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Supplemental road log 1, from Lordsburg to Redrock to Ash Creek in the northern Burro Mountains, New Mexico

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SUPPLEMENTAL ROAD LOG 1, FROM LORDSBURG TO REDROCK TO ASH CREEK AND JACK CREEK IN THE NORTHERN BURRO MOUNTAINS, NEW MEXICO

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WEDNESDAY (PRE-MEETING), OCTOBER 18, 2000

Assembly point: Departure time: Distance: Stops: Holiday Inn Express, Lordsburg. 7:30 a.m. 65.9 mi 3; with 3 foot-log stops.

SUMMARY

The Redrock area in the northern Burro Mountains in southwestern New Mexico (Fig. S.1.1) is a complex Proterozoic terrain consisting of metamorphic rocks (Bullard Peak and Ash Creek Series) intruded by a variety of granitic rocks (Hewitt, 1959; Hedlund, 1980; McLemore et al., this volume, p. 117). The purpose of this trip is to acquaint visitors with the complexity of the Proterozoic granitic rocks. Stops 1 and 2 are on the Redrock Wildlife Refuge; permission must be obtained from the New





FIGURE S.1.1. Generalized geologic map of the Proterozoic rocks in the Burro Mountains. Geology complied from Drewes et al. (1985).



Mexico Game and Fish Department to enter refuge. At Stop 1, we will examine the relationships between anorthosite xenoliths, metamorphic xenoliths, and miarolitic biotite granite [Redrock granite (informal name)]. Approximately 50 small anorthosite xenoliths are scattered in a northeast-trending zone throughout the miarolitic biotite granite phase of the Redrock granite (Hewitt, 1959; Hedlund, 1980). No other Proterozoic anorthosite occurrences have been reported from New Mexico and they are, in general, quite rare throughout the United States.

At Stop 2, we will have lunch and examine an intrusive contact between the Redrock granite (hornblende-granite phase) and Jack Creek rapakivi granite (informal name). Rapakivi is Finnish for rotten or crumbly rock and describes the tendency of the rapakivi granite found throughout the eastern portion of the game refuge to weather easily. The rapakivi texture refers to the mantling of K-feldspar phenocrysts by plagioclase (Haapala and Rämö, 1990). Most rapakivi granites are middle–early Proterozoic, although rapakivi textures have been described from some Phanerozoic and Archean granites (Murakami and Imaoka, 1985; Sibiya, 1988). The petrogenesis of rapakivi granites is controversial and questions remain as to the source of the rapakivi magma, the genetic relationships between the granite and penecontemporaneous mafic rocks, the origin of the rapakivi texture, and the tectonic setting of these rocks (see Rämö and Haapala, 1995, for a review).

At Stop 3 we will examine possible coeval enclaves and synplutonic dikes of lamprophyre (minette) found associated with the Jack Creek rapakivi granite. The relationship and petrogenesis of spatial and temporal association between the rapakivi granite and minette remains unknown. Spatial and temporal association of rapakivi granite and lamprophyre is rare in the world. Mileage

- 0.0 Holiday Inn Express. **Proceed north** on Main Street (NM-494), under I-10 overpass. **0.7**
- 0.7 Intersection with Motel Drive. Proceed to center lane and turn left, under the railroad overpass to US-70. 0.1

Turn right at stop sign onto US-70. 2.0

- 2.8Junction with US-90, continue on US-70. Burro Mountains on skyline to right and Peloncillo Mountains on skyline to left. US-90 cuts through the middle Burro Mountains and passes the Tyrone porphyry-copper mine operated by Phelps Dodge Corporation. The Tyrone porphyry-copper deposit in the Burro Mountains district occurs within a quartz-monzonite laccolith and adjacent Proterozoic rocks. The age of the Tyrone stock is 54.5 ± 0.5 Ma (unpublished data, Phelps Dodge Corporation). The ore contains minor amounts of gold and silver, especially in the enriched zones. At least three cycles of supergene enrichment have concentrated the ore (DuHamel et al., 1995). Approximately 300 million short tons (st) of ore grading 0.81% Cu were processed at the concentrator from 1969 to 1992. Approximately 425 million st of ore grading 0.35% Cu have been leached. Gold and silver were recovered only from the concentrate. In 1998, leaching reserves (recoverable copper) were estimated as 466.3 million st of ore grading 0.32% copper. 1.7
- 4.5 Junction with NM-464 (Redrock Road). Turn right onto NM-464 (north). The Burro Mountains were named a long time ago because the mountain range is identified on Juan Nentwig's 1762 map (Julyan, 1996). The mountains consist of mostly Proterozoic granite, gneiss, schist, quartzite, and amphibolite that are unconformably overlain locally by Cretaceous Beartooth Quartzite and Colorado Shale, and mid-Tertiary volcanic rocks; Laramide and mid-Tertiary plutons, dikes, and plugs have locally intruded the older rocks. The Peloncillo Mountains may be derived from the Spanish *peloncillo* meaning "little baldy" or from the Spanish piloncillo meaning "sugar lump" or conical pieces of unrefined sugar (Julyan, 1996); the mountain range certainly resembles either term. Mid-Tertiary volcanic rocks make up most of the Peloncillo Mountains, but Cretaceous and Proterozoic granite and Paleozoic sedimentary rocks are exposed in northwest-trending fault blocks in the central portion of the mountain range (Armstrong et al., 1978; Drewes and Thorman, 1980; McIntyre, 1988). The route crosses a prominent bajada formed by coalescing alluvial fans derived from the Burro Mountains (Clemons et al., 1980). 14.3
- 18.8 Grant-Hidalgo County line. Steeple Rock and Summit Mountains are at 11:00, northern Burro Mountains at 11:30–1:30. The Summit Mountains consist of a complex of andesitic and rhyolitic volcanic rocks of mid-Tertiary age (McLemore, 1993; McLemore, this vol-

ume, p. 51; McLemore et al., this volume, p. 127). Canador Peak and Black Mountains at 10:00. Mogollon Mountains in far northern skyline behind the Burro Mountains. **2.6**

- 21.4 Redrock Road CMR (dirt) to Tyrone on right (past MP-16), keep straight. 0.5
- 21.9 Descend into Redrock subbasin of the Gila River valley. Dissected hills at 12:00 are in ancestral Gila River deposits, which are also exposed in road cuts ahead.3.0
- 24.9 Sharp bend in road to right. 0.6
- 25.5 NM-464 turns into a gravel road at MP-21. 0.5
- 26.0 Cross cattle guard and pass Redrock General Store on left. A U.S. Post Office operated in 1896–1968 (Julyan, 1996). There is some confusion as to whether the name is spelled as two words, Red Rock, or one word, Redrock; the Geographic Names Information System uses one word, but many maps and local signs use two words (Julyan, 1996).
- 26.1 Road cut in poorly sorted, consolidated Miocene-Pliocene Gila Group. 0.1
- 26.2 Road junction. **Turn left**, cross bridge over Gila River. **0.2**
- 26.4 Road junction. **Turn right** onto Game Department Road CMR. **0.6**
- 27.0 Road junction, keep right. 0.7
- 27.7 Road junction, keep left. Cross over cattle guard. Sign to Redrock Wildlife Refuge, New Mexico Department of Game and Fish, "No hunting, no dogs allowed." The Redrock Wildlife Refuge was established about 1963 for exotic animals. Oryx, ibex, Barbary sheep, and gazelle were first raised here in the 1960s. In the 1970s, the exotic animals were removed and Bighorn sheep were raised on the refuge. Today, approximately 65 sheep roam the rugged refuge (Fig. S.1.2). Other animals inhabit the area as well, including javelina, coyote, mountain lion, mule deer, coatimundi, and a variety of birds. 0.3
- 28.0 Road junction to game warden's residence. Stay on main road. The game warden's residence was a private hunting lodge in the 1950s. Clark Peak at 1:00 on the skyline with Lydian Peak in front. Clark Peak consists of mid-Tertiary ash-flow tuffs and volcanic andesitic



FIGURE S.1.2. Bighorn sheep on eastern slopes of Lydian Peak.

megabreccias associated with the Schoolhouse Mountain caldera (Finnell, 1987; W. C. McIntosh, personal commun., October 1999). Lydian Peak consists of Proterozoic quartzofeldspathic schist (mapped incorrectly as granulite by Hedlund, 1980). A Proterozoic diabase intrusion forms the western slopes and Jack Creek rapakivi granite forms the eastern slopes. Cliffs at 12:00 are Gila Group. **1.5**

29.5 Road junction, keep left. Cross Smith Creek. 0.5

- 30.0 Road junction. Turn left. Sign: "Shikar-Safari International Club Conservation Project, Redrock Pasture." The Shikar-Safari International Club donated money to build fences for the Redrock Wildlife Refuge. Lydian Peak at 12:00. 0.7
- 30.7 Locked gate into pasture. Must have permission from the New Mexico Department of Game and Fish to proceed any farther. A four-wheel-drive vehicle may be needed. Lydian Peak is at 1:00. Gila Box at 3:00. Great Eagle fluorite mine is at the mouth of Gila Box. A. B Conner discovered the deposit in 1911 and produced fluorite until 1914 (Hewitt, 1959). A mill was erected about 1919 by the Great Eagle Mining Co. but was closed soon after because it was not able to treat the siliceous ore. Several owners operated the mine until the early 1980s, when it finally closed (McAnulty, 1978). Total production from 1911 to 1978 is 15,215 st (McAnulty, 1978). Fluorite occurs in irregular veins and breccia cement in a fault zone in Jack Creek rapakivi granite with quartz, iron oxides, pyrite, malachite, clay, and calcite. 0.4
- 31.1 Road junction. Turn right along slope of Lydian Peak. White scar at head of Smith Canyon at 10:00 is a magnesite prospect. The small lenticular deposit occurs along the fault between Proterozoic rocks and Gila Group and consists of magnesite, quartz, calcite, and dolomite. Magnesite is a source of magnesium, which is used as a refractory and a variety of other uses, including antacid. This deposit probably represents mid-Tertiary hydrothermal alteration of metamorphic serpentine-carbonate xenoliths, although a Paleozoic age of the sediments is possible (Hewitt, 1959). Cross fault between metamorphic schists and Gila Group. 0.4
- 31.5 Cross contact between quartzofeldspathic schist and Jacks Creek rapakivi granite. **0.1**
- 31.6 Road junction. Keep left. Water guzzler on right to provide water for wildlife. 0.2
- 31.8 Road junction, turn right. Cliffs at 12:00 are Jack Creek rapakivi granite. 0.1
- 31.9 Road junction at gate, turn left. Leave gates as you find them. 0.6
- 32.5 Gate and water guzzler. 0.1
- 32.6 Road junction at gate, keep right. 0.1
- 32.7 Cross contact between Redrock granite and Jack Creek rapakivi granite. Pegmatite dikes intrude the rapakivi granite and parallel the contact. 0.1
- 32.8 Road junction, keep right. Diabase dikes intruding rapakivi granite at 11:00. 0.1
- 32.9 Road junction, keep right. Clark Peak at 12:00. 0.1
- 33.0 Go through gate. Road in gabbro/diorite and metamorphic rocks. 0.1
- 33.1 Road cut in banded green and white serpentine vein cutting metamorphic rocks. 0.2

33.3 STOP 1-Ash Creek and Smith Mountain. Diabase and metamorphic rocks form the south side of the canyon and the Redrock granite forms the north side (Fig. S.1.3). The contact is exposed farther downstream in the canyon. The Redrock granite consists of four phases, including miarolitic biotite granite, K-feldspar granite, hornblende granite, and biotite-hornblende granite. Although these granites are texturally and mineralogically distinct, they have similar chemical compositions and are interpreted as a single, zoned pluton (McLemore et al., Redrock area, this road log. The miarolitic biotite granite is orange-pink and fine-medium grained. It contains miarolitic cavities that are nearly circular-elliptical in shape and range from <1 in. to 7 in. in diameter (Fig. S.1.4). Selected chemical analyses of samples from the Smith Mountain area are in Table S.1.1. Metamorphic and anorthosite/leucogabbro xenoliths are common in the miarolitic biotite granite. Small lenses and dikes of white-light pinkish-gray, fine-grained K-feldspar granite occur within the



FIGURE S.1.3. Geologic map of part of Smith Mountain and Jack Creek, Stops S.1.1–3.

TABLE S.1.1. Chemical analyses of miarolitic biotite granite and anorthosite from \$mith Mountain area, near Stop 3A.

SAMPLE	RED 3 ¹	RED 5 ²	RED 4 ³	RED 7 ³	RED 15 ³	RED 2 ³
SiO ₂	77.03	60.51	51.36	49.25	50.18	50.89
TiO ₂	0.11	1.43	0.19	1.36	0.51	0.45
Al_2O_3	12.57	13.66	29.10	22.10	24.76	26.71
Fe ₂ O ₃ T	0.74	8.09	1.12	7.22	4.94	2.60
MgŐ	0.16	2.55	0.30	2.02	1.71	0.77
CaO	0.25	10.71	12.11	9.92	9.56	9.42
Na ₂ O	2.79	0.74	4.08	3.78	3.66	3.74
K ₂ O	5.91	0.28	0.58	1.48	2.10	2.72
MnO	0.01	0.09	0.01	0.11	0.07	0.04
P_2O_5	0.03	0.49	0.03	0.34	0.11	0.09
LOI	0.55	2.42	1.16	2.16	2.89	3.04
TOTAL	100.15	100.97	100.04	99.74	100.49	100.47
As	<1	1	<1	1	<1	<1
Ga	18	27	18	21	20	18
Zn	10	65	13	68	48	37
Cu	<1	<1	<1	8	4	4
Mo	<1	<1	<1	<1	<1	<1
Ni	2	4	5	13	20	8
Ba	290	102	108	319	326	399
V	4	<2	12	73	48	32
Cr	<1	<1	8	18	31	13
Pb	11	65	3	33	5	10
Th	40	17	<1	4	<1	<1
Rb	296	7	32	115	220	257
U	6	8	<1	1	<1	<1
Sr	51	400	551	490	430	472
Y	55	166	2	20	11	8
Zr	152	306	10	67	31	29
Nb	21	37	<1	<1	<1	<1

Lithology: ¹miarolitic granite; ²altered miarolitic granite; ³anorthosite

miarolitic biotite granite. The coarse-grained hornblende granite is orange-red-brown and consists of plagioclase, K-feldspar, quartz, and hornblende; biotite is generally absent. Xenoliths are rare. The medium-coarse-grained biotite-hornblende granite is orange-red-brown and consists of plagioclase, Kfeldspar, quartz, biotite, and locally, hornblende. The biotite-hornblende granite grades into the hornblende granite (Fig. S.1.5). Xenoliths are rare. We will examine only the miarolitic biotite granite at this stop. The hornblende granite forms the top of Smith Mountain. Boulders of the hornblende granite are found in the canyon and we will examine the hornblende and biotitehornblende granite at Stop 2. The K-feldspar granite is exposed along Smith Mountain to the west of this stop



FIGURE S.1.5. Hornblende granite (Redrock granite).



FIGURE S.1.4. Miarolitic cavities in miarolitic biotite granite (Redrock granite).

(McLemore et al., Redrock area, this road log).

We will first examine a xenolith of anorthosite in the canyon downstream of the road junction with Ash Canyon. The contacts between the anorthosite and the granite are not exposed in the canyon, but the anorthosite is well exposed. The anorthosites are tan-white-gray, fine-coarse grained with small patches of black and white gabbroic anorthosite (Fig. S.1.6). Euhedral plagioclase crystals vary in size from a few centimeters to 15 cm long. Selected chemical analyses from the Smith Mountain area are in Table S.1.1.

Walk up the road on Smith Mountain several hundred yards to examine the miarolitic biotite granite, finegrained biotite granite dikes, metamorphic xenoliths, and anorthosite xenoliths. At a road cut just before the bend to the right, miarolitic cavities are well exposed in the granite. The miarolitic biotite granite is strongly altered to epidote, quartz, and chlorite along fractures, in thin veins and surrounding the miarolitic cavities. Altered zones are as much as 6 ft wide and controlled by fractures and also form thin veins, less than several millimeters wide. The epidote, quartz, and chlorite alteration has formed greenish-gray aggregates or balls within miarolitic cavities up to 7 in. in diameter. Some of these epidote balls occur alone within the granite surrounded by relatively unaltered granite, whereas other



FIGURE S.1.6. Anorthosite in Ash Creek.

SUPPLEMENTAL ROAD LOG 1



IGURE S.1.7. Contact between Redrock granite (upper part of the photograph) and Jack Creek rapakivi granite.

areas exhibit vertical trains or linear arrays of these balls connected by fractures containing epidote, quartz, and chlorite. Locally coarse-grained K-feldspar phenocrysts form a halo surrounding the balls. Hematite is locally abundant in the veins and cavities. This alteration greisen or tourmaline alteration of granite elsewhere in the world, but with different mineralogy and chemical composition. Continue along the road to examine the contacts between anorthosite xenoliths and the miarolitic biotite granite. Fine-grained biotite dikes and simple quartz-feldspar-muscovite pegmatites locally intrude the miarolitic biotite granite. Return to vehicles and retrace route to gate at 33.0. **0.4**

- 33.7 Go through gate. 0.1
- STOP 2-contact between Redrock granite and Jack 33.8 Creek rapakivi granite (Fig. S.1.3). Lunch. Park vehicles in road and walk up hill to examine diabase dike and the contact between the different granitic rocks. The hornblende granite forms the top of the ridge and grades into the biotite-hornblende granite along the slopes. At the contact between the hornblende granite and the rapakivi granite, the hornblende granite is medium grained and increases in grain size away from the contact (Fig. S.1.7). The rapakivi granite is foliated at the contact. Rapakivi texture is well preserved on weathered outcrops (Fig. S.1.8). Simple, quartzfeldspar-muscovite pegmatite dikes intruded the rapakivi granite parallel to the contact between the rapakivi granite and hornblende granite. Pegmatite dikes are typically rare in the rapakivi granite. Collectively, these field relationships suggest that the Redrock granite is the younger granite. 0.2
- 34.0 Cross contact between Redrock granite and Jack Creek rapakivi granite. 0.1
- 34.1 Gate, continue straight. 0.3
- 34.4 Road junction, keep right. 0.3
- 34.7 Road junction at gate, turn left. 0.2
- 34.9 STOP 3—Gate. Park and walk through gate to Jack Creek for approximately 0.6-mi foot tour (Fig. S.1.3). STOP 3A—outcrop of a metamorphic xenolith. The xenolith is gray and consists of quartz, biotite, plagioclase, and K-feldspar. It was most likely once a sedimentary rock. Note the sheared contact between the rapakivi granite and the xenolith.



FIGURE S.1.8. Rapakivi texture in Jack Creek rapakivi granite.

Continue up Jack Creek to **STOP 3B**, outcrops of rapakivi granite and K-rich lamprophyre (minette) pillows. Selected chemical analyses are in Table S.1.2. Most minette inclusions are rounded and ovoid in shape; cross sections are typically ellipsoidal (Fig. S.1.9). Locally angular, lenticular, or cigar-shaped minette bodies are found mostly in minette swarms. Minette occurs as isolated enclaves, swarms of enclaves, and synplutonic dikes in the Jack Creek rapakivi granite. At Stop 3B, a swarm of enclaves is exposed; isolated minette pillows are found in the rapakivi granite throughout the Jack Creek area. The minette is dark gray, fine-medium grained, and porphyritic with dark mica and, presumably, pyroxene phe-

TABLE S.1.2. Chemical analyses of rapakivi granite, lamprophyre, and syenite from Jack Creek area, near Stop 3B and C.

SAMPLE	NM 211-98 ¹	NM 210-98 ²	NM216-99 ²	NM219-993
SiO ₂	71.16	57.09	67.86	58.67
TiO ₂	0.34	1.30	0.78	0.44
Al_2O_3	14.00	13.32	13.13	17.81
Fe ₂ O ₃ T	2.21	6.76	4.76	5.05
MgO	1.39	3.88	2.50	1.99
CaO	0.63	4.27	0.96	0.34
Na ₂ O	3.33	1.63	1.66	0.21
K ₂ O	5.61	6.82	6.80	13.40
MnO	0.03	0.11	0.04	0.03
P_2O_5	0.17	0.94	0.63	0.28
LOI	0.97	3.88	1.45	1.73
TOTAL	99.84	100.00	100.57	99.95
As	<1	2	3	4
Ga	18	22	19	15
Zn	33	97	72	33
Cu	<1	20	6	8
Mo	<1	1	<1	<1
Ni	30	119	117	41
Ba	1213	1144	1300	1250
V	35	137	83	54
Cr	54	237	207	100
Pb	48	91	73	5
Th	34	27	22	34
Rb	268	460	365	555
U	5	9	12	6
Sr	377	208	227	28
Y	17	55	23	18
Zr	169	445	297	214
Nb	6	16	7	2
LITHOLOGY	Y: ¹ rapakivi granit	e; ² lamprophyre; ³	syenite	

SUPPLEMENTAL ROAD LOG 1



FIGURE S.1.9. Minette pillows in rapakivi granite.

nocrysts that have been altered into fine-grained amphibole. The main constituents in the groundmass are Kfeldspar, dark mica, and amphibole. The enclaves are distinctly finer in grain size then the enclosing granite. The crenulate to cuspate margins of many of the enclaves show evidence for intensive mingling with the rapakivi granite host (Fig. S.1.10); quartz and Kfeldspar megacrysts have been mechanically incorporated into the lamprophyre and quartz xenocrysts are often mantled by amphibole. Hybrid pillows are common within swarms of enclaves. The hybrid varieties are lighter in color and have incorporated large Kfeldspar and quartz phenocrysts that are embayed, corroded, and commonly surrounded by biotite or hornblende. Gradational boundaries are common, although locally the margins are finer grained indicating a chilled margin.

STOP 3C—continue up Jack Creek to examine brick red, metasomatic syenite plug in rapakivi granite. The metasomatic syenite consists of K-feldspar, biotite, and plagioclase; quartz is absent. It exhibits similar coarse-grained texture as the enclosing rapakivi granite. The syenite contains 13.40% K₂O and 0.21% Na₂O (Table S.1.2) and is grossly similar in composition and occurrence to metasomatic and intrusive syenites that are characteristic of Cambro–Ordovician alkaline magmatism in New Mexico (McLemore and McKee, 1988; McLemore et al., 1999a; McMillan et al., this volume). Retrace route along Jack Creek to vehicles. **Turn vehicles around and follow road to Lydian Peak and return to Lordsburg**. **0.3**

35.2 Road junction, keep right through gate. 0.1

35.3 Road junction, turn left. 0.3



FIGURE S.1.10. Comingling textures along the edges of a minette pillow in Jack Creek rapakivi granite.

- 35.6 Road junction at water guzzler, keep right. 0.4
- 36.0 Road junction at fence corner, turn left. Cross fault between metamorphic schist and Pleistocene fan deposits (Hedlund, 1980). 0.8
- 36.8 Locked gate, continue straight. 0.3
- 37.1 Road junction, keep right. 0.1
- 37.2 Road junction, **continue right** onto main graded road. **0.4**
- 37.6 Cross Smith Creek, **continue to right** at bend in road. **1.5**
- 39.1 Turn-off to game warden's residence, continue straight.1.6
- 40.7 Road junction, **turn left**. Cross bridge at Gila River. **0.3**
- 41.0 Road junction, turn right. 0.2
- 41.2 Redrock General Store. 0.1
- 41.3 Paved road, continue straight. 3.6
- 44.9 Climb to top of Lordsburg Mesa. 2.1
- 47.0 Grant-Hidalgo County line. Lone Mountain at 1:00. 14.3
- 61.3 Road junction, **turn left** onto US-70. Mountains at 12:00 are Pyramid Mountains, south of Lordsburg (see First-day Road Log, this volume). **1.3**
- 62.6 Junction with US-90, continue straight on US-70. 1.2
- 63.8 Lordsburg City limit. 1.1
- 64.9 Proceed under the railroad overpass to loop road to Motel Drive. Continue east on Motel Drive to Main Street. **0.2**
- 65.1 Road junction, turn right onto Main Street. 0.6
- 65.7 I-10 overpass, continue on Main Street. 0.2
- 65.9 Holiday Inn Express on left.
 - End of Supplemental Road Log 1 (pre-meeting).