Text and references to accompany NBMG Map 102

GEOLOGIC HISTORY OF THE HOOVER DAM 7.5' QUADRANGLE

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The Hoover Dam area contains exposures of Precambrian metamorphic rock, Tertiary volcanic and plutonic rock, and Quaternary gravels (table 1). Paleozoic rocks are restricted to roof pendants in Tertiary plutons and xenolithic blocks in mafic lava flows. With rare exception, rocks of the Hoover Dam area have been broken along numerous late Miocene faults with complex slip components and the Mead Slope left-lateral strike-slip fault. Geochemical analyses of igneous rocks in the Hoover Dam area are presented in table 2.

STRATIGRAPHIC UNITS

PRECAMBRIAN

Precambrian gneiss, amphibolite, schist, and pegmatite (p£m) of the Lake Mead area are dated at 1.5 to 1.8 Ga (Volborth, 1973; Condie, 1982). Outcrops of Precambrian rock occur only in the southern map area. These outcrops are commonly intruded by the Wilson Ridge and Paint Pots plutons.

PALEOZOIC / MESOZOIC

After deposition of a thick sequence of Paleozoic and Mesozoic clastic and carbonate rock, a series of north-trending antiforms or arches formed from southern Arizona northward to the Lake Mead area, possibly during the Sevier orogeny (Bohannon, 1984). Formation of these structural highs resulted in erosion of most of the Paleozoic and Mesozoic rock in the Lake Mead area (Bohannon, 1984). Small outcrops of Cambrian(?) shale and limestone (Pzlu) occur as roof pendants in the Paint Pots pluton (Tppc) and are located to the west of Fortification Hill. Rare xenoliths of Paleozoic limestone occur in the Kingman Wash Road basaltic andesite (Tkw).

CENOZOIC

Tertiary

The oldest Tertiary rock in the Hoover Dam area is represented by the Patsy Mine Volcanics, a series of andesite flows and flow breccias that erupted primarily from volcanoes in the Eldorado Mountains south of Hoover Dam 18.5 to about 12 Ma (Anderson, 1971; Darvall and others, 1991). About 2 km south of Hoover Dam, the uppermost andesite flows yield a whole-rock $^{40}Ar/^{39}Ar$ age of 14.19 ± 0.03 Ma (P. Gans and J. Faulds, written commun., 1994)

Tilted lavas of the Patsy Mine Volcanics are unconformably overlain by the Dam conglomerate (Tdc). The Dam conglomerate is the first unit in a series of 11 informal units that make up the local assemblage of clastic rocks and lavas informally referred to here as the Black Canyon assemblage (listed in table 1). Deposition of the Dam conglomerate was interrupted by eruption of the first cooling units of the tuff of Hoover Dam (Thd; Smith, 1984). In some areas, upper beds of the Dam conglomerate are ash-rich and may be gradational with the tuff. In other areas, the contact between the tuff of Hoover Dam and Dam conglomerate is sharp. The base of the tuff of Hoover Dam has an $^{40}Ar/^{39}Ar$ biotite age of 13.9 ± 0.1 Ma (P. Gans and J. Faulds, written commun., 1994).

The highly eroded surface of the tuff of Hoover Dam Is unconformably overlain by two units; a dacitic breccia and a separate andesitic flow breccia (both mapped as Tbr) and the Spillway conglomerate (Tsc). These units are restricted to outcrops at Hoover Dam. The Switchyard basaltic andesite (Tsb) conformably overlies the Spillway conglomerate and breccia units and was erupted from a series of dikes and sills now exposed along walls of Black Canyon directly south of Hoover Dam. The Sugarloaf dacite (Tsd), composed of basal dacitic volcaniclastic rocks, flow breccias and a capping dacite flow, conformably overlies the Switchyard basaltic andesite. Biotite separates from the dacite flow have recently been dated at 13.11 ± 0.02 Ma using the $^{40}Ar/^{39}Ar$ method (P. Gans and J. Faulds, written commun., 1994). The dacite flow was erupted from a dacite dome complex in the extreme southwest corner of the map area. The Sugarloaf dacite is conformably overlain by clastic rocks of either the Dry Wash conglomerate (Tdw), the Dry Camp conglomerate (Tdcc), or unnamed Tertiary tuffaceous sandstone and conglomerate (Tts). In some areas, the tuffaceous Tertiary rocks (Tts) are conformably overlain by a second dacite flow, the Black Canyon dacite (Tbc) which is distinguished in outcrop from the Sugarloaf dacite by the inclusion of numerous magmatic enclaves of basaltic composition. The source for the Black Canyon dacite has not been located. The final pulse of volcanism associated with the Black Canyon assemblage is the eruption of the Kingman Wash Road basaltic andesite (Tkw) dated at 12.66 ± 0.1 Ma ($^{40}Ar/^{39}Ar$ whole-rock) (P. Gans and J. Faulds, written commun., 1994). This basaltic andesite conformably overlies the Black Canyon dacite, the Dry Wash conglomerate and the Dry Camp con-glomerate. The source of this lava has not been located. The Kingman Wash Road basaltic andesite and the Dry Camp con-glomerate are unconformably overlain by regionally extensive gravels of the Black Mountains conglomerate (Tbm). The gravels are derived from erosion of the Wilson Ridge pluton and local Precambrian outcrops in the southern map area. The Black Mountains conglomerate is locally conformably overlain by flows of the basalt of Callville Mesa (Tcm) (10.46 to 8.49 Ma) and basalt of Fortification Hill (Tfb) (5.88 to 4.73 Ma; Feuerbach and others, 1991). Outcrops of interbedded sand-stone and conglomerate along the north shore of Lake Mead belong to the Muddy Creek Formation (Tmc) and are probably equivalent in age and stratigraphic position to the Black Mountains conglomerate.

Plutonism in the Hoover Dam area is represented by the Boulder City pluton (Tbc), the Wilson Ridge pluton (Twr), and the Paint Pots pluton (Tpp). The Boulder City pluton has been dated by the K/Ar method at 13.8 Ma (Anderson and others, 1972) and was the most likely source for volcanic units in the Eldorado and McCullough Mountains based on geochemical correlations by Weber and Smith (1987). Erosion of this pluton may have contributed to some of the clastic units in the Hoover Dam area. The Wilson Ridge pluton has been dated at 13.3 to 13.5 Ma (K/Ar, biotite) by Larsen and Smith (1990) and has been shown to be cogenetic with the tuff of Hoover Dam and the Sugarloaf dacite (Mills, 1985). Erosion of the Wilson Ridge pluton contributed significant detritus to the conglomeratic units in the Black Canyon assemblage and to the gravels of the Black Mountains conglomerate. The radiometric age of the Paint Pots pluton is unknown because of extensive hydrothermal alteration that has precluded geochemical analysis and age dating. The pluton intrudes the tuff of Hoover Dam on the northern end of Promontory Point indicating a maximum age of 13.9 Ma. To the west of Fortification Hill, a small area of the Paint Pots pluton contains roof pendants of Cambrian(?)limestone and shale (Pzlu, Tppc). Although contacts between the Paint Pots pluton and Wilson Ridge pluton are not exposed, the Paint Pots pluton is inferred to be a younger, separate phase of the Wilson Ridge pluton (Mills, 1994, unpubl. data).

Other intrusives in the Hoover Dam area are mafic and ultramafic dikes (Tidy The majority of dikes in the Hoover Dam region are basaltic in composition and are geochemically similar *to the mafic* lavas *of* the Black *Canyon* assemblage. Minette dikes are uncommon to rare and are only found along the southern end of Indian Canyon. The northern end of the

TABLE 1. Stratigraphy of the Hoover Dam 7.5-Minute Quadrangle.

Time		Unit		Symbol	Age (Ma)	References
CENOZOIC	Quaternary		Disturbed ground	d		
			Alluvium	Qal		
			Talus	Qt		
		Fortification Hill talus	Active talus slope	Qtl		
			Older talus slope	Qt2		
			Pediment surface	Qt3		
			Older alluvium	Qao		
			Colorado River gravels	Qcr		
	Tertiary Pliocene - Miocene		Basalt of Fortification Hill	Tfb	5.88 - 4.73	Feuerbach and others, 1991
			Basalt of Callville Mesa	Tcm	10.46 - 8.49	Feuerbach and others, 1991
			Muddy Creek Formation	Tmc		
			Black Mountains conglomerate	Tbm		
		Black Canyon assemblage	Dry Camp conglomerate	Tdcc		
			Kingman Wash Road basaltic andesite	Tkw	12.66	Gans and Faulds, written commun., 1994
			Dry Wash conglomerate	Tdw		
			Black Canyon dacite	Tbc		
			Tuffaceous sandstone and conglomerate	Tts		
			Sugarloaf dacite	Tsd	13.11	Gans and Faulds, written commun., 1994
			Switchyard basaltic andesite	Tsb		
			Spillway conglomerate	Tsc		
			Breccia	Tbr		
			Tuff of Hoover Dam	Thd	13.9	Gans and Faulds, written Commun. 1994
			Dam conglomerate	Tdc		
			Dikes	Tid		
			Paint Pots pluton - roof pendant zone	Tppc		
			Paint Pots pluton	Tpp		
			Wilson Ridge pluton	Twr	13.3 - 13.5	Larsen and Smith, 1990
			Boulder City pluton	Tb	13.8	Anderson and others, 1972
			Patsy Mine Volcanics	Tpm	14.19 18.5 - 12.0	Gans and Faulds, written commun., 1994 Anderson, 1971; Darnall and others, 1991
PALEOZOIC	Cambrian(?)		Undifferentiated limestone and shale	Pzlu		
PROTEROZOIC	Precambrian		Metamorphic and igneous rock	p-Єm	1,500 - 1,800	Volborth, 1973; Condie, 1982

TABLE 2. Major and trace element geochemistry of igneous rocks in the Hoover Dam 7.5-minute Quadrangle, Nevada-Arizona.

Unit	Tpm	Thd[1]	Thd[2]	Tsb	Ted	Tkw	Tbc	Tbc[3]	Tcm	Tib	Tid[4]	Tld[5]	Th[6]	Ter[7]	TWr[8]
Sample number	**84-85**	**BH-15**	**BH-18**	**85-18**	**084-4**	**G84-5**	**93M1L-5**	**92M1L-11**	**92M1L-15**	**84-80**	**84-54**	**8450**	**343**	**84-58**	**84-57**
Major elements (wt %)															
SiO_2	57.31	58.93	66.39	59.20	69.02	56.11	62.10	47.88	60.43	48.87	50.20	49.12	63.27	66.15	73.99
Al_2O_3	14.97	15.24	12.86	13.82	14.51	16.84	15.17	17.56	13.38	15.25	14.38	13.77	15.63	15.02	12.71
TiO_2	1.26	0.90	0.54	0.78	0.42	1.36	0.54	0.98	0.57	1.53	1.28	1.36	0.85	0.44	0.21
Fe_2O_3	7.63	4.73	4.03	7.42	3.83	7.50	ND	ND	ND	10.11	6.41	7.11	5.48	4.51	2.27
FeO	ND[9]	ND	ND	ND	ND	ND	3.72	7.50	5.08	ND	ND	ND	ND	ND	ND
MgO	1.41	1.90	1.64	0.32	0.77	3.83	1.76	3.31	2.12	7.15	3.87	7.72	1.82	1.12	0.35
CaO	2.67	3.99	3.59	4.29	2.97	7.39	4.18	8.58	0.05	9.53	7.47	8.79	3.42	1.86	0.91
Na_2O	3.05	1.92	2.47	2.39	3.60	3.93	4.10	3.06	9.75	3.19	6.73	4.58	4.08	4.36	3.59
K_2O	7.73	8.45	4.48	8.26	4.24	2.28	2.91	4.67	0.32	1.23	0.66	2.44	4.56	4.45	4.82
MnO	0.29	0.36	0.17	0.23	0.04	0.12	0.07	0.18	0.02	0.17	0.14	0.15	0.06	0.05	0.06
P_2O_5	0.41	0.14	0.07	0.34	0.13	0.45	0.26	0.82	0.00	0.37	0.70	1.59	0.28	0.15	0.04
L0I	ND	2.38	1.70	2.10	0.54	0.76	ND	ND	0.58	ND	ND	ND	0.07	ND	ND
Total	96.76	99.20	98.13	99.15	100.33	100.83	94.82	94.53	92.29	97.41	91.84	96.63	99.85	98.11	98.97
Trace elements (ppm)															
Rb	145.7	217.2	145.0	180.0	120.8	32.2	96.9	129.1	13.5	32.4	23.2	37.4	130.0	88.5	129.1
Sr	315.2	ND	ND	353.0	630	860	725.8	1551.6	69.1	264.0	205.9	727.8	880.0	314.1	101.8
Th	22.14	19.77	12.84	ND	15.29	6.86	ND	ND	ND	2.49	10.45	10.62	23.02	15,38	21.05
Ba	1276	1384	699	1020	1730	1280	1268	1645	273	482	1672	1797	1890	1944	732
Zr	285	ND	ND	224	240	350	248	253	160	145	259	341	480	247	145
La	141.4	84.4	47.9	62.3	56.0	47.5	36.5	79.5	ND	27.8	84.8	135.5	93.4	80.9	64.2
Ce	201.9	185.8	94.3	ND	77.9	73.6	ND	ND	ND	39.7	115.1	231.5	206.4	119.0	88.6
Nd	82.11	51.59	32.82	ND	30.48	13.21	ND	ND	ND	17.63	58.19	98.76	53.44	34.20	24.42
Sm	10.04	10.44	4.76	ND	7.15	1.33	ND	ND	ND	4.66	10.02	18.63	8.85	6.53	4.11
Eu	1.67	2.93	1.47	ND	1.03	1.74	ND	ND	ND	1.62	2.40	4.16	2.36	1.28	0.63
Yb	2.31	2.1	1.23	ND	1.48	1.75	ND	ND	ND	1.70	1.92	1.55	3.02	1.52	1.44
Lu	0.45	0.36	0.22	ND	0.39	0.22	ND	ND	ND	0.32	0.31	0.30	0.37	0.35	0.31

[1]Tuff of Hoover Dam, base
[2]Tuff of Hoover Dam, top
[3]Magmatic enclave in the Black Canyon dacite
[4]Basaltic dike (southern Paint Pots area)
[5]Lamprophyre dike (Indian Canyon area)
[6]Boulder City pluton, intermediate phase
[7]Wilson Ridge pluton, most matic phase
[8]Wilson Ridge pluton, most felsic phase
[9]ND = Not determined

Wilson Ridge pluton is intruded by many basaltic dikes (Feuerbach, 1986). Dikes exposed within outcrops of the Black Canyon assemblage and Patsy Mine Volcanics are compositionally identical to the Switchyard basaltic andesite and are inferred to be the feeder dikes for the lava flows of this unit. The dike complex on trend with the source area for the basalt of Fortification Hill is part of the feeder system for this series of lava flows and is exposed from the southern boundary of the quadrangle to the northern end of Fortification Ridge.

Quaternary

Paleo-Colorado River gravels (Qcr) may be the oldest Quaternary units in the Hoover Dam area. These gravels are only exposed on the east side of Sugarloaf Mountain in the southwestern map area and are in unconformable contact with the Sugarloaf dacite.

Sediment surfaces (Qt_3) derived from the erosion of the basalt of Fortification Hill are present in the Fortification Hill area but are erosionally isolated from this sediment source. Units designated as Qt_2 represent older talus slopes of Fortification Hill that have recently been cutoff from the eroding basalt flows. The talus is composed primarily of boulders of the basalt of Fortification Hill. Actively prograding talus slopes surrounding Fortification Hill are mapped as Qt_1. Older stream gravels that are currently undergoing erosion have been mapped as Qao. Some of these older gravels may be equivalent in age to the paleo-Colorado River gravels. Currently active talus slopes in areas not associated with Fortification Hill are mapped as Qt. Active stream and wash channel deposits are mapped as Qal. Sites of gravel dumping during the construction of Hoover Dam are mapped as disturbed ground (d).

STRUCTURE

The structural history of the Hoover Dam area is defined in three stages; 1) preextension basement uplift, 2) extension related listric normal faulting and left-lateral strike-slip faulting and 3) extension related high-angle normal faulting.

Stage one is represented by syn- or post-Sevier orogeny uplift of the Precambrian basement, subsequent erosion of Paleozoic and Mesozoic strata, and the initial deposition of Tertiary strata (Bohannon, 1984). Stage two involves the initiation of extension at about 17 Ma in the Lake Mead region in a S70°W orientation (Bohannon, 1984; Weber and Smith, 1987). This event marked the beginning of listric normal faulting of the Tertiary strata in the Hoover Dam area and initiated the eastward tilting of the Patsy Mine volcanic section. Extension and normal faulting continued through deposition of the Kingman

Wash Road basaltic andesite. In the Hoover Dam area most strata dip east and northeast and are cut by many down-to-thewest and down-to-the-southwest faults, a structural style that characterizes a large area to the south and southwest of the Hoover Dam Quadrangle (Anderson, 1977, 1978). To the north-east, in the area south and northwest of Fortification Hill, most fault displacements are down to the east and northeast. Northwest of Fortification Hill, strata equivalent to those at Hoover Dam dip steep to the southwest. According to R.E. Anderson (written commun., 1994), this structural style continues for about 8 km to the northeast into the Wilson Ridge pluton and is probably related to syn- and post-emplacement uplift of the Black Mountains structural block. An approximate 1-m down-to-the-west offset of the basalt of Callville Mesa (Tens) and older Quaternary stream gravels (Qao) on the Mead Slope fault west of Fortification Hill may represent Quaternary reactivation of this fault system. This fault is most likely an extension of either the left-lateral strike-slip Lake Mead fault system as defined by Bohannon (1984) or the left-lateral strike-slip Hamblin Bay fault as defined by Anderson (1973). Complex normal and strike-slip components along faults in the Hoover Darn area were studied by Angelier and others (1985). They determined that the least principal stress direction (63) during stage two extension rotated from an early orientation of northeast-southwest to a late stage west-northwest-east-southeast orientation. This rotation of σ3 is consistent with other Basin and Range data (Angelier and others, 1985). Stage three is represented by north-trending high-angle faults such as the Indian Canyon and Fortification Ridge faults. Activity on these faults probably ranged from 10 Ma to 6 Ma. Continuation of the third stage, or the initiation of a fourth stage of deformation in the Hoover Dam region is indicated by Quaternary re-activation of the older left-lateral strike-slip Mead Slope fault based upon the down-to-the-west offset of older Quaternary units (Qao).

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