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TO ACCOMPANY MAP I-2201

GEOLOGIC MAP OF BARE MOUNTAIN, NYE COUNTY, NEVADA

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GEOLOGIC HISTORY

Bare Mountain comprises the isolated complex of mountain peaks southeast of the town of Beatty in southern Nye County, Nevada. This small mountain range lies between the alluvial basins of Crater Flat to the east and the northern Amargosa Desert to the southwest (fig. 1; see map). The northern boundary of the range is less well defined, but for this report, the terrane of faulted Miocene volcanic rocks underlying Beatty Mountain and the unnamed hills to the east are considered to be the northernmost part of Bare Mountain. The southern tip of the mountain range is at Black Marble, the isolated hill at the southeast corner of the map. The main body of the range, between Fluorspar Canyon and Black Marble, is a folded and complexly faulted, but generally northward-dipping (or southward-dipping and northward-overturned), sequence of weakly to moderately metamorphosed upper Proterozoic and Paleozoic marine strata, mostly miogeoclinal (continental shelf) rocks. The geology of Bare Mountain was mapped previously at a scale of 1:62,500 by Cornwall and Kleinhampl (1961). The surficial deposits surrounding Bare Mountain were mapped at a scale of 1:48,000 by Swadley and Parrish (1988).

The marine strata at Bare Mountain form a remarkably complete section representing Late Proterozoic through Mississippian time. The upper Proterozoic and Lower Cambrian rocks are mostly argillite, siltite, quartzite, and sparse but conspicuous dolomite beds; they are part of the westward-thickening wedge of siliceous clastic rocks forming the lower part of the Cordilleran miogeoclinal (continental shelf) succession, previously described by many authors (for example, Stewart, 1970; Stewart and Poole, 1974). Middle Cambrian through Devonian time is represented mainly by continental shelf carbonate rocks, which also are part of the Cordilleran miogeoclinal succession and described in many reports (for example, Stewart and Poole, 1974). The Mississippian rocks are mostly argillite and quartzite, which Poole (1974) interpreted as flysch deposited in the foreland basin of the Antler orogenic belt. Neither Pennsylvanian nor Permian rocks are exposed at Bare Mountain.

Metamorphism of the upper Proterozoic and Paleozoic rocks ranges from greenschist to low amphibolite grade and is a product of thermal events that, at least in part, accompanied Mesozoic deformation. The ages of these events are not precisely known (Monsen, 1983). Low amphibolite- to high greenschist-grade rocks containing staurolite- and garnet-bearing mineral assemblages are present in the northwestern part of the range (Conejo Canyon area), but rapidly give way southward and eastward to medium and low greenschist-grade, biotite- and (or) chlorite-bearing rocks (Monsen, 1983). Large-scale folding (amplitudes as large as several kilometers) and thrust faulting deformed and repeated sections of the originally flat-lying miogeoclinal rocks in one or more of the orogenic events that affected the Cordillera during the Mesozoic. Outcrop-scale folds, as well as both penetrative and spaced cleavages, are present locally in the pre-Tertiary rocks throughout the range, but prevail in the highest grade metamorphic rocks and the upper Proterozoic and Lower Cambrian units containing interbedded argillite and quartzite. These ductile structures also were interpreted as Mesozoic by Monsen (1983). Late Cretaceous (fig. 2 and table 1) granitic rocks crop out near the mouth of Fluorspar Canyon and are presumed to intrude the metasedimentary sequence. The granitic rocks are not penetratively deformed, suggesting that ductile deformation of the metasedimentary rocks largely had ceased and the peak of metamorphism had passed by the time of their intrusion. A gap in the geologic record at Bare Mountain is noted between the intrusive event represented by these granitic rocks and the oldest documented Tertiary event, the intrusion of east-northeast-striking diorite dikes isotopically dated as approximately 26 Ma (table 2). Whereas the Late Cretaceous granitic rocks only are inferred to post-date ductile deformation and metamorphism at Bare Mountain, the late Oligocene dikes unequivocally cut the ductile structures and metamorphic fabrics.

The oldest Tertiary basin deposits near Bare Mountain belong to the Oligocene and Miocene(?) Titus Canyon Formation of Reynolds (1969, 1974), which is unconformable on upper Proterozoic and Paleozoic rocks along the east flanks of the Funeral and Grapevine Mountains (20 km west of Bare Mountain) but is not exposed at Bare Mountain. There is no stratigraphic record of extensional tectonism older than Oligocene in the region, and the exposure of upper Proterozoic rocks at the pre-Oligocene land surface indicates that substantial uplift and denudation of Proterozoic and Paleozoic bedrock units resulted from Mesozoic orogenesis, as well as pre-Oligocene isostatic uplift and denudation (Reynolds, 1974). Consequently, significant unroofing of the deformed, high-grade metamorphic rocks in the region that includes Bare Mountain must have predated the additional unroofing and exposure of such rocks that resulted from Cenozoic extension. Metamorphic micas from the Wood Canyon Formation in the northwestern part of Bare Mountain yield reset conventional potassium-argon ages ranging from 44 to 51 Ma (table 2). It is not yet known whether these isotopic systems finally reached their blocking conditions during the Eocene as a result of protracted cooling, whether the isotopic ages indicate an abrupt onset of extensional tectonism in the Eocene, or whether the ages result from some disturbance of the isotopic system and are meaningless in terms of a tectonic interpretation.

The oldest Tertiary rocks exposed at Bare Mountain are a succession of lacustrine siltstone, crystal tuff, and conglomerate in Joshua Hollow. These rocks may correlate with an unnamed sequence of Miocene tuff and sedimentary rocks described by Reynolds (1969, p. 124, 1974) that disconformably overlies the Titus Canyon Formation in the Funeral and Grapevine Mountains. The crystal tuff and sedimentary rock units in Joshua Hollow are faulted against underlying Paleozoic rocks.

The low hills north of Fluorspar Canyon expose a strongly faulted sequence of middle Miocene ash-flow tuffs containing subordinate silicic lava and basalt flows. The lower part of the section consists of a concordant sequence of ash-flow tuff units that are equivalent to some of the tuff units below the Crater Flat Tuff that were described by Carr and others (1986b), as well as the Crater Flat and Paintbrush Tuffs previously described from extensive exposures in the surrounding area (for example, Byers and others, 1976; Carr and others, 1986b). These tuff units range in age from approximately 15 to 12.8* Ma (Marvin and others, 1970; Carr and others, 1986b). The middle part of the section is a paraconformable succession containing a bedded unit of nonwelded pyroclastic flows, a rhyolitic lava flow, and the Timber Mountain Tuff. The bedded pyroclastic flow unit rests with angular unconformity on the Paintbrush Tuff in the northernmost part of Bare Mountain and on the tilted crystal tuff and sedimentary rocks of Joshua Hollow. The rhyolitic lava flow wedges out from west to east across northernmost Bare Mountain. The two members of the Timber Mountain Tuff were dated isotopically elsewhere in the region at approximately 11.6* and 11.4* Ma (Kistler, 1968; Byers and others, 1976), which places an upper constraint on the age of the unconformity. The Timber Mountain Tuff is overlain by a bimodal sequence of intercalated basalt flows, silicic ash-flow tuff cooling units, and beds of nonwelded, silicic pyroclastic rocks that form the upper part of the middle Miocene section at northernmost Bare Mountain. The lowermost basalt flows (unit 1), isotopically dated at 10.7 Ma (table 2), are conformable on the Timber Mountain Tuff, but at least one angular unconformity is present higher within this bimodal sequence of volcanic rocks.

The upper Miocene and Pliocene gravel of Sober-up Gulch rests with angular unconformity on older Miocene volcanic and sedimentary rocks and on Paleozoic rocks north and northeast of Bare Mountain. The gravel beds retain their original depositional geometry in most places, lying flat or dipping a few degrees toward the basins; their deposition apparently postdated much of the faulting in the immediately subjacent rocks. However, the gravel beds are offset by the northern part of the fault system that follows the east side of Bare Mountain. East of this fault system, the gravel beds tilt gently westward toward the mountain range. Outcrops of the gravel are poor, and although the general attitiude of layering is visible from a distance, reliable bedding measurments were possible only in the dry stream cuts east of the map area.

Upper Pliocene(?) and Quaternary alluvial fan deposits apron Bare Mountain on the southwest and east. These deposits lap over bedrock along the southwestern flank of the mountain range but are faulted against bedrock along the fault system on the east side of the range.

The network of Cenozoic faults that cut Bare Mountain formed during the protracted period of extension that has opened the Great Basin. Diachronous basin-filling episodes and unconformities, as well as crosscutting structural relations throughout the region suggest that extension was accomodated locally by episodic faulting concentrated during different times in different structural domains. Structures formed during an early phase of extension in one structural domain were, in many cases, reactivated during later deformation in that same area.

The earliest documented Tertiary faulting at Bare Mountain occurred along the set of east-dipping faults that dominate the structural pattern of the central part of the range. One such fault, 400 m southeast of the Panama Mine, is cut by a quartz latite dike belonging to a set of dikes radiometrically dated elsewhere at Bare Mountain at 13.9 Ma (table 2; Carr, 1984). Other such faults offset the 13.9-Ma dikes, but separate the dikes less than the country rock. Along the eastern front of Bare Mountain, faults belonging to this set offset latest Pleistocene or Holocene deposits (Reheis, 1988). Gently southeast-dipping normal faults, such as the fault along the south wall of Chuckwalla Canyon, the fault that crosses the range north of Wildcat Peak, and the fault along the north side of Black Marble, cut off, or in other cases curve to join, members of the east-dipping fault set, dividing the central part of Bare Mountain into rhombehedral blocks. There are no constraints on the earliest movement history of the gently southeast-dipping normal faults, except that they cut and therefore postdate, some of the faults of the east-dipping fault set. The gently dipping fault north of Wildcat Peak may cut dikes of the 13.9-Ma dike set, but talus deposits obscure the critical exposures. The gently southeast-dipping fault in Chuckwalla Canyon continues northeastward to join the fault system along the east front of the range, where it recurrently offsets Quaternary deposits (Reheis, 1988). Thus, movement on the main fault network cutting central Bare Mountain has occurred episodically from at least the early middle Miocene to the present. The onset of faulting predated the injection of the north-trending set of quartz latite dikes about 13.9 Ma. These dikes are older than or equivalent in age to all rocks in the northernmost Bare Mountain section except the tuffs underlying the Crater Flat Tuff (Carr and others, 1986b, fig. 2), indicating that the onset of faulting at least predated the eruption of the Crater Flat Tuff.

The zone of gently north- to northeast-dipping faults that crosses Conejo Canyon cuts numerous faults of the east-dipping set and locally cuts out as much as 1400 m of stratigraphic section. The metamorphic grade of the rocks in the hanging wall of the fault zone in Conejo Canyon is higher than that of equivalent rocks in the footwall farther south on Bare Mountian, and it appears that the hanging-wall rocks were derived from north-northwest of their present position. The zone of gently dipping faults in Conejo Canyon offsets elements of the east-dipping fault set and, therefore, formed later than the onset of the movement along the east-dipping faults. The later histories of both sets of faults are at least partly related because of geometric connections among individual members of each of the fault sets.

A gently north-dipping fault in Fluorspar Canyon separates the faulted Miocene volcanic sequence in the hills of northernmost Bare Mountain from the faulted upper Proterozoic and Paleozoic rocks underlying the rest of Bare Mountain. This fault is interpreted as a segment of an areally extensive low-angle fault system at the base of a major extensional allochthon, which continues westward at least as far as the Grapevine Mountains (Carr and Monsen, 1988). This extensional allochthon apparently broke away from the relatively unfaulted terrane of Miocene volcanic rocks northeast of Bare Mountain. A fault pattern dominated by northwest-dipping normal faults characterizes the upper plate of the fault in Fluorspar Canyon and is distinct from the fault pattern in most of Bare Mountain. In the Meiklejohn Peak area, Paleozoic rocks are contained in the upper plate of another segement of the low-angle fault system. The Paleozoic rocks there are cut by a set of northwest-dipping faults geometrically similar to those cutting the Miocene rocks farther west in the upper plate of the fault in Fluorspar Canyon. The fault in Fluorspar Canyon apparently merges eastward with segments of the system of thrust faults, inferred to be Mesozoic, that passes south of Meiklejohn Peak. Parts of that thrust system were reactivated with minor normal displacement during the Tertiary.

The ages of several events in the extensional allochthon above the low-angle fault in Fluorspar Canyon are constrained by unconformities. The oldest known faulting event in the allochthon (at Bare Mountain) is represented by an unconformity at the base of the bedded pyroclastic flows above the Paintbrush Tuff (between approximately 12.8 and 11.6* Ma). Two episodes of faulting, coeval with the deposition of the bimodal sequence of late Miocene volcanic rocks, are indicated by angular unconformities and by stratigraphic overlap of faults by unfaulted younger deposits. One episode began after the eruption of the unnamed late Miocene ash-flow tuff unit that overlies the 10.7-Ma basalt unit 1; the episode ended before the eruption of the basalt unit 2. Another episode followed the eruption of the basalt unit 3 and ended before the deposition of the gravel of Sober-up Gulch during the late Miocene (Carr and Monsen, 1988). No great offsets of the gravel of Sober-up Gulch are observed in the area north of Bare Mountain.

Quaternary deposits are offset by faults along most of the eastern front of Bare Mountain (see also, Swadley and others, 1984; Reheis, 1988) and by the fault along the southeast side of Tates Wash. Deposits of presumed latest Pleistocene or Holocene age are disrupted locally by faulting at the range front (Reheis, 1988). Older alluvial fan deposits (Pliocene and (or) early Pleistocene) are offset, but intermediate alluvial fan deposits (middle and late Pleistocene) do not appear to be cut in a trench exposure of the northwest-dipping fault along the south side of Tates Wash. (The trench has been refilled.) This fault projects northeastward to an intersection with the northernmost surface ruptures on the fault along the east front of Bare Mountain. Quaternary movement on the faults within the range can neither be demonstrated nor dismissed owing to the lack of surficial deposits there.

The west-facing Beatty escarpment, along the west side of Bare Mountain, previously was interpreted as a Quaternary fault scarp (for example, Cornwall and Kleinhampl, 1964). More recent studies, however, have suggested that this escarpment may not be a tectonic feature, but rather an erosional escarpment cut by lateral migration of the Amargosa River into the lower parts of alluvial fans shed from the west side of Bare Mountain (Swadley and others 1988).

Quaternary faulting at and near Bare Mountain may represent the final stages of a waning Miocene extensional regieme as suggested by Carr (1984) and Hamilton (1988), or it may mark the beginning of another episode of activity in the continuing regional extension of the Great Basin. Movement should be expected to continue into the near geologic future on the fault along the eastern front of Bare Mountain and on related faults, judging from their history of recurrent movement during the recent geologic past. The rates of such movement cannot be calculated meaningfully on the basis of currently available information.

* Isotopic ages marked by an asterisk are based on ages reported by Kistler (1968) and Marvin and others (1970) but are corrected for currently accepted decay and abundance constants using tables from Dalrymple (1979). The geologic time scale used throughout this report is that compiled by Palmer (1983).

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Table 1. *Uranium-thorium-lead isotopic data for zircon a granitic intrusion near mouth of Fluorspar Canyon*

[Uranium-thorium-lead analysis and age calculation by R.E. Zartman, U.S. Geological Survey, Denver, Colorado. Samples collected by S.A. Monsen and M.D. Carr, U.S. Geological Survey, Menlo Park, California. Isotopic abundances as decay constants used in this study are those recommended by the IUGS Stratigraphic Commission, Subcommission on Geochronology (Steiger Jäger, 1977). Location of sample 83–90: lat. 36°53'48"N., long. 116°44'12"W.]

Sample	Mesh size	Concentration (parts per million)			Isotopic composition of lead (atom percent)				Age (Ma)			
		U	Th	Pb	^{204}Pb	^{206}Pb	^{207}Pb	^{208}Pb	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{208}Pb/^{232}Th$
83–90	-150+200	593.7	128.0	28.11	.0843	81.82	8.369	9.725	279	435	1379	323
	-250+325	651.2	156.3	18.68	.0196	85.27	6.798	7.909	180	265	1107	194
	-400	673.7	172.9	16.93	.0857	82.64	6.943	10.33	151	207	903	157

Table 2. *Potassium-argon ages for rocks from Bare Mountain area*

[Isotopic abundance and decay constants used in this study are those recommended by the IUGS Stratigraphic Commission, Subcommission on Geochronology (Steiger and Jäger, 1977). K_2O analyzed by L. Espos, P. Klock, S. Neil, and D. Vivit, U.S. Geological Survey, Menlo Park, Calif.]

Sample number	Rock type and unit	General area	Location		Age (Ma)	Mineral	K_2O (weight percent)	$^{40}Ar(rad)$ / $^{40}Ar(total)$	$^{40}Ar_{rad}$ moles/gm	Collected by
			Latitude	Longitude						
JN85BM-2[1]	Quartz latite dike	Joshua Hollow	36°54'	116°39'	13.9±0.1	Biotite	8.45 8.49	0.68	$1.705x10^{-10}$	J.K. Nakata M.D. Carr
JN85BM-3[1]	Quartz latite dike	Tarantula Canyon	36°52'	116°39'	13.8±0.2	Biotite	8.57 8.64	0.58	$1.720x10^{-10}$	J.K. Nakata M.D. Carr
102887-3[1]	Basalt—unit Tb_1	East of Beatty Mountain	36°54'55"	116°41'44"	10.7±0.2	Whole rock	1.79 1.83	0.69	$2.799x10^{-11}$	M.D. Carr
R85-B1B[1]	Ash-fall tuff within gravel of sober-up Gulch	Western Crater Flat (east of map area)	36°53'30"	116°36'30"	8.2±0.4	Biotite	7.95[2] 8.00	0.10	$9.434x10^{-11}$	M.C. Reheis
					8.7±0.2	Feldspar	1.04 1.06	0.55	$1.317x10^{-11}$	
					7.7±0.1	Feldspar (backpicked)	1.07 1.06	0.56	$1.180x10^{-11}$	
83-89[2]	Schist from Wood Canyon Formation	Northwest Bare Mountain	36°52'45"	116°44'51"	51.6±1.3	Muscovite	9.51 9.58	0.71	$7.187x10^{-10}$	S.A. Monsen
					46.0±1.2	Biotite	8.54	0.59	$5.724x10^{-10}$	
JN85B-3[1]	Schist from Wood Canyon Formation	Southeast Bullfrog Hills	36°53'30"	116°45'32"	45.2±0.3	Muscovite–1	9.88 9.86	0.87	$6.503x10^{-10}$	J.K. Nakata
					44.3±0.3	Muscovite–2	do	0.79	$6.372x10^{-10}$	
					48.6±0.3	Biotite–1	9.21 (n=2)	0.90	$6.529x10^{-10}$	
					49.2±0.4	Biotite–2	do	0.80	$6.610x10^{-10}$	
82-489[2]	Diorite dike	Northwest Bare Mountain	36°51'45"	116°44'36"	26.1±1.7	Hornblende	.854 .851	0.28	$3.223x10^{-11}$	S.A. Monsen
					16.6±1.2	Biotite	7.11 7.16	0.29	$1.718x10^{-10}$	

[1] Argon measurements and age calculated by John Nakata, U.S. Geological Survey, Menlo Park, Calif.

[2] Argon measurements and age calculated by James Saburomaru and Jarel Von Esssen, U.S. Geological Survey, Menlo Park, Calif.

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