concerned with mineral exploration, who need an orderly frame work as a basis for interpreting subsurface information, gratefully acknowledge the value and quality of the work that has been done.

Throughout this review of the Precambrian, we frequently have referred to unsolved problems or gaps in knowledge. Our intent is not to be critical but to define questions and problems that seem to us to merit further attention. Possibly some of the questions raised already have been solved, and answers will be available when the final map and text are published or when work now in progress in other laboratories is completed.

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SPECTROSCOPIC DISTRIBUTION OF THE TRACE ELEMENTS IN
THE PRECAMBRIAN GRANITES OF SOUTHEASTERN MISSOURI

by

Eva B. Kisvarsanyi¹

INTRODUCTION

This report is based on the study of spectrographic analyses of 44 granite samples from the St. Francois Mountains in southeastern Missouri. Particular emphasis is given to the distribution of the trace elements, because available chemical analyses provide data on major chemical elements in these rocks.

Several distinct granite types have previously been distinguished in the district by: 1) geologic mapping (Robertson, 1940), 2) the amount and distribution of the heavy accessory minerals (Tolman and Koch, 1936), and 3) the aid of the petrographic microscope (Tolman and Robertson, in preparation). There is the question as to whether or not the granite types exhibit a characteristic distribution of their trace elements; therefore, in the present study an attempt is made to recognize the distribution pattern of the trace elements in the rocks, and, if possible, to establish a scheme by which they can be identified on such a basis.

No pretense is given that this is a complete and conclusive study. Several of the trace elements, which are likely to occur in granites, such as lanthanum (La), yttrium (Y), neodimyum (Nd), rubidium (Rb), gallium (Ga), scandium (Sc), thallium (Tl), and columbium (Cb) were not looked for, and the rock forming minerals were not analyzed separately. It is hoped that this trace element study may serve as the initial step of a detailed spectrographic investigation of the Precambrian rock types of southeastern Missouri.

The writer is indebted to Paul D. Proctor, Chairman of the Department of Geology, Missouri University, School of Mines and Metallurgy, who suggested the problem and gave helpful criticism and advice; to Frank G. Snyder, Chief Geologist of the St. Joseph Lead Company, who contributed 10 granite samples for analysis; and to several of the staff members of the Missouri Geological Survey for their cooperation in the work, especially to Miss Mabel E. Phillips, Chemist, for her valuable help in the practical spectrographic work, and to William C. Hayes, Assistant State Geologist, for his aid in the preparation of the manuscript.

SAMPLE PREPARATION

Special attention was given to obtaining fresh material of various rock samples. The samples were collected from the rock exposures which showed the least weathering. In order to prevent contamination, the labeled samples were placed in clean paper bags. The location of each sample is given in the appendix.

Thin sections were made and studied under the petrographic microscope for the majority of the rock specimens (Kisvarsanyi, 1960).

The samples selected for spectrographic analysis were large. Most samples weighed about

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1.0 pound each. Only 10 samples were smaller; the smallest (a contributed sample from Knoblick) weighed about 1 ounce. The purpose of using large rock samples was to obtain a spectrographic sample representative of certain rock types and to reduce the possibility of contamination during crushing.

The crushing of the material consisted of two stages: 1) the sample was crushed to minus one-half inch in a jaw crusher made of cast iron; 2) it was then pulverized in a pulverizer with cast iron plates to a fine powder of minus 100 mesh. The trace element composition of the jaws and the plates is not available, but is not considered important because of the sampling procedure used. Both the crushing and the pulverizing equipment were thoroughly cleaned after each sample. The powdered sample was thoroughly mixed on glazed paper, and a small portion of it was placed in clean, labeled, paper bags.

OPERATING TECHNIQUE

The Missouri Geological Survey, 3-meter, 15,000 line per inch, grating spectrograph made by Baird Associates was used for the spectrographic analyses. The total number of grating rulings is 55,000. The useful, wavelength range of the instrument ranges from 1,800 Å to 5,250 Å. The dispersion at the setting used was 5.5 Å/mm over the entire plate for the first order.

The cathode layer method (Strock, 1936) of carbon arc spectral analysis was used in the determination. The D. C. arc was operated at 10 amperes and 35-45 volts.

A small amount (about 0.2 grams) of each sample was taken from the paper bags and dampened with a special mixture of collodion and anisole. This made the mounting easier, and because they are both organic materials there was no danger of introducing alien elements into the sample. The samples then were mounted in pure graphite electrodes. Iron, magnesium, manganese, and sodium were present as impurities in the electrodes.

In order to determine the majority of the elements being sought, a wavelength range was selected between 2,460 and 3,875 Å. For barium and strontium, a different range was required, because the most sensitive lines of these elements lie above 4,000 Å. Separate analyses were run on these two elements in the range between 3,640 and 5,050 Å.

The recording of the spectra was done on Spectrum Analysis No. 1 emulsion on 4- by 10-inch plates. Three exposures were made for each sample: 0.5 minute, 1.0 minute, and 2.0 minutes. For barium and strontium, only two exposures were made: one exposure for 1.0 minute, the other for 2.0 minutes. The spectrographic plates were developed in D-19 solution for 3 minutes with continuous agitation.

The plates were analyzed by Miss Mabel E. Phillips of the Missouri Geological Survey on a Jarrel and Ash type comparator-densitometer.

QUALITATIVE ANALYSIS

The present study is restricted to qualitative analysis, though a semiquantitative aspect is used. Instead of merely noting the presence or absence of an element, an estimate is made of the relative density of the element line when compared with the same line in other spectra on the same plate. Because the density of a line is a function of the amount of the element present, one can tell that sample 1, for instance, has more of a certain element than sample 2, and less than sample 3. Of course this gives no indication as to absolute quantities.

To facilitate the work, an arbitrary scale was established to indicate relative quantities of the elements. The scale is as follows:

- H - High, major constituent
- P - Present, intermediate quantity
- L - Low, minor constituent
- VL - Very low, less than low
- T - Trace amount present
- ST - Slight trace, barely detected
- ND - Not detected

These symbols are valid in comparisons of a single element in different samples only. The sensitivities of various elements vary widely and, therefore, a quantity of an element designated as "trace" in a sample might really be less than that indicated by a "slight trace" for another element.

In order to indicate approximately the concentration of the trace elements present in the granites, each element line in each spectrum was compared with the respective element lines in the Bureau of Standards Samples Nos. 91 (opal glass), 97 (flint clay), and 98 (Plastic clay). Thus, it was possible to place the amount of each trace element in a certain concentration range. This range for each element appears in Table 1. The values are given in percentages. The last column (ND) gives the relative sensitivity of the element. It is expressed as the limit of detection, that is, the lowest detectable concentration in percentages.

Table 2 lists results of the spectrographic analyses. The major elements, silicon (Si), aluminum (Al), iron (Fe), calcium (Ca), sodium (Na), and potassium (K), are not indicated on this table, because they were not considered important for the purposes of this study. In all samples, Si and Al were present as major constituents, Fe, Na, and K as intermediate quantities, and Ca as a minor constituent.

DISTRIBUTION OF TRACE ELEMENTS IN THE VARIOUS GRANITE TYPES

Most of the trace elements listed in Table 2 occur in all of the various granite types designated by Tolman and Robertson. Titanium (Ti) and manganese (Mn) are always present in low concentration (L); strontium (Sr), barium (Ba), zirconium (Zr), nickel (Ni), and copper (Cu) always as traces (T); molybdenum (Mo) in slight traces (ST). Those elements, which show variation in amount in the different rock types, were selected as index trace elements and were used in describing the characteristics of the various granites. These elements were found to be the following: magnesium (Mg), vanadium (V), chromium (Cr), cobalt (Co), boron (B), zinc (Zn), tin (Sn), and lead (Pb).

For purposes of comparison between the granite types, simple "rose" diagrams were constructed for each (Figure 1). Eight-spoked wheels were plotted for each granite type. Each spoke represents a given index trace element, and the length of the spoke the relative amount of that element. The scale is arbitrary.

Comparisons of relative amounts between granite types can be made when only one element is considered; the ratio of the lengths of spokes when two elements are considered has no meaning, whether on the same or on two different wheels. For an indication of an actual concentration range, Table 1 should be consulted.

The first and second rows of Figure 1 indicate the maximum and minimum amounts of the individual elements in each rock type, respectively. The third row represents the characteristic

Table 1

Approximations of Ranges of Concentration for Elements

Found in the Granites (in percentages).

Element	L	VL	T	ST	ND (relative sensitivity, limit of detection)	
Mg	0.1 -1.0	0.05-0.1	0.005-0.05	-	0.0001	0.0005*
Sr	-	-	cca. 0.01	-	0.001-0.0001	0.0002
Ba	-	-	cca. 0.01	-	0.001-0.0001	0.0002
Ti	0.5 -2.0	-	-	-		0.0002
Zr	-	-	0.05 -0.5	-	0.001	
V	-	-	0.01 -0.05	0.001-0.01	0.001-0.0005	0.001
Cr	-	-	0.01 -0.05	less 0.01	0.0001	
Mo	-	-	-	cca. 0.0001	0.0001	
Mn	0.005-0.10	-	-	-	0.0003	0.0002
Co	no data				0.0002	0.0005
Ni	no data				0.0002	0.0003
Cu	-	-	0.001-0.01	-	0.0001	
Ag	no data				0.0001-0.00003	0.0001
Zn	-	-	0.05 -0.1(?)	0.005-0.05	0.01	0.02
Sn	no data				0.001	
Pb	no data				0.001	
B	no data				0.001	0.002

Relative sensitivities are after Ahrens (1950a).

*Values in the second column are after Myers (1961)

Table 2

Qualitative Spectrographic Analysis of the Precambrian

Granites of Southeastern Missouri

Group	Granite type	No.	Mg	Sr	Ba	Ti	Zr	V	Cr	Mo	Mn	Co	Ni	Cu	Ag	Zn	Sn	Pb	B
UNASSIGNED GRANITES	From Viburnum	58	T	T	T	L	T	T	ST	ST	L	-	T	T	-	-	ST	ST	-
	From Ste. Genevieve	59	VL	T	T	L	T	T	ST	ST	L	ST	T	T	-	-	ST	ST	ST
	From Ste. Genevieve	71	L	T	T	L	T	T	ST	ST	L	ST	T	T	-	-	-	ST	ST
	From Higdon area	60	T	T	T	L	T	ST	ST	ST	L	-	T	T	-	-	ST	ST	-
	From Higdon area	62	T	T	T	L	T	ST	T	ST	L	ST	T	T	ST	-	ST	ST	-
	From Wayne county	70	T	T	T	L	T	ST	ST	ST	L	-	T	T	-	ST	ST	T	-
	From subsurface	63	L	T	T	L	T	T	ST	ST	L	T	T	T	-	-	ST	ST	ST
	From subsurface	65	T	T	T	L	T	ST	ST	ST	L	T	T	T	-	-	ST	ST	ST
	From subsurface	66	T	T	T	L	T	ST	ST	ST	L	ST	T	T	-	-	ST	ST	-
	From subsurface	67	T	T	T	L	T	ST	ST	ST	L	ST	T	T	-	-	ST	ST	-
	From subsurface	68	T	T	T	L	T	ST	ST	ST	L	-	T	T	-	ST	ST	ST	-
	From subsurface	69	T	T	T	L	T	ST	ST	ST	L	ST	T	T	-	-	ST	ST	-
BEVOS GROUP	Graniteville granite	1	T	T	T	L	T	ST	-	ST	L	T	T	T	T	-	T	T	-
	Graniteville granite	52	T	T	T	L	T	ST	-	ST	L	ST	T	T	-	-	ST	T	ST
	Graniteville granite	53	T	T	T	L	T	ST	-	ST	L	ST	T	T	-	-	ST	T	ST
	Graniteville granite	54	T	T	T	L	T	ST	ST	ST	L	ST	T	T	-	-	ST	T	-
	Bread Tray granite	24	L	T	T	L	T	T	ST	ST	L	T	T	T	-	-	ST	ST	ST
	Bread Tray granite	36	L	T	T	L	T	T	-	ST	L	ST	T	T	-	ST	T	T	ST
	Bread Tray granite	41	L	T	T	L	T	T	-	ST	L	T	T	T	-	-	T	T	-
	Bread Tray granite	44	L	T	T	L	T	T	-	ST	L	T	T	T	-	ST	T	T	-
	Bread Tray granite	45	L	T	T	L	T	T	-	ST	L	ST	T	T	-	-	T	T	-
	Bread Tray granite	47	T	T	T	L	T	ST	-	ST	L	ST	T	T	-	ST	ST	T	-
	Bread Tray granite	48	T	T	T	L	T	ST	-	ST	L	-	T	T	ST	T	ST	T	-
	Butler Hill granite	29	L	T	T	L	T	ST	ST	ST	L	ST	T	T	-	ST	ST	T	ST
	Butler Hill granite	30	L	T	T	L	T	ST	-	ST	L	ST	T	T	-	ST	ST	T	ST
	Butler Hill granite	31	L	T	T	L	T	ST	-	ST	L	T	T	T	-	ST	ST	T	ST
	Butler Hill granite	37	L	T	T	L	T	T	-	ST	L	ST	T	T	-	ST	T	T	ST
	Butler Hill granite	38	L	T	T	L	T	T	-	ST	L	T	T	T	-	ST	T	T	ST
	Butler Hill granite	39	L	T	T	L	T	T	-	ST	L	T	T	T	-	-	T	T	ST
	Butler Hill granite	40	L	T	T	L	T	T	ST	ST	L	T	T	T	-	ST	T	T	ST
	Knoblick granite	64	VL	T	T	L	T	T	ST	ST	L	ST	T	T	ST	ST	ST	ST	ST
	Silvermine Granite	15	L	T	T	L	T	T	-	ST	L	T	T	T	-	ST	-	ST	ST
	Silvermine Granite	21	L	T	T	L	T	T	-	ST	L	T	T	T	-	ST	ST	T	ST
	Silvermine Granite	22	L	T	T	L	T	T	-	ST	L	T	T	T	-	ST	ST	T	-
	Silvermine Granite	23	L	T	T	L	T	T	-	ST	L	T	T	T	-	ST	ST	ST	ST
	Silvermine Granite	26	L	T	T	L	T	T	ST	ST	L	T	T	T	-	ST	ST	ST	ST
MUSCO GROUP	Slabtown granite	6	L	T	T	L	T	T	ST	ST	L	T	T	T	ST	ST	ST	T	-
	Slabtown granite	7	T	T	T	L	T	T	ST	ST	L	T	T	T	-	ST	ST	ST	-
	Slabtown granite	8	L	T	T	L	T	T	-	ST	L	T	T	T	-	ST	ST	ST	-
	Slabtown granite	9	L	T	T	L	T	T	ST	ST	L	T	T	T	-	ST	ST	ST	-
	Slabtown granite	14	L	T	T	L	T	ST	-	ST	L	T	T	T	-	ST	-	ST	ST
	Slabtown granite	18	T	T	T	L	T	T	-	ST	L	T	T	T	-	-	ST	ST	ST
	Stono granite	49	L	T	T	L	T	T	-	ST	L	T	T	T	ST	T	ST	T	-
	Carver Creek gr. p.	57	L	T	T	L	T	T	-	ST	L	ST	T	T	-	ST	ST	ST	-

Not detected in any samples: Bi, Cd, Sb, As, Au, W, Ta, Ge, Be, Cs, Li, and P.

LEGEND

Symbol	Relative quantity present	Symbol	Relative quantity present
L	Low, minor constituent	ST	Slight trace
VL	Very low, less than low	-	Not detected
T	Trace		

distribution of trace elements in these. It should be born in mind that the wheels do not represent the analysis of an individual specimen and that in comparisons only the same elements should be considered. Only one specimen each of the Knoblick and Stono granites and the Carver Creek granite porphyry was analyzed. The result appears in the bottom of the diagram and represents that analysis.

In addition to the 8 index trace elements, the distribution of silver (Ag) will also be mentioned in the description of the various granite types, although its sporadic presence in some samples of several granite types seems to indicate a local controlling factor of its occurrence.

DISTRIBUTION OF THE INDEX TRACE ELEMENTS
IN THE SOUTHEASTERN MISSOURI GRANITE TYPES

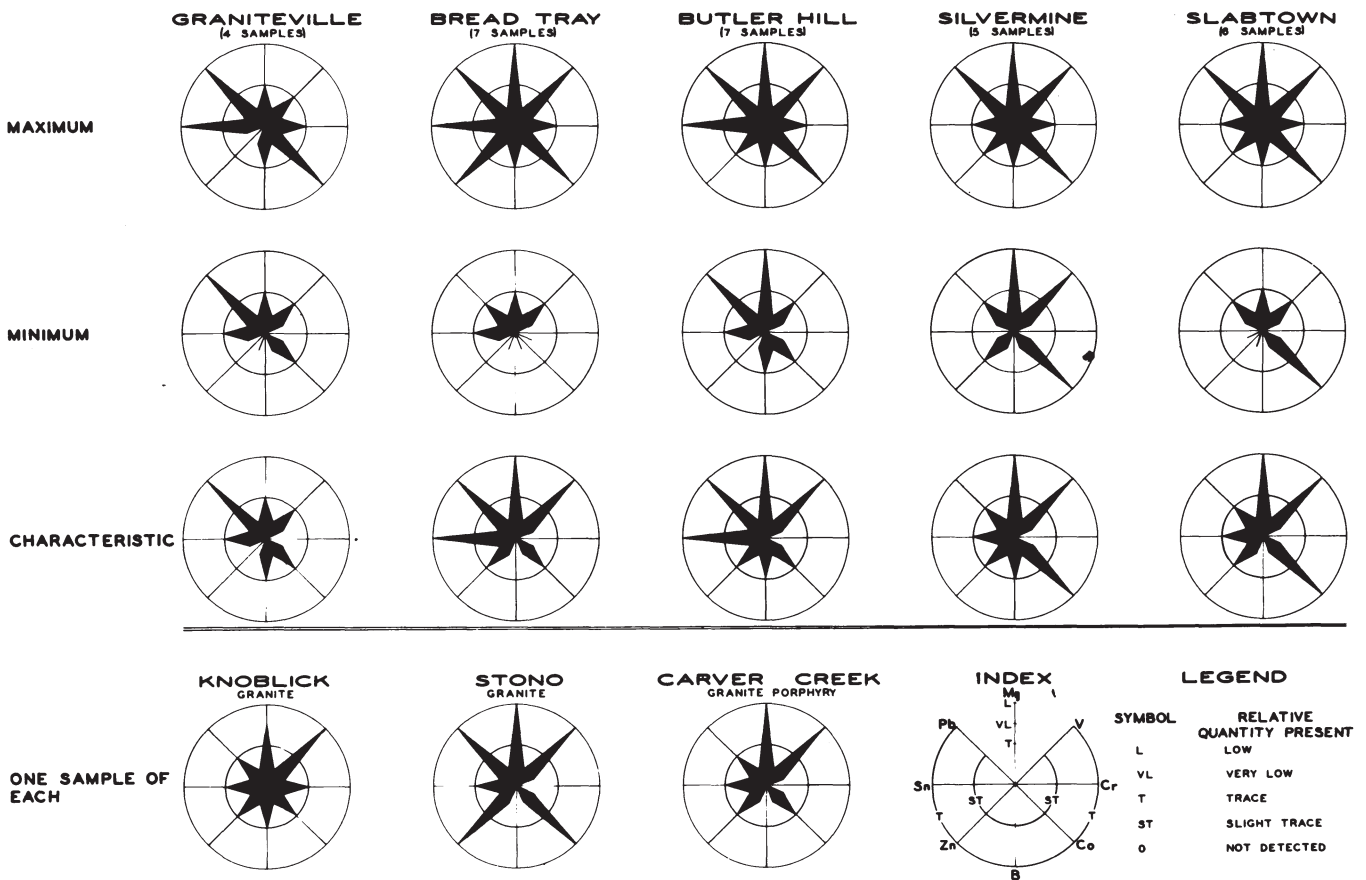


Figure 1

Musco Group

Granites of this group are generally more basic than those of the Bevos group. Accordingly, the amounts of tin and lead are smaller (ST) than in the more acidic rocks. Chromium is present in 3 samples in slight traces, silver occurs in only one sample of the Slabtown and in the Stono granite (ST). According to their more basic character, the Musco rocks contain traces of vanadium and cobalt in the great majority of the samples. Magnesium is present in low amounts (L), zinc may be absent or occurs as slight trace (ST). Boron is generally absent from these rocks, except in samples Nos. 14 and 18 where it occurs as slight trace.

Bevos Group

It is interesting to observe how closely the trace element distribution of the more basic rock types of the Bevos group (Silvermine and Knoblick granites) corresponds to that of the Musco group. It is especially evident in the case of the Silvermine granites, the characteristic diagram of which (see Figure 1) is identical with that of the Slabtown granite. Silver, however, is entirely absent from the Silvermine, while zinc is always present in slight traces. The most significant difference between the Slabtown and Silvermine granites is the greater abundance of boron in the Silvermine. The Knoblick granite is differentiated from the Silvermine by the presence of slight traces of silver and by its smaller amount of cobalt.

The most acidic granites of the area are the Bread Tray, Butler Hill, and Graniteville granites of the Bevos group. The characteristic trace element distribution of the former two are similar (see Figure 1) except for the boron content which is more abundant in the Butler Hill. Both lead and tin occur in greater amounts (T) than in the more basic rocks. Chromium is generally absent, silver occurs in only one sample of the Bread Tray granite (ST). Magnesium is rather abundant, but vanadium and especially cobalt are generally less than in the Musco group. Zinc may be absent in both the Bread Tray and Butler Hill granites, but generally it is present in slight trace. Boron is always present as slight trace in the Butler Hill but is mostly absent from the Bread Tray.

The Graniteville granite has a rather unique trace element distribution. The amount of lead is high (T), but that of tin is less than in the Bread Tray and Butler Hill (ST). Magnesium, vanadium, and cobalt occur in slight trace. Both chromium and silver occur in only one sample. The complete absence of zinc in this granite type is very characteristic. Boron may be absent or present as slight trace.

Unassigned Granites

The trace element distribution in the 12 samples of unassigned granites can be read from Table 2. Magnesium occurs in traces, except in the specimens from Ste. Genevieve County and the Pea Ridge shaft (No. 63), where its amount is higher (L, VL). In these samples and in the one from Viburnum, the amount of vanadium is higher (T) than in all the rest of the unassigned granites analyzed. The amount of cobalt varies from ND to T. Chromium is present in all the analyzed samples in slight trace, except in No. 62 from the Higdon area where it occurs as trace. This is the only sample where silver is present in slight trace. Zinc is found in only two samples (Nos. 70 and 68). Tin and lead are generally present in slight traces. Boron was detected in samples Nos. 59, 71, 63, and 65 in slight traces.

On the basis of the trace element distribution, therefore, samples Nos. 59, 71, and 63 can be fairly closely correlated with rocks of the Musco group, except for their boron content. The rest of the unassigned granites, however, would require much more detailed study before a correlation could be attempted. The low tin and lead content in the majority of these rocks is not characteristic

of the Bevos group, their low magnesium, vanadium, and cobalt content on the other hand is not characteristic of the Musco group.

COMPARISON OF TRACE ELEMENT CONTENT OF THE GRANITES OF MISSOURI WITH GRANITES OF OTHER AREAS

According to Ahrens (1950b, p. 143), the following minor elements can usually be detected spectrochemically in granites: beryllium (Be), zirconium (Zr), lanthanum (La), yttrium (Y), neodimyum (Nd), barium (Ba), strontium (Sr), rubidium (Rb), cesium (Cs), lithium (Li), gallium (Ga), lead (Pb), nickel (Ni), cobalt (Co), chromium (Cr), vanadium (V), scandium (Sc), copper (Cu), germanium (Ge), thallium (Tl), columbium (Cb), silver (Ag), tin (Sn), boron (B), and fluorine (F). Of these 25 elements, 12 were found in the Missouri rocks. Beryllium, cesium, lithium, and germanium were not detected in any of the samples. The rest of the elements were not determined. Only zinc and molybdenum, which Ahrens does not mention as typical constituents of granitic rocks, were found in the Missouri samples.

Results of the spectrographic analysis were compared with similar analyses of granites from Colorado (Bray, 1942) and New England (Shimer, 1943). The Missouri rocks differ from the two other areas in their abundance in copper and molybdenum, in the relatively frequent occurrence of tin and boron, in the relative rareness of chromium and the lack of correlation between chromium and vanadium, in the much higher abundance of zinc, and in abundance in lead accompanied with very little silver. Table 3 illustrates the comparison of the trace element content between the three different areas.

SUMMARY AND CONCLUSIONS

Qualitative spectrographic analysis of 44 Precambrian granite samples from southeastern Missouri show the following results:

1. The presence of Mg, Sr, Ba, Ti, Zr, V, Cr, Mo, Mn, Co, Ni, Cu, Ag, Zn, Sn, Pb, and B was detected in these rocks.
2. Because most of these elements occur in each granite type, a distinctive trace element suite for any one granite type could not be distinguished.
3. The relative abundance of 8 elements (Mg, V, Cr, Co, B, Zn, Sn, and Pb) vary in the different rock types. These elements were selected as index trace elements and were used in the description of the various rock types. This proved to be a useful method in recognizing distinctive characteristics.
4. The Musco granites and the more basic members of the Bevos group contain less tin and lead, but generally contain more magnesium, cobalt, and vanadium than the more acidic members of the Bevos group. The Graniteville granite is characterized by an absence of zinc.
5. Chromium and silver show a somewhat unusual distribution. Contrary to that observed elsewhere (Bray, 1942; and Shimer, 1943), the former element does not exhibit a correlation with the amount of vanadium present. Silver occurs sporadically in some samples of several granite types where it might have been introduced by the action of late magmatic fluids. An example is sample No. 1, a Graniteville granite from Sheahan Quarry, Iron County. At other facilities, however, this relationship is not so clearly seen.
6. The uniformity of the trace element content of the granites indicates that they are related to the same magmatic province.

As indicated, this investigation is considered preliminary. More detailed spectrographic research is necessary in order to learn more about the relationships between the different rock types. Spectrographic research should also be extended to the felsites and the basic rocks of the area.

Table 3

Comparison of Trace Elements of
 Granites from Colorado (Bray), New England
 (Shimer), and Southeastern Missouri (this Report).

Trace Element	Colorado Granites			SE Missouri Granites			New England Granites	
	A	ST	T	A	ST	T	A	T
Mg			_____			_____		_____
Sr			_____			_____		_____
Ba			_____			_____		_____
Ti			_____			_____		_____
Zr			_____			_____		_____
V		_____	_____		_____	_____		_____
Cr		_____	_____	_____	_____	_____		_____
Mo	ND				_____		ND	
Mn			_____			_____		_____
Co	_____	_____			_____	_____	_____	
Ni	_____	_____				_____	_____	
Cu	_____					_____	_____	
Ag	_____	_____		_____	_____		_____	
Zn	_____			_____	_____		_____	
Sn	_____				_____		_____	
Pb	_____	_____			_____	_____	_____	
Be				_____			ND	
Cs	ND			_____			ND	
Li	ND			_____			ND	
Ge	_____			_____			ND	
B	ND			_____	_____		ND	
Ga	ND			ND				_____
La	_____	_____		ND				_____
Sc	_____	_____		ND				_____
Y	_____	_____		ND				_____
Ce	_____	_____		ND			_____	
Nd	_____	_____		ND			_____	

Symbols: A - absent ST - slight trace T - trace ND - not determined

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APPENDIX

Key to the Location of Analyzed Samples

<u>No.</u>	<u>Location</u>	<u>Rock Type</u>
1	SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 11, T34N, R3E	Graniteville granite
6	NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 21, T34N, R6E	Slabtown granite
7	SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 28, T34N, R6E	Slabtown granite
8	NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 26, T34N, R6E	Slabtown granite
9	N $\frac{1}{2}$ NE $\frac{1}{4}$ sec. 2, T33N, R6E	Slabtown granite
14	SE $\frac{1}{4}$ S $\frac{1}{2}$ sec. 6, T33N, R7E	Slabtown granite
15	NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 9, T33N, R6E	Silvermine granite
18	SE $\frac{1}{4}$ S $\frac{1}{2}$ sec. 4, T33N, R6E	Slabtown granite
21	SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 7, T33N, R6E	Silvermine granite
22	SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 12, T33N, R5E	Silvermine granite
23	SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 31, T34N, R5E	Silvermine granite
24	SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 32, T34N, R5E	Bread Tray granite
26	N $\frac{1}{2}$ sec. 3, T33N, R5E	Silvermine granite
29	SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T34N, R6E	Butler Hill granite
30	SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 30, T34N, R6E	Butler Hill granite
31	SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 24, T34N, R5E	Butler Hill granite
36	SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 16, T34N, R5E	Bread Tray granite
37	SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 9, T34N, R5E	Butler Hill granite
38	NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 10, T34N, R5E	Butler Hill granite
39	secs. 35-36, T34N, R5E	Butler Hill granite
40	SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 8, T34N, R6E	Butler Hill granite
41	NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 24, T34N, R4E	Bread Tray granite
44	SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 6, T34N, R5E	Bread Tray granite
45	NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 29, T35N, R5E	Bread Tray granite
47	SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 26, T35N, R4E	Bread Tray granite
48	S $\frac{1}{2}$ sec. 3, T35N, R4E	Bread Tray granite
49	S $\frac{1}{2}$ sec. 3, T35N, R4E	Stono granite
52	NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 22, T34N, R3E	Graniteville granite
53	NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 10, T34N, R3E	Graniteville granite
54	SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 10, T34N, R3E	Graniteville granite
57	SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 28, T33N, R3E	Carver Creek granite
58	N $\frac{1}{2}$ sec. 16, T35N, R2W	prophyry From Viburnum
59	NW $\frac{1}{4}$ sec. 8, T36N, R7E	From Ste. Genevieve County
60	SE cor. sec. 1, T33N, R7E	From Higdon area
62	SW cor. sec. 4, T33N, R8E	From Higdon area
63*	Pea Ridge shaft	Pegmatite
64*	sec. 8, T34N, R6E	Knoblick granite
65*	sec. 7, T36N, R4E	From subsurface
66*	NW $\frac{1}{4}$ sec. 15, T35N, R2W	From subsurface
67*	SW $\frac{1}{4}$ sec. 16, T36N, R5E	From subsurface
68*	sec. 35, T34N, R7E	From subsurface
69*	sec. 1, T36N, R2W	From subsurface
70*	SE $\frac{1}{4}$ sec. 13, T30N, R5E	From Wayne County
71*	sec. 7, T36N, R7E	From Ste. Genevieve County

*Contributed by Frank G. Snyder, Chief Geologist of the St. Joseph Lead Company.