LITHIUM PEGMATITES OF THE WHITE PICACHO DISTRICT, MARICOPA AND YAVAPAI COUNTIES, ARIZONA

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This one-day field trip visits several small lithium pegmatites on private property in typical desert terrain, and normal desert field equipment (boots, hat, canteen, etc.) is recommended. Two short hikes will be made totaling about 2 km. The road to the pegmatites has too many sharp curves for buses, but can be negotiated by ordinary sedans if drivers are careful not to become stuck in the loose sand of San Domingo Wash.

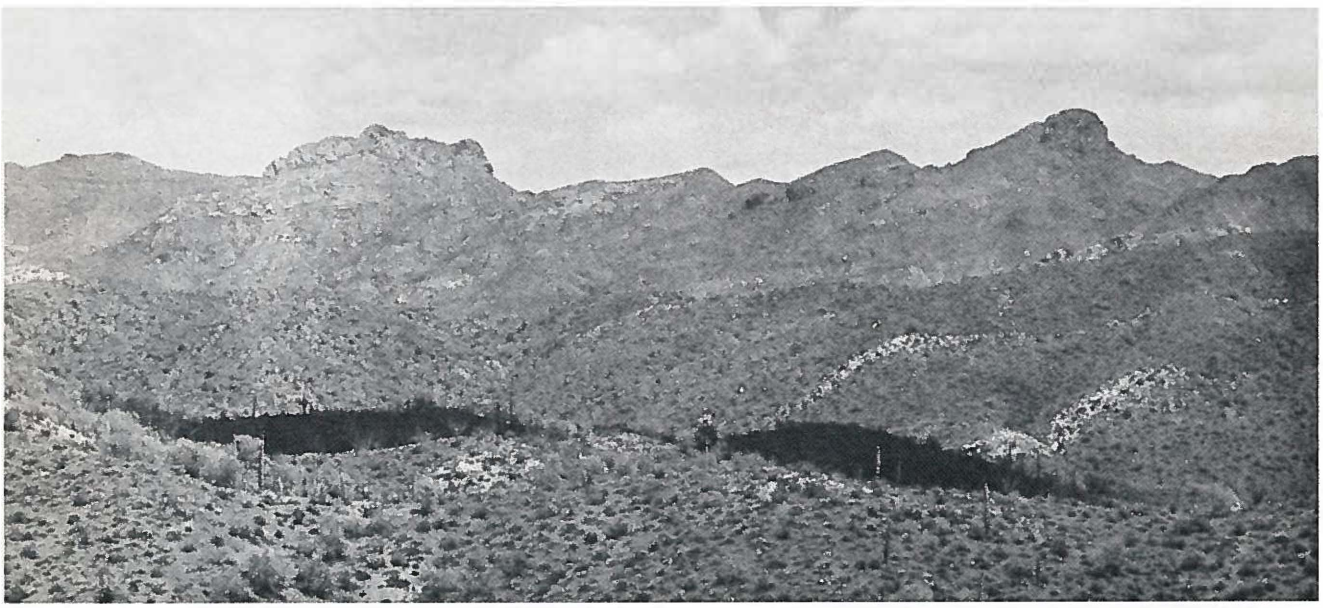


Figure 1. View of the Red and White Picachos from the west.

INTRODUCTION

The Arizona pegmatite belt is a broad region that extends from central to northwestern Arizona (Jahns, 1952). The White Picacho pegmatite district is located near the SE end of this belt. The Arizona Bureau of Mines bulletin by Jahns (1952) remains the best general reference on the district, and the reader is referred to it for a more complete description of the pegmatites. Jahns' detailed maps of the geology of the pegmatite workings are still usable, inasmuch as only minor mining and development work has been carried out in the district over the past 25 years.

Later geologic studies in the district include the county maps by Wilson et al. (1957) and the Arizona Bureau of Mines (1958), a study of tungsten deposits by Dale (1959), an age-dating study of pegmatite minerals by Laughlin (1969), a study of placer gold by Johnson (1972), and a thesis study of the volcanic rocks to the east by Ward (1977). This guide incorporates, in addition, preliminary results of thesis research by London (in progress, 1978). The discovery of eucryptite in the district (Burt et al., 1977) has been confirmed by Jahns (personal communication, 1977).

The pegmatites of the White Picacho district are mainly indicated on the Red Picacho 7.5′ topographic quadrangle map of the U.S. Geol. Survey (1964), although several workings on this map are misnamed. The district derives its name from White Picacho, a prominent peak about 1 km northeast of Red Picacho (fig. 1). The field trip area spans the Maricopa/Yavapai county line and lies mainly in sections 10 and 16, T7N, R3W. This is about 80 km northwest of Phoenix and 10 km east of Wickenburg, in the southwest foothills of the Wickenburg Mountains, at an elevation of 800–900 m (2,600–3,000 ft.). The main drainages are San Domingo Wash, which also provides

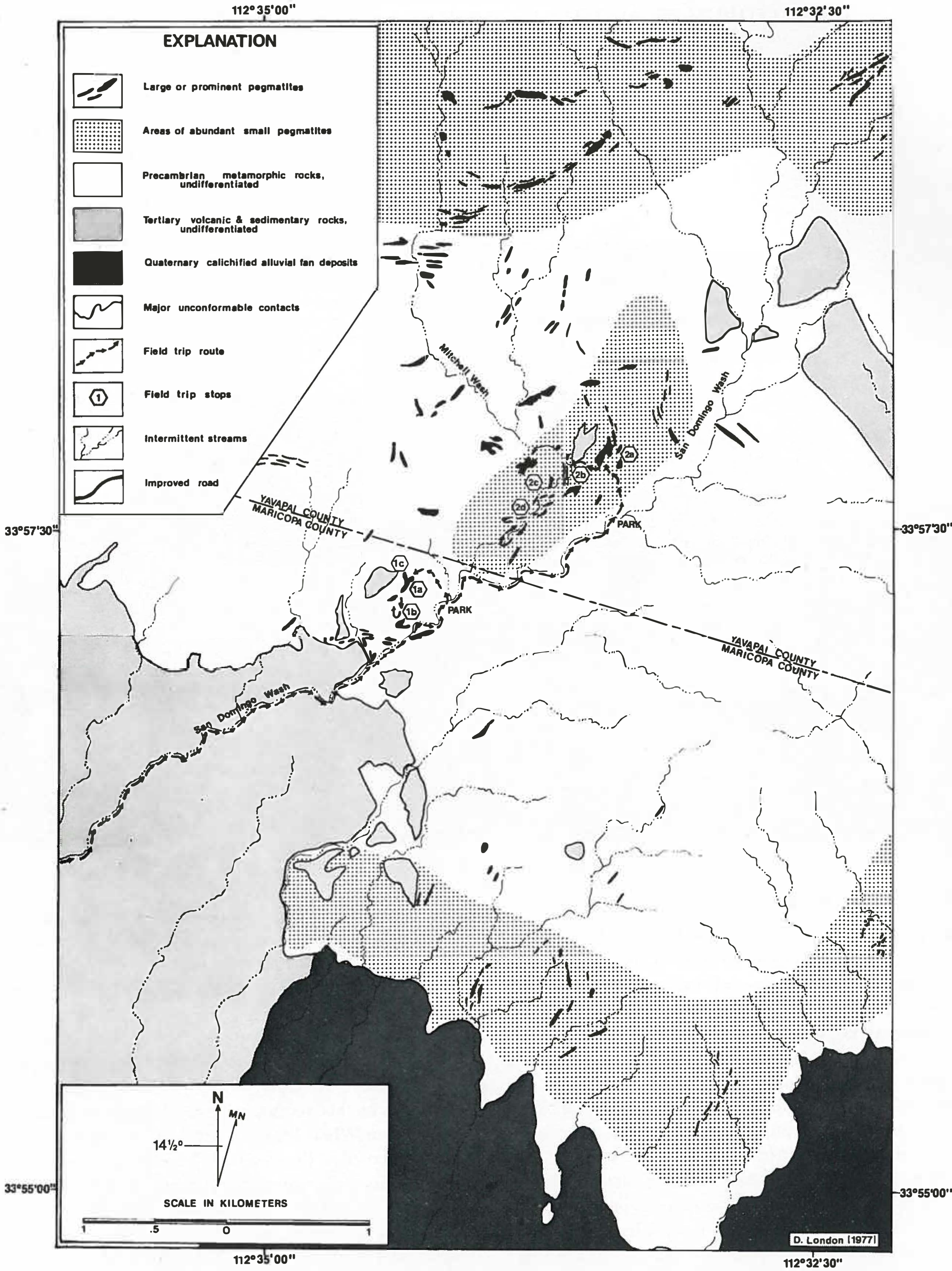
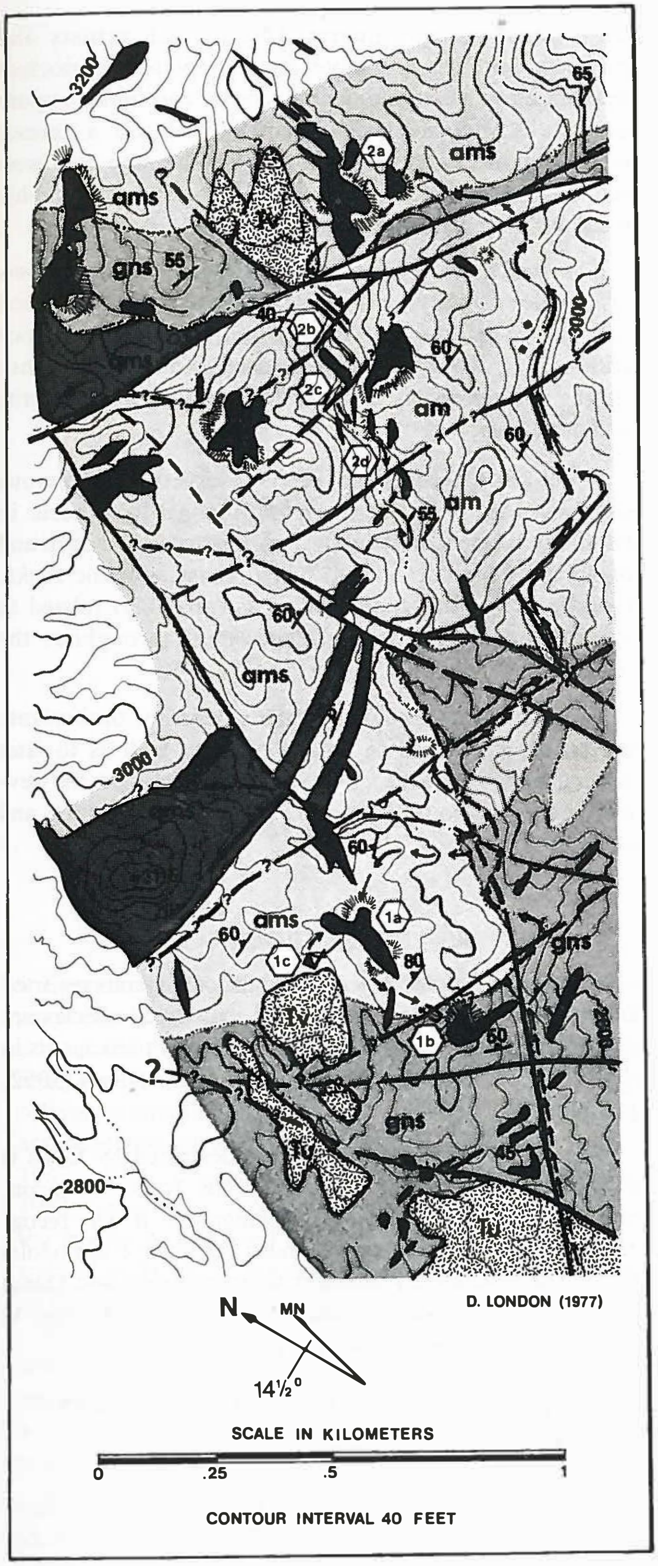


Figure 2. Map showing the distribution of major rock types in the district.



EXPLANATION

Large or prominent pegmatites.

Dump material.

ams

Northern part of map area: predominantly fine to medium grained, well foliated hornblende amphibolite, containing significant amounts of sulfides (pyrite and chalcopyrite) as disseminated grains and discontinuous patches parallel to foliation; heavily rust stained on weathered surfaces; black on fresh surfaces.

Southern part of map area: sulfidic biotite-hornblende amphibolite and biotite schist.

am

Predominantly hornblende-epidote amphibolite and hornblende-plagioclase amphibolite. Hornblende-epidote amphibolite is fine to medium grained, well foliated, with irregular, discontinuous epidote-rich layers; hornblende-plagioclase amphibolite is medium grained, well foliated, and homogeneous. Weathers dark gray to black, locally rust stained; unit contains minor fine grained, gray, massive quartz-muscovite impure quartzites. Well exposed in Mitchell Wash.

qms

Medium grained, well foliated muscovite-quartz schist; locally contains small, euhedral, pink garnets; foliation surfaces are multiply crenulated; silvery on fresh and weathered surfaces, locally rust stained.

gns

Predominantly very fine to fine grained, well foliated quartz-chlorite-epidote (?) schists, quartz-feldspar-biotite or chlorite gneisses, and biotite schists; heavy brown-black varnish on weathered surfaces, green or black on fresh surfaces. Similar rocks occurring in some shear zones and around most pegmatites appear to be products of retrograde hydrothermal alteration.

Tv

Tertiary volcanic rocks: predominantly porphyritic gray intermediate volcanics; phenocrysts are plagioclase and biotite in fine grained gray groundmass.

Tu

Tertiary volcanic and sedimentary rocks, undifferentiated.

Mostly subvertical fault zones of sheared or brecciated rock; some breccia zones are welded with very fine grained chlorite/epidote matrix; others are welded with very coarsely crystalline buff-colored calcite. Nature of offset in the various types of fault zones is not known at this time. Faults verified by ground truth.

Extention of fault zone based on air photo linears and topography. Faults may be verified by further ground mapping.

?—?—?—

Extension of fault zone based solely on topography. Fault zones may be buried by unconsolidated materials and thus are not directly observable on the ground.

Sharply gradational lithologic contact, dashed where approximately located.

Broadly gradational lithologic contact, approximately located.

60

Strike and dip of layering and foliation in metamorphic rocks.

Field trip route.

1a

Field trip stops.

Vertical mine shaft.

Figure 3. Reconnaissance geologic map of the field trip area.

vehicle access, and its tributary, Mitchell Wash, which will be visited on foot. Flora and fauna are typical of the upper Sonoran desert region; visitors are especially warned to watch out for rattlesnakes and wasps, which abound in the old pegmatite workings.

STRUCTURAL SETTING

Figure 2 shows the distribution of major age/lithologic rock types in the district. The pegmatite minerals have been dated by Laughlin (1969); K-Ar dates on different minerals yield apparent ages ranging from 750–1580 m.y., with muscovite giving a minimum age of 1270 m.y.

The northern part of the area depicted in figure 2 is dominated by Precambrian igneous and metamorphic rocks; the eastern and southwestern parts by Tertiary volcanics and sediments. A stratigraphy of Tertiary rocks exposed to the east of the map area has been developed by Ward (1977). Poorly consolidated alluvial deposits cover much of the area to the south; these deposits are presumably Quaternary in age.

The pegmatites exposed in the White Picacho district lie in a broad zone that generally trends northeast. Pegmatites in the south part of the district are grossly discordant; to the north, however, the pegmatites conform to the regional strike (but not necessarily dip) of the host rocks. The significance of host rock petrochemistry and regional structure as influences on pegmatite mineralogy, shape, and trend is currently under investigation. A study of various types of remote sensing imagery of the area (E. B. H. London, unpublished report, 1977) revealed that San Domingo Wash is a major lineament that appears on all types of imagery (LANDSAT, ERTS, high-level color infrared, and black and white photography). Preliminary imagery interpretation and reconnaissance mapping indicate that generally east-west trending metamorphic rocks and pegmatite zones bend abruptly into parallelism with the San Domingo lineament, most prominently in the upper reaches of San Domingo Wash.

Pegmatites are abundant in a zone along San Domingo Wash, although this is not the only belt in which they are concentrated (see fig. 2). Ground reconnaissance and imagery interpretation suggest that other features, such as rock types and lithologic contacts, may be important in determining zones of pegmatite concentration.

The San Domingo lineament can be traced northeast into the Spud Fault zone of Blacet (1966) (Anderson and Blacet, 1972); the observation of shear textures and major discontinuities across San Domingo Wash suggests that the Spud Fault system may extend into this area.

Figure 3 is a reconnaissance geologic map of the field trip area. The region consists of greenschists (probably chlorite-(muscovite)-quartz), biotite-rich schists and gneisses, hornblende-epidote and hornblende-plagioclase amphibolites, muscovite-quartz schists, and minor impure quartzites. Mineralogy and grain size suggest a general increase in metamorphic grade from southeast to northwest across the area; as of this writing, however, no petrographic work has been performed to verify mineral assemblages.

The rocks are extensively sheared by a set or sets of complex fault systems; most fault zones are subvertical and consist of sheared, mylonitized, or brecciated rock fragments. Rocks in and around most fault zones cutting metamorphic rocks are highly altered to chlorite and/or epidote.

Small-scale folds have been observed in numerous outcrops. Pre- or synmetamorphic isoclinal folds occur in the thinly layered amphibolites; postmetamorphic open and ptygmatic folds occur in all types of metamorphic rocks. Drag folds in fault zones and folds (probably) related to pegmatite emplacement are prevalent throughout the region.

As regards the structures of the pegmatites themselves, the reader is referred to Jahns (1952) as well as to later general reviews (Jahns, 1953; 1955). Details on the several pegmatites to be visited are given in the road log and stop guide.

MINERALOGY

For reference, table 1 is a partial list of minerals reported from the pegmatites of the district; underlined species are those regarded as likely to be encountered by participants in the field trip. For a more complete list, consult Jahns (1952, p. 33–34).

The only mineral on this list not described by Jahns is eucryptite, which, together with albite, forms an inconspicuous alteration product of spodumene. It was recognized by its red fluorescence under short wave ultraviolet light. The reaction by which it formed (Brush and Dana, 1880) involves sodium metasomatism of spodumene to yield intimately intergrown eucryptite and albite:

$$\underset{\text{spodumene}}{2\ LiAlSi_2O_6} + Na^+ \rightarrow \underset{\text{eucryptite}}{LiAlSiO_4} + \underset{\text{albite}}{NaAlSi_3O_8} + Li^+$$

The fact that the silica-deficient mineral eucryptite commonly occurs with quartz implies that end member spodumene must be unstable at low pressures and temperatures (Burt et al., 1977). Spodumene is indeed heavily altered in most pegmatites of the district, most commonly to muscovite or various clay minerals. Studies of spodumene alteration and eucryptite genesis are in progress.

TABLE 1. SOME MINERALS FROM THE WHITE PICACHO PEGMATITES

NAME	COMPOSITION
Quartz (milky)	SiO_2
Perthitic Microcline	$(K,Na)AlSi_3O_8$
Albite (Cleavelandite)	$NaAlSi_3O_8$
Eucryptite	$LiAlSiO_4$
Muscovite (incl. pink muscovite)	$KAl_2AlSi_3O_{10}(OH)_2$
Lepidolite	$K(Li,Al)_3(Si,Al)_4O_{10}(F,OH)_2$
Zinnwaldite	$KLiFe^{2+}Al(AlSi_3)O_{10}(F,OH)_2$
Biotite	$K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$
Cookeite	$LiAl_4(AlSi_3)O_{10}(OH)_8$
Tourmaline	$(Na,Ca)\ (Fe^{2+}, Fe^{3+}, Al,Li)_3Al_6(BO_3)_3Si_6O_{18}(OH,F)_4$
Schorl	
Elbaite	
Beryl	$Be_3Al_2Si_6O_{18}$
Spessartine	$Mn_3Al_2Si_3O_{12}$
Spodumene	$LiAlSi_2O_6$
Lithiophilite - Triphylite	$Li(Mn,Fe)PO_4$
Amblygonite	$LiAlPO_4(F,OH)$
Triplite	$(Mn,Fe)_2PO_4(F,OH)$
Apatite	$(Ca,Mn)_5(PO_4)_3F$
Monazite	$(Ce,La)PO_4$
Fluorite	CaF_2
Scheelite	$CaWO_4$
Columbite - Tantalite	$(Mn,Fe)\ (Nb, Ta)_2O_6$
Microlite - Pyrochlore	$(Na,Ca)_2\ (Ta,Nb)_2O_6(O,OH,F)$
Cassiterite	SnO_2
Magnetite	Fe_3O_4
Gahnite	$ZnAl_2O_4$
Sulfides (pyrite, pyrrhotite, loellingite, etc.)	

ECONOMIC IMPORTANCE

Economic mineral production from the White Picacho pregmatites has been small. Mining has included the lithium ore minerals spodumene, lepidolite, and amblygonite, and the nonlithium ores of feldspar, mica, beryl, columbite-tantalite, and bismuth minerals. Most mining and development work appears to have been done between 1947, when lithium minerals were first discovered, and 1952, when Jahn's report appeared. Later small-scale mining has been performed by the long-time owners, Earl F. and Sidney B. Anderson of Mesa, who maintain a caretaker on their property.

For current data relating to lithium uses and resources, consult, *e.g.*, Vine (1976). The implication is that the pegmatites exposed in the district do not at present represent a large enough resource to justify a large-scale mining operation.

Elsewhere in the district there has been minor production of gold and tungsten (scheelite) from quartz veins and placers, and of copper from meta-volcanics.

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ROAD LOG AND STOP GUIDE

MILES Interval	Total	
0.0	0.0	Leave the loading dock behind the F-wing, Physical Sciences Center (Geology-Physics) at A.S.U.; turn left (west) onto University Dr., and proceed through the next 6 traffic lights.
2.6	2.6	Turn left (south) onto 48th St.
0.4	3.0	Turn right onto I-10 westbound (Phoenix); stay on I-10/I-17 for the next 22.6 miles.
0.3	3.3	Phoenix South Mountain Park, largest municipal park in the U.S., lies to the south; the mountains are composed of Precambrian gneisses, schists, and greenstones and Tertiary granodiorite.
2.1	5.4	To the right (northeast) is Camelback Mountain. The camel's head, to the west, is composed of Tertiary arkosic sandstones and conglomerates; it sits unconformably on a body of Precambrian granite. The sharp peak to the northwest of Camelback is Squaw Peak, composed of Precambrian metarhyolites, metatuffs, quartzites, and greenstones. It is the site of Field Trip No. 8.
4.1	9.5	The Sierra Estrella (Precambrian) lie to the left (southwest), downtown Phoenix is to the right.
10.5	20.0	The Phoenix Mountains to the right (east) are composed chiefly of Precambrian phyllites and schists. The hills to the north and west of the Phoenix Mountains are mostly intermediate to mafic volcanics of probable Tertiary age.
5.6	25.6	Exit right onto Bell Rd. westbound; stay on Bell Rd. for the next 13.8 mi.
12.7	38.3	The White Tank Mountains are straight ahead (west), the Wickenburg Mts. are northwest, and the Hieroglyphic Mts. are north. All three ranges are composed of Precambrian igneous and metamorphic rocks overlain by Tertiary igneous and sedimentary rocks.
1.1	39.4	Turn right (northwest) onto Grand Ave. (U.S. 60 and 89; State 93) to Wickenburg; stay on it for the next 20.6 mi., to Morristown.
20.3	59.7	Morristown railroad overpass. The famous Vulture gold mine is located in the Vulture Mts. to the northwest. Red Picacho is the knob to the north; White Picacho which gives the pegmatite district its name is hidden behind it. The pegmatites to be visited are about 5 km west of Red Picacho.
0.3	60.0	Morristown. Turn right (northeast) onto the Castle Hot Springs Rd. (just past the Morristown sign).
1.6	61.6	Cross State 70. Continue straight onto gravel road; Red Picacho is straight ahead.
2.5	64.1	Turn left at fork near top of hill; if you miss this turnoff, another is available over the hill, 200 m farther.
0.4	64.5	Continue straight ahead (northwest) on the Old Wickenburg Stage Route. Exposures for the next 6 mi. are of volcanic and sedimentary rocks of probable Tertiary age. The volcanic rocks are predominantly flows of intermediate composition (maroon to mauve colored quartz latites or rhyodacites), with minor layers of basalt and tuffaceous rhyolite. The sedimentary rocks, well exposed in San Domingo Wash, are predominantly pebbly arkosic sandstones and subangular, polymictic conglomerates. The rock fabric, long tabular beds, and absence of channel features suggest that these are alluvial fan deposits. Very coarse conglomeratic breccias (?) appear to be debris flows of unknown (sedimentary or volcanic) origin.
1.1	65.6	Bear left across the wash; a placer gold operation is visible to the right.
1.9	67.5	Make a hard right turn into San Domingo Wash; continue up the wash and avoid stopping in loose sand.
0.5	68.0	On the left (west) is a good exposure of a low angle fault (fig. 4). The fault surface dips about 25° to the east; drag folds indicate dextral motion of the upper block to the north-northeast. This fault probably represents a décollement, inasmuch as at least one other low angle fault in the area shows an opposite direction of transport. However, block rotations of nearly 90° are common in the sedimentary rocks; thus apparent thrusts or décollements may be normal faults rotated by subsequent deformation.
2.5	70.5	You are crossing the buried contact between the Tertiary volcanics and sediments and the Precambrian metamorphics.
0.5	71.5	**STOP 1.** Park in San Domingo Wash at the foot of the trail to the North Morning Star pegmatite.

Figure 4. Low angle fault in the Tertiary sedimentary rocks exposed in San Domingo Wash.

STOP 1a: Hike up the path to the North Morning Star pegmatite. WATCH OUT FOR RATTLESNAKES. The North Morning Star (fig. 5) is one of the best-exposed lithium pegmatites in the district. Like other relatively large pegmatites, it shows a textural gradation from a medium grained border zone to a giant textured core. Mineral assemblage zones are particularly well developed, although this may not be immediately apparent. The pegmatite core consists of giant-textured, anhedral quartz; lithium minerals, mostly amblygonite and spodumene, are concentrated in the inner intermediate zones; predominantly quartz-perthite pegmatite constitutes the outer intermediate and border/wall zones. The North Morning Star's zones are unusually uniform in thickness and regular in extent (see figs. 6 and 7); the pegmatite is more sheet-like than most other lithium pegmatites of the district (for example, the South Morning Star pegmatite, **STOP 1b.** Jahns (1952) concluded that most of the pegmatites were emplaced along pre-existing fractures, along foliation, or along other planar features in the host rocks; the relations of the North Morning Star to its confining rocks appear to support this interpretation. Although some pegmatites show signs of forceful injection, the North Morning Star may have undergone relatively passive emplacement. Foliation and layering in the country rocks are consistent up to the pegmatite's border zone; there are no forcefully intruded dikelets nor drag-folded metamorphics at the borders. No offset of the host rocks has been observed across the pegmatite, and no shear or breccia

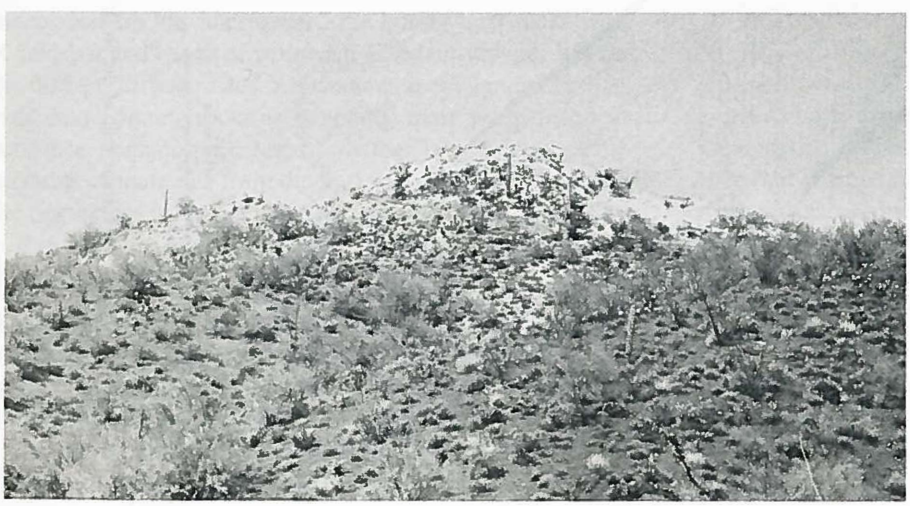

Figure 5. The North Morning Star pegmatite, viewed from the east.

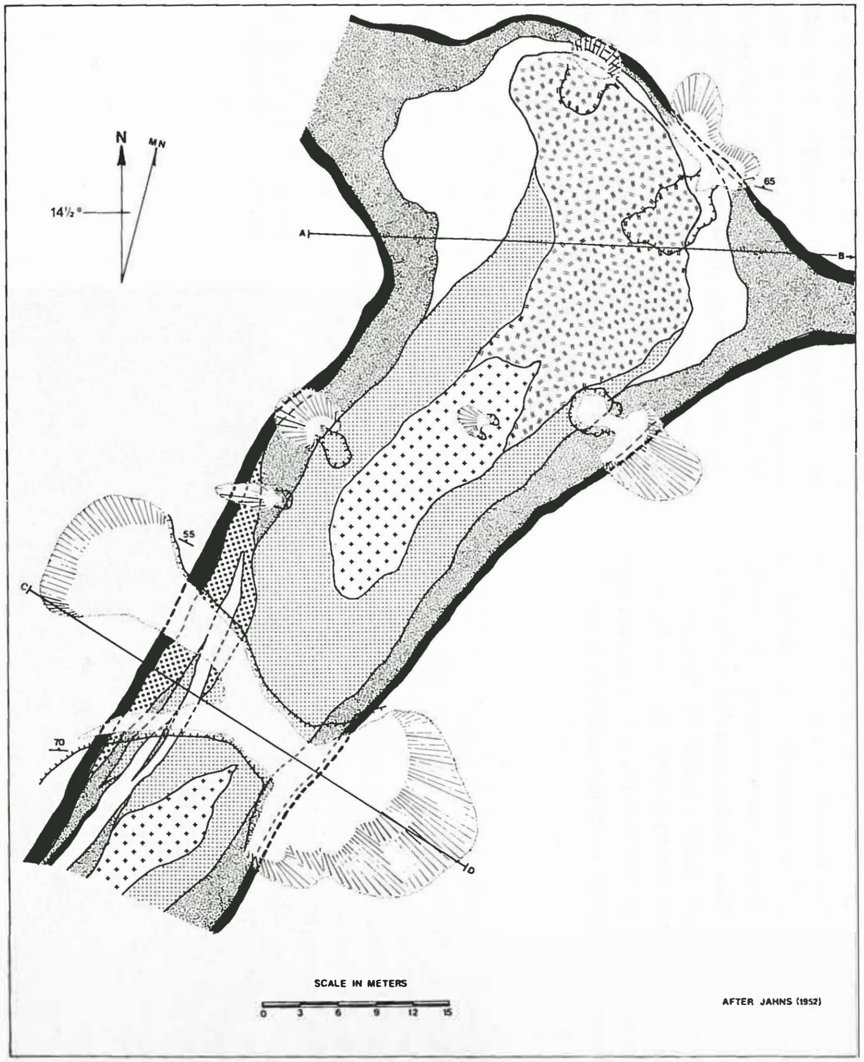

Figure 6. Geologic map of the North Morning Star pegmatite.

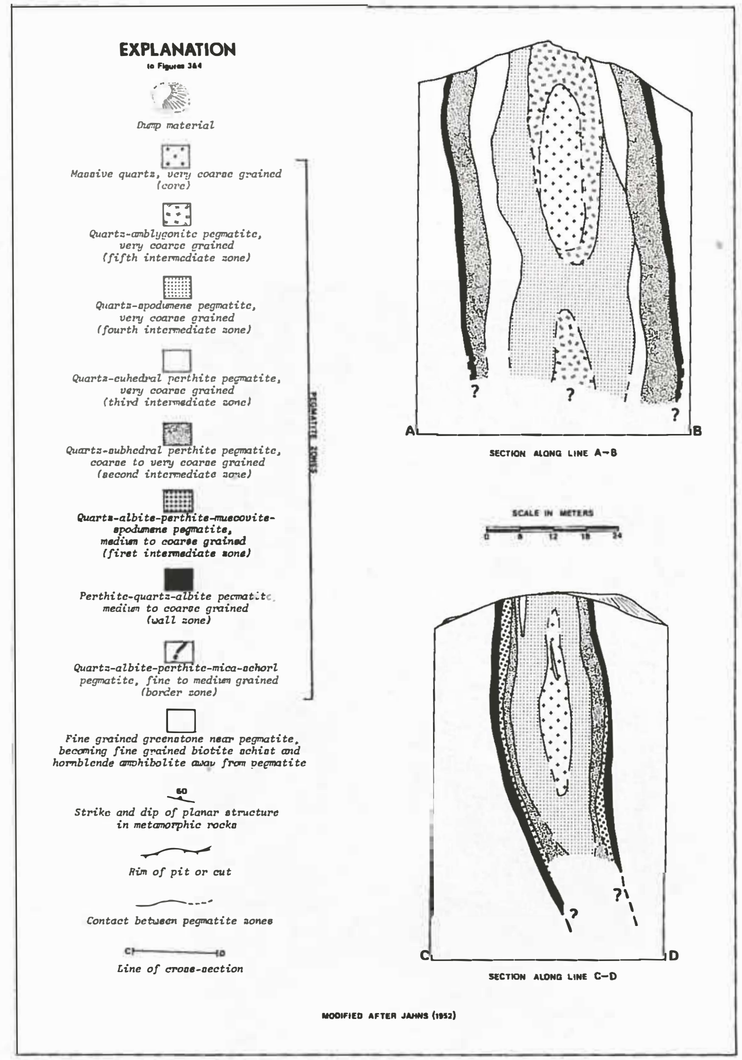

Figure 7. Cross sections through the North Morning Star pegmatite.

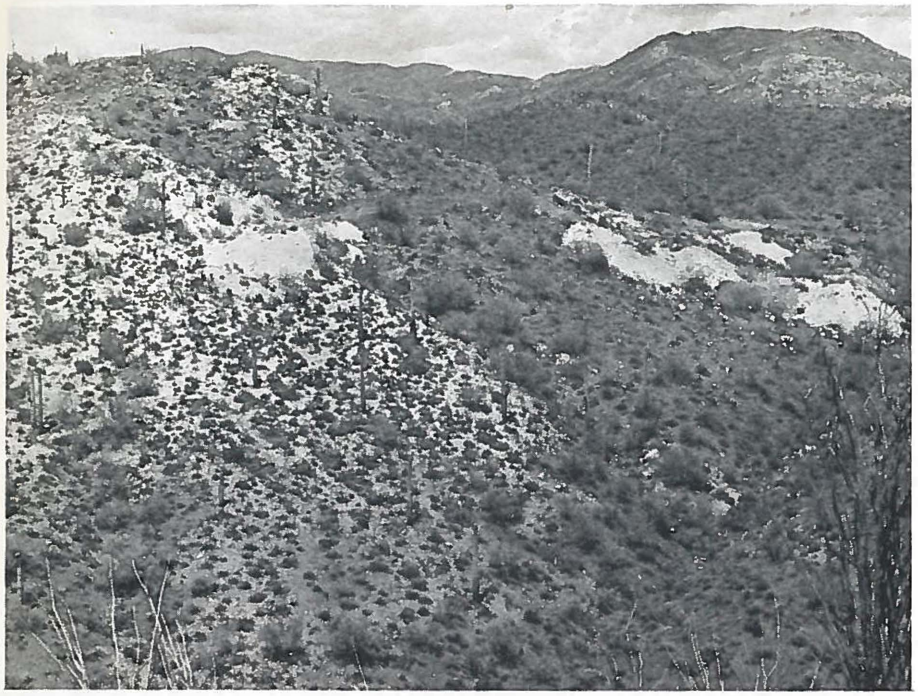

Figure 8. The White Ridge pegmatite, viewed from the south.

zone can be traced into the metamorphic rocks in either direction off the pegmatite's long axis. The absence of deformation or brecciation localized at the pegmatite borders suggests that the North Morning Star was emplaced in a tensional structural environment.

STOP 1b. Follow the path from the North Morning Star pegmatite south to the South Morning Star pegmatite. The South Morning Star is mineralogically similar to the North Morning Star but differs from it in shape. The bulbous, irregular shape of the South Morning Star is characteristic of pegmatites in the district that intrude well-foliated muscovite or chlorite schists. Muscovite schists exposed to the north and west of the South Morning Star are highly folded and crenulated; foliation in these rocks appears to wrap around the pegmatite. Jahns (1952) reports that potassium metasomatism has impregnated the border host rocks with K-feldspar and books of yellowish-green muscovite. Within the district, diffusion and metasomatism of pegmatite materials into country rocks is generally most pronounced in schistose metamorphic rocks; whether or not appreciable amounts of materials from the host rocks have diffused into the pegmatites is not known at this time.

Return to the north end of the North Morning Star; cross the ravine to the west.

STOP 1c. Copper and gold prospect in amphibolite. This hill displays some of the salient geologic features of the region. The unconformable contact of Tertiary volcanics on Precambrian metamorphics can be seen half way up the ridge. Fresh pieces of volcanics and sulfide-rich amphibolite are visible on the main (eastern) dump. Also in the dump are chunks of altered amphibolite breccia, indicating the presence of a fault zone (in or near the ravine). Brecciation probably facilitated the formation of enriched copper minerals, such as bornite and malachite; malachite-stained breccia and amphibolite occur on the small stockpile to the north of the main prospect. BE CAREFUL AROUND PROSPECT PITS AND SHAFTS. There are numerous copper prospects and mines throughout the region; the Abe Lincoln and Constellation Mines are among the largest. Pyrite, however, is by far the most abundant sulfide; its uniform, widespread distribution through the amphibolite suggests that it has a primary volcanic origin.

Return to the North Morning Star, and take the path back to the cars. Proceed up San Domingo Wash 1.3 mi. to **STOP 2.** You will pass the old mica mill and homestead of the Anderson brothers on the left.

STOP 2. Park in the wash, and proceed up the path to the left (northwest) to **STOP 2a.** Along the path are rather poor exposures of breccia zones, altered diabase dikes, and sheared greenstones and schists. This is part of a major fault zone that extends from the upper reaches of Mitchell Wash southeast across most of the Red Picacho quadrangle. The fault is easily traced on air photos for about 8 km; apparent sinistral offset of almost a kilometer can be observed in steeply-dipping metamorphic rocks in the southeast portion of the fault zone.

STOP 2a. White Ridge lithium pegmatite (fig. 8). WATCH FOR WASPS IN THE ADIT! The White Ridge consists of several large, irregular pegmatite dikes and pods. Jahns (1952) does not report lithium minerals from the White

Figure 9. View looking southwest down Mitchell Wash Canyon.

Ridge, but subsequent development work revealed a zone of fresh, very coarse to giant-textured spodumene-quartz-albite pegmatite. Traces of lithium phosphates have also been seen in the dumps and in the eastern pegmatite cuts. Note the pink weathering of the otherwise fresh white spodumene. The White Ridge was not mapped by Jahns (1952), and a detailed description of its zoning is not yet available.

Return to the path leading into Mitchell Wash. Once in the wash, head southwest into Mitchell Wash Canyon (fig 9).

STOP 2b. A prominent shear zone is well-exposed where the wash first jogs from southwest to west. The wash is clearly controlled by lithology, attitude of layering and foliation, and sheared fault zones throughout its length. Small, irregular pegmatite pods and stringers are ubiquitous in the wash exposures. Most pegmatites are composed of perthite-quartz-(spodumene)-schorl; the schorl is noticeably concentrated along pegmatite borders and occasionally permeates the host rock up to about 10 cm from the contact.

STOP 2c. Lower Jumbo lithium pegmatite. The Lower Jumbo (figs. 10 and 11) consists of two large pegmatite bulges; the large bulge exposed in Mitchell Wash contains a core zone of giant spodumene crystals up to about 2 m in

Figure 10. The Lower Jumbo pegmatite viewed from above.

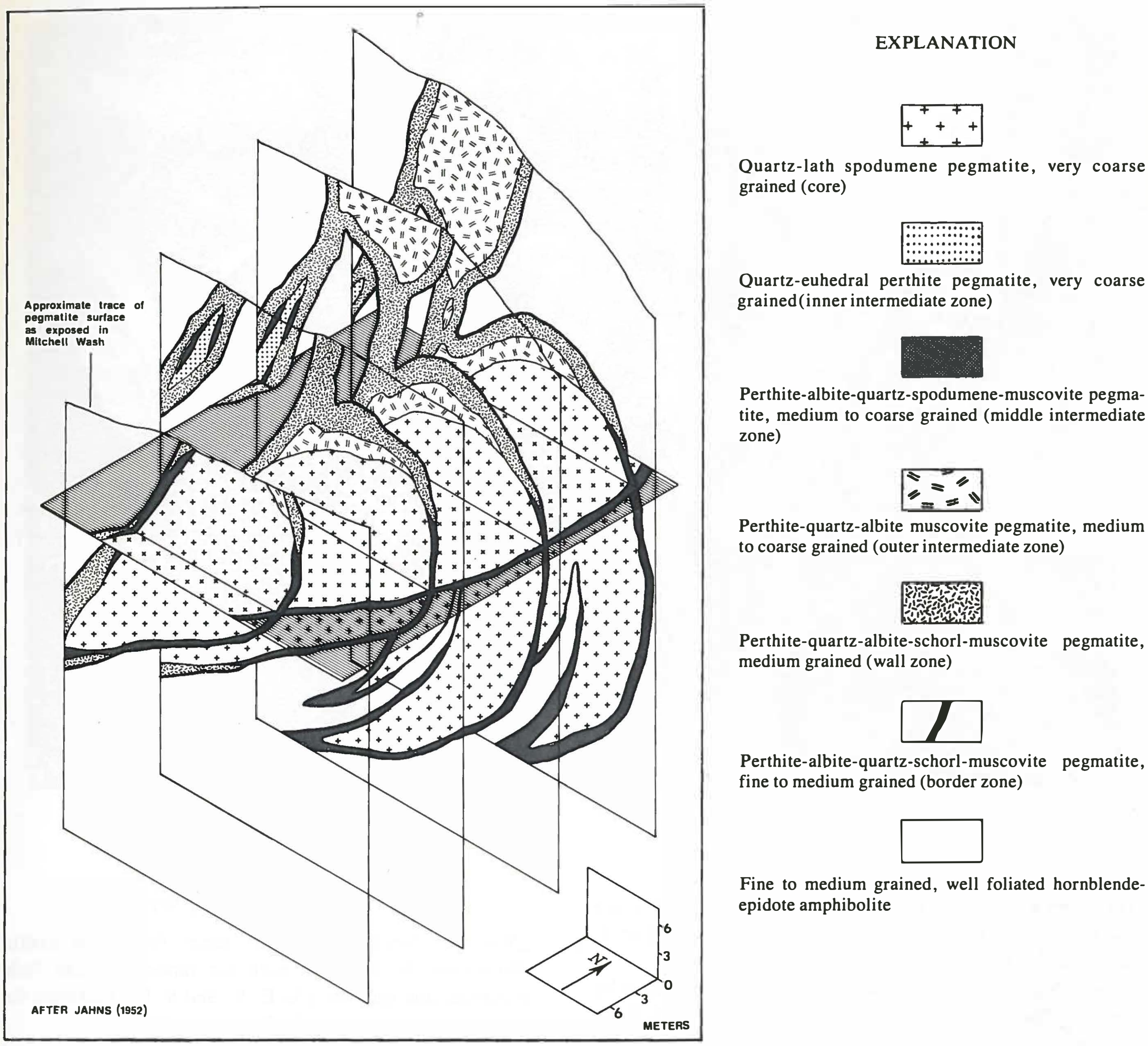

Figure 11. Isometric plate diagram of the Lower Jumbo pegmatite.

length enclosed in anhedral quartz. Note the diverse "jackstraw" orientation of the spodumene lathes.

Continue down the wash to **STOP 2d.**

STOP 2d. A portion of the wash in which tourmaline metasomatism of the host rocks is particularly well-developed. Even thin pegmatites have relatively thick border zones of almost pure schorl (fig. 12); tourmalinization of host rocks can also be observed in many outcrops. Pegmatite stringers anastomose through the host rocks and appear as stockworks following pre-existing joint patterns in the metamorphic rocks (Jahns, 1952).

Retrace the path to the north end of Mitchell Wash Canyon.

OPTIONAL STOPS

OPTION 1. Hike up Mitchell Wash and up a trail to the left to the Sunrise pegmatite (a zoned lithium pegmatite similiar to the North Morning Star, and mislabelled "Picacho View" on the Red Picacho 7.5′ topographic map). The Picacho View pegmatite (a large zoned non-lithium pegmatite) is not shown on the topographic map, but is visible from the Sunrise about 1 km to the northeast, across Mitchell Wash. It can also be visited.

Figure 12. Tourmalinization of host rocks along pegmatite contact, Mitchell Wash Canyon.

OPTION 2. Return to Phoenix via State Highway 74 to see the Pike's Peak Precambrian iron formations (Field Trip 4, this guidebook).

In either case, return to the Castle Hot Springs Road by retracing the trip route. Turn around in San Domingo Wash and proceed down the wash for 4.8 miles; take the improved dirt road to the left (the Old Stage Road).

ACKNOWLEDGEMENTS

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