U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

POTASSIUM-ARGON APPARENT AGES OF ROCKS FROM THE WESTERN OKANOGAN RANGE, THE METHOW BASIN, AND ADJACENT AREAS, NORTH-CENTRAL WASHINGTON

by

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No.	Field No.	Unit	Latitude N	Longitude W	Quadrangle	Rock type	Material dated	Ave. K_2O	$^{40}Ar^*/\Sigma^{40}Ar$	$^{40}Ar^*$	Age	±Analytical
			o ' "	o ' "				%	%	moles/gram	(Ma)	error (Ma)
					Okanogan Range batholith							
1	DM-1(H)	Kec	48 34 48	120 09 54	Doe Mountain	Trondhjemite	Hornblende	1.08	80	1.67962 E-10	104.8	2.6
2	DM-1(B)	Kec	48 34 48	120 09 54	Doe Mountain	Trondhjemite	Biotite	9.30	78	1.45763 E-9	105.7	2.6
3	DM-9	Klb	48 35 50	120 09 41	Doe Mountain	Trondhjemite	Biotite	9.25	80	1.40394 E-9	102.5	2.6
									92	1.36545 E-9	99.8	2.5
4	BBM-5		48 26 22	119 59 34	Loup Loup	Aplite	Muscovite	10.67	93	1.54999 E-9	98.2	2.5
5	DM-48(B)	Kdm	48 35 48	120 05 16	Doe Mountain	Trondhjemite	Biotite	9.25	84	1.31631 E-9	96.3	2.4
6	DM-48(M)	Kdm	48 35 48	120 05 16	Doe Mountain	Trondhjemite	Muscovite	10.78	90	1.53589 E-9	96.4	2.4
7	RF-83-4(B)	Kdm	48 18 18	119 54 24	Loup Loup	Granod-trond.	Biotite	8.78	94	1.25739 E-9	96.8	2.4
8	RF-83-4(M)	Kdm	48 18 18	119 54 24	Loup Loup	Granod-trond.	Muscovite	9.66	89	1.29808 E-9	91.0	2.3
9	DM-83(B)		48 40 27	120 06 14	Doe Mountain	Trondhjemite	Biotite	8.71	88	1.23282 E-9	95.7	2.4
10	DM-83(M)		48 40 27	120 06 14	Doe Mountain	Trondhjemite	Muscovite	10.61	85	1.50634 E-9	96.1	2.4
11	DM-84	KJtm	48 36 18	120 00 54	Doe Mountain	Trondhjemite	Biotite	9.42	81	1.30968 E-9	94.1	2.4
									91	1.33734 E-9	96.1	2.4
12	DM-85	KJtm	48 36 18	120 00 54	Doe Mountain	Quartz diorite	Biotite	9.28	67	1.40841 E-9	102.5	2.6
									92	1.30687 E-9	95.3	2.4
13	TM-3	KJtm	48 39 44	119 58 00	Tiffany Mt	Trondhjemite	Biotite	9.35	92	1.28128 E-9	92.8	2.3
									90	1.27731 E-9	92.5	2.3
14	DM-45	Km	48 34 00	120 10 18	Doe Mountain	Mylonite	Biotite	9.40	76	1.40885 E-9	101.3	2.5
									89	1.41254 E-9	101.5	2.5
15	DM-58(H)		48 31 28	120 07 00	Doe Mountain	Amphibolite	Hornblende	0.94	82	1.45886 E-10	105.2	2.6
16	DM-58(B)		48 31 28	120 07 00	Doe Mountain	Amphibolite	Biotite	8.73	57	1.30290 E-9	100.8	2.5
									93	1.30422 E-9	100.9	2.5
17	TE-1	pKlm	48 15 17	120 05 38	Twisp East	Amphibolite	Hornblende	0.29	63	4.95590 E-11	114.6	2.9
18	TE-3(H)	pKlm	48 15 45	120 03 56	Twisp East	Tonalite	Hornblende	0.82	56	1.38602 E-10	114.3	2.9
19	TE-3(B)	pKlm	48 15 45	120 03 56	Twisp East	Tonalite	Biotite	9.35	90	1.26841 E-9	91.9	2.3
									90	1.32619 E-9	96.0	2.4
20	LL-1	Ksc	48 16 47	119 59 07	Loup Loup	Trondhjemite	Biotite	9.22	95	1.37274 E-9	100.6	2.5
									94	1.3636 E-9	99.9	2.5
21	B-1	Ksc	48 14 24	119 58 30	Brewster	Trondhjemite	Biotite	9.24	84	1.38458 E-9	101.2	2.5
22	TM-6	Kbs	48 45 55	119 56 19	Tiffany Mt	Monzogranite	Biotite	7.95	83	1.04619 E-9	89.2	2.2
23	RF-83-10(B)	Kc	48 49 36	120 00 59	Coleman Peak	Monzogranite	Biotite	8.92	89	1.27154 E-9	96.4	2.4
24	RF-83-10(M)	Kc	48 00 00	120 00 00	Coleman Peak	Monzogranite	Muscovite	10.07	84	1.41197 E-9	94.9	2.4
25	Met-4	pKmg	48 09 02	120 03 16	Methow	Trondhjemite	Biotite	5.07	66	4.5755 E-10	61.7	1.5
					Plutons	within	Methow basin					
26	M-85(H)	Jbc	48 42 34	120 17 31	Mazama	Tonalite	Hornblende	0.45	48	1.04074 E-10	153.2	3.8
27	M-85(B)	Jbc	48 42 34	120 17 31	Mazama	Tonalite	Biotite	5.14	91	1.12317 E-9	145.9	3.6
28	M-22	Jbc	48 40 01	120 15 26	Mazama	Tonalite	Hornblende	0.28	39	6.30170 E-11	150.2	3.8
									42	6.26588 E-11	149.4	3.7
29	TW-30	KJac	48 20 31	120 09 23	Twisp West	Quartz diorite	Hornblende	0.72	62	1.48311 E-10	137.3	3.4
30	T-1(H)	KJfc	48 24 21	120 03 31	Blue Buck Mt	Quartz diorite	Hornblende	1.12	63	2.17834 E-10	130.1	3.3

31	T-1(B)	KJfc	48 24 21	120 03 31	Blue Buck Mt	Quartz diorite	Biotite	9.34	88	1.43464 E-9	103.7	2.6
									59	1.49099 E-9	107.6	2.7
32	TW-42		48 17 35	120 09 07	Twisp West	Tonalite	Hornblende	0.24	41	4.33643 E-11	119.2	3.0
33	Met-1	Ktc	48 14 25	120 04 56	Methow	Tonalite	Hornblende	0.29	44	3.59005 E-11	84.4	2.1
									30	3.68246 E-11	86.5	2.2
34	Met-2	Ktc	48 13 28	120 03 51	Methow	Monzogranite	Biotite	7.99	88	1.04692 E-9	88.8	2.2
									91	1.03173 E-9	87.5	2.2
35	M-10	Kfp	48 35 41	120 22 10	Mazama	Monzodiorite	Biotite	7.89	55	1.01083 E-9	86.9	2.2
						Porphyritic	**sills and dikes**					
36	PM-17	Ksd	48 31 51	120 16 26	Mazama	Quartz	Hornblende	0.36	33	4.27941 E-11	81.7	2.0
						monzodiorite			22	4.55485 E-11	86.8	2.2
37	TR-30	Ksd	48 23 29	120 18 21	Thompson	Qz monzonite	Hornblende	0.41	56	4.92481 E-11	81.2	2.0
					Ridge				55	4.84655 E-11	79.9	2.0
38	PM-28A	Ksd	48 39 57	120 18 40	Mazama	Quartz diorite	Hornblende	0.48	31	6.16983 E-11	87.8	2.2
									29	5.89735 E-11	84.0	2.1
39	DM-54	Ksd	48 46 08	120 07 23	Doe Mountain	Monzodiorite	Hornblende	0.25	19	3.17377 E-11	85.8	2.1
40	M-16	Ksd	48 37 56	120 21 33	Mazama	Diorite	Hornblende	0.32	10	4.45549 E-11	93.2	2.3
41	M-84-6D	Ksd	48 32 12	120 18 48	Mazama	Quartz diorite	Hornblende	0.25	34	3.22630 E-11	87.5	2.2
42	TR-37	Ksd	48 25 44	120 17 16	Thompson	Qz monzonite	Hornblende	0.45	25	5.83677 E-11	87.9	2.2
					Ridge							
					Black	**Peak batholith**						
43	RM-84-MB(H)	Kbp	48 30 25	120 43 48	Washington	Granodiorite	Hornblende	0.70	36	1.02420 E-10	98.5	2.5
					Pass							
44	RM-84-MB(B)	Kbp	48 30 25	120 43 48	Washington	Granodiorite	Biotite	9.12	86	9.62293 E-10	71.8	1.8
					Pass				91	9.64628 E-10	72.0	1.8
					Tertiary	**plutons and**	**dikes**					
45	RM-84-J	Tgh	48 30 54	120 38 42	Washington	Granite	Hornblende	1.04	35	6.68558 E-11	44.0	1.1
					Pass							
46	RM-84-K	Tgh	48 34 14	120 38 00	Washington	Monzogranite	Biotite	8.45	72	5.78111 E-10	46.9	1.2
					Pass							
47	RM-84-MA		48 30 29	120 43 48	Washington	Dacite	Biotite	9.30	66	6.43161 E-10	47.4	1.2
					Pass							
48	OP-3B	Tcm	48 07 07	120 12 53	Oss Peak	Granodiorite	Biotite	7.87	62	5.47635 E-10	47.7	1.2
49	CM-84-5	Tcm	48 01 25	120 06 26	Cooper Mt	Granodiorite	Biotite	8.79	79	6.07308 E-10	47.4	1.2
									48	6.05546 E-10	47.2	1.2
50	CM-84-1	Tcm	48 03 54	120 01 30	Cooper Mt	Granodiorite	Biotite	8.40	83	5.96754 E-10	48.7	1.2
51	CM-84-3	Tcm	48 03 20	120 06 18	Cooper Mt	Monzogranite	Biotite	8.23	85	5.66441 E-10	48.5	1.2
52	OP-3C		48 07 07	120 12 53	Oss Peak	Lamprophyre	Biotite	8.62	88	5.82924 E-10	46.4	1.2
									82	5.90625 E-10	47.0	1.2
53	M-49A		48 37 48	120 26 04	Mazama	Basaltic	Whole rock	1.93	80	1.38394 E-10	49.2	1.2
						andesite			85	1.34262 E-10	47.8	1.2

54	PM-25B		48 39 20	120 24 44	Mazama	Basalt	Whole rock	0.22	36	1.48372 E-11	47.3	1.2
55	HP-44		48 18 26	120 15 23	Hoodoo Peak	Basaltic	Whole rock	0.88	59	6.30619 E-11	49.0	1.2
						andesite						
56	OP-3A		48 07 07	120 12 53	Oss Peak	Granite	Biotite	7.98	81	4.04551 E-10	34.9	0.9
						Volcanic	**rocks**					
57	DM-25A	KJvu	48 31 30	120 10 39	Doe Mountain	Basalt	Whole rock	0.34	70	5.96807 E-11	117.5	2.9
58	TW-38	KJn	48 21 45	120 07 59	Twisp West	Basaltic	Whole rock	0.23	28	2.76707 E-11	81.3	2.0
						andesite						
59	TW-18C	KJn	48 15 32	120 10 36	Twisp West	Basaltic	Whole rock	0.05	44	1.11382 E-11	136.6	6.3
						andesite			53	1.13430 E-11	139.1	6.4
60	TW-14B(A)	KJn	48 15 23	120 10 18	Twisp West	Andesitic tuff	Whole rock	0.20	73	3.83830 E-11	131.1	3.3

APPENDIX

Analytical methods

Conventional potassium-argon age determinations were made in the isotope laboratories of the U.S. Geological Survey at Menlo Park, California using the methods described by Dalrymple and Lanphere (1969). Argon analyses were made by J.K. Nakata and C.D. Ortenburger.

Argon was extracted on an ultra-high vacuum system by fusion; the reactive gases were then scrubbed by an artificial molecular sieve, copper/copper oxide and titanium metals. The spectrometry was performed on Nier-type, 15 cm radius, 60° sector and multichannel, 23 cm radius, 60° sector mass spectrometers both operated in the static mode. Argon was analyzed by comparing the liberated gas to a ^{38}Ar spike of known volume and composition added during fusion. The decay constants used are those recommended by Steiger and Jager (1977).

Potassium was analyzed by flame photometry using a lithium internal standard by means of a procedure described by Cremer and others (1984). K_2O analyses were made by M. Dyslin, L. Espos, P. Klock, S. Macpherson, S. Pribble, and D. Vivit. Ages are calculated using the average of multiple K_2O determinations.

The assigned errors are estimates (1 standard deviation) of the analytical reproducibility, or precision, of the apparent ages. For samples run prior to 1980, errors are estimated at 3.0 percent. A change to digital measurements of peak heights in 1980 increased the precision of argon analyses in the U.S. Geological Survey laboratory in Menlo Park; the estimated error of apparent ages measured after this change is 2.5 percent. Where two splits of the same sample were analyzed, the replicate analyses generally show good agreement within this 2.5 percent error estimate.

Inspection of a large number of replicate analyses made at the Menlo Park laboratory suggests that for samples with more than about 50 percent radiogenic ^{40}Ar, apparent ages are reproducible to within 3 percent or better; for samples with smaller fractions of radiogenic ^{40}Ar, reproducibility is less good (Tabor and others, 1985).

Additional sample data

1. Trondhjemite[1] of Eightmile Creek (Kec)(Todd, 1995a); strongly foliated hornblende-biotite trondhjemite.
2. do
3. Trondhjemite of Lamb Butte (Klb)(Todd, 1995a); gneissic biotite trondhjemite.
4. Garnetiferous muscovitic aplite dike in trondhjemite of Lamb Butte.

5. Trondhjemite of Doe Mountain (Kdm)(Todd, 1995a); weakly foliated to massive muscovite-biotite trondhjemite.
6. do
7. Trondhjemite of Doe Mountain; weakly foliated muscovite-biotite borderline granodiorite-tonalite.
8. do
9. Fine-grained muscovite-biotite trondhjemite dike in trondhjemite of Doe Mountain.
10. do
11. Gneissic trondhjemite of Tiffany Mountain (KJtm)(Rinehart, 1981; Stoffel and McGroder, 1989; Todd, 1995a); gneissic biotite trondhjemite (leucosome).
12. Gneissic biotite quartz diorite (melanosome of No. 11).
13. Gneissic trondhjemite of Tiffany Mountain; coarse-grained gneissic biotite trondhjemite (average rock of unit).
14. Mylonitic rocks unit (Km)(Todd, 1995a); mylonitic granodiorite gneiss about 400 m away from Pasayten fault.
15. Amphibolite (metagabbro) inclusion in trondhjemite of Eightmile Creek.
16. do
17. Amphibolite body in Leecher Metamorphics (pKlm)(Barksdale, 1975; Bunning, 1990).
18. Biotite-hornblende tonalite gneiss; unnamed body in Leecher Metamorphics.
19. do
20. Summit Creek pluton (Ksc)(Barksdale, 1975); strongly foliated biotite trondhjemite.
21. Summit Creek pluton; foliated biotite trondhjemite.
22. Bottle Spring pluton (Kbs)(Rinehart, 1981); massive biotite monzogranite.
23. Cathedral pluton (Kc)(Rinehart, 1981); weakly foliated to massive muscovite-biotite monzogranite.
24. do
25. Methow Gneiss (pKmg)(Barksdale, 1975; Bunning, 1990); gneissic biotite trondhjemite.
26. Button Creek stock (Jbc)(Barksdale, 1975; Todd, 1995b); massive biotite-hornblende tonalite.
27. do
28. Button Creek stock; mylonitic tonalite gneiss.
29. Alder Creek stock (KJac)(Barksdale, 1975; Bunning, 1990); weakly foliated biotite-hornblende quartz diorite; intrudes volcanic and sedimentary rocks of the undivided Newby Group (Barksdale, 1975; Bunning, 1990).
30. Frazer Creek complex (KJfc)(Barksdale, 1975; Bunning, 1990); strongly foliated biotite-hornblende quartz diorite.
31. do
32. Unnamed stock composed of fine- to medium-grained biotite-hornblende tonalite; intrudes volcanic and sedimentary rocks of the undivided Newby Group.

33. Texas Creek stock (Ktc)(Barksdale, 1975; Bunning, 1990); massive biotite-hornblende tonalite.
34. Texas Creek stock; non-foliated monzogranite.
35. Fawn Peak stock (Kfp)(Barksdale, 1975; Riedell, 1979; Todd, 1995b); weakly foliated clinopyroxene-hornblende-biotite monzodiorite.
36. Porphyritic sills and dikes (Ksd)(Todd, 1995a); quartz monzodiorite sill in Virginian Ridge Formation of Barksdale (1975); satellitic to Fawn Peak stock?
37. Porphyritic sills and dikes; quartz monzonite sill in Mignight Peak Formation of Barksdale (1975).
38. Porphyritic sills and dikes; quartz diorite sill in Panther Creek Formation of Barksdale (1975).
39. Porphyritic sills and dikes; monzodiorite sill or dike in trondhjemite of Doe Mountain.
40. Porphyritic sills and dikes; diorite sill in Winthrop Sandstone of Barksdale (1975).
41. Porphyritic sills and dikes; fine- to medium-grained quartz diorite dike in Midnight Peak Formation.
42. Porphyritic sills and dikes; quartz monzonite sill in Virginian Ridge Formation.
43. Black Peak batholith (Kbp)(Barksdale, 1975); weakly foliated hornblende-biotite granodiorite.
44. do
45. Golden Horn batholith (Tgh)(Stull, 1969; Barksdale, 1975); massive biotite-hornblende granite.
46. Golden Horn batholith; massive biotite monzogranite.
47. Porphyritic dacite dike in Black Peak batholith; located about 3.8 km from contact with Golden Horn batholith.
48. Cooper Mountain batholith (Tcm)(Barksdale, 1975); massive biotite granodiorite.
49. Cooper Mountain batholith; porphyritic biotite granodiorite.
50. Porphyritic biotite granodiorite dike (Tcm?) in Methow Gneiss.
51. Fine-grained biotite granodiorite dike in Cooper Mountain batholith.
52. Basaltic (lamprophyre) dike in Cooper Mountain batholith.
53. Porphyro-aphanitic basaltic andesite dike in Midnight Peak Formation.
54. Porphyro-aphanitic basaltic dike in Midnight Peak Formation.
55. Basaltic andesite dike in volcanic and sedimentary rocks of the undivided Newby Group.
56. Fine-grained granitic dike in Cooper Mountain batholith.
57. Volcanic rocks, undivided (KJvu)(Todd, 1995a); basalt flow.
58. Volcanic and sedimentary rocks of the undivided Newby Group (KJn)(Barksdale, 1975; Bunning, 1990); basaltic andesite flow.
59. do
60. Volcanic and sedimentary rocks of the undivided Newby Group; andesitic tuff.

[1] Plutonic rock names after Streckeisen (1973).

Significance of conventional potassium-argon apparent ages

Most of the potassium-argon ages in this report are minimum ages, that is, they represent either ages of uplift and cooling of igneous bodies through potassium-argon blocking temperatures or ages of resetting by subsequent intrusive or metamorphic events.

Okanogan Range batholith

Apparent ages of plutonic units of the western Okanogan Range batholith (Nos. 1-10), which has yielded U-Pb isotopic emplacement ages of 114-111 Ma (Hurlow and Nelson, 1993), are probably cooling ages but may also have been affected by intrusion of the relatively massive Bottle Spring and Cathedral plutons to the east (Nos. 22-24). The Cathedral pluton, which intruded the gneissic trondhjemite of Tiffany Mountain, gives nearly concordant biotite and muscovite ages of 96 and 95 Ma, respectively, ages that fall within the 98- to 94-Ma range of biotite ages reported by Stoffel and McGroder (1989). The gneissic trondhjemite of Tiffany Mountain (Nos. 11-13), which was also intruded by the trondhjemite of Doe Mountain, yields potassium-argon cooling ages that range from about 94 to 105 Ma (Stoffel and McGroder, 1989). Emplacement ages of the intrusive component of the unit, which may be as old as Jurassic, were apparently reset during intrusion of the Okanogan Range batholith. The age of a sample of mylonitic rocks adjacent to the Pasayten fault (No. 14) is a minimum age for the granitoid protolith and for ductile deformation in the fault zone. Ages of the amphibolite inclusion in the trondhjemite of Eightmile Creek (Nos. 15, 16) fall within the range of cooling ages for the batholith. The inclusion, which shows relict igneous textures and is similar to other amphibolite-metagabbro bodies and inclusions within the Eightmile Creek and correlative units (Bunning, 1990), may represent remnants of a mafic marginal unit of the batholith.

Potassium-argon hornblende ages of about 114 Ma for the Leecher Metamorphics (Nos. 17-19) are probably too young since the unit is intruded by elements of the Okanogan Range batholith (the Summit Creek pluton and the Methow Gneiss). Regional evidence led Bunning (1990) to assign a pre-Cretaceous age to the Leecher Metamorphics. However, uncertainties in the crystallization ages of the Summit Creek pluton and the Methow Gneiss allow room for the possibility that the Leecher is as young as earliest Cretaceous. Biotite ages of about 101 Ma for the Summit Creek pluton (Nos. 20, 21) are probably minimum ages given the variable degrees of ductile deformation and recrystallization of the pluton. The age of the Methow Gneiss is unknown; the unit is structurally concordant with the Leecher Metamorphics and was metamorphosed with it (Bunning, 1990) and, like the Leecher, is assigned a pre-Cretaceous crystallization age. Sample No. 25 has an anomalously low K_2O value; its biotite age may reflect an early Tertiary resetting event.

Plutons and sills within the Methow basin

Hornblende ages of mafic granitoid plutons or of mafic phases of granitoid plutons in the Methow basin range from Late Jurassic to Late Cretaceous. Two samples of the Button Creek stock (Nos. 26-28) have nearly concordant hornblende ages (about 150 Ma) and may have Late Jurassic emplacement ages. The Alder Creek stock and Frazer Creek complex (Nos. 29-31) yielded earliest Cretaceous hornblende ages. Bunning (1990) reported a slightly older age (139 Ma) for the Frazer Creek and assigned a latest Jurassic or earliest Cretaceous age to both plutons. As reported by Bunning (1990), one of the Carlton stocks has a hornblende age of 129.6 Ma; this stock and No. 32 in this study may be part of the latest Jurassic-earliest Cretaceous magmatic episode. Parts of all of these bodies have undergone ductile deformation, which suggests that the hornblende ages are minimum ages. All but the Carlton stocks intruded sedimentary and volcanic rocks of the undivided Newby Group, which may constrain its age to pre-latest Jurassic. The Texas Creek stock (Nos. 33, 34), which intruded the Summit Creek pluton and the Leecher Metamorphics, may be significantly younger than the above stocks; its potassium-argon ages (about 89 to 84 Ma) are similar to those of the Fawn Peak stock and the porphyritic sills and dikes.

Potassium-argon ages of the Fawn Peak stock that fall consistently within the range 88 to 87 Ma (Riedell, 1979; Todd, 1995b)(No. 35) are considered to be emplacement ages. Hornblende ages of porphyritic sills and dikes range from 93 to 80 Ma (Nos. 36-42) but cluster near the age of the Fawn Peak stock. This and compositional similarities between the stock and the sills suggests that together they represent a relatively short-lived magmatic event.

Black Peak batholith

The 98.5-Ma hornblende age (No. 43) for granodiorite from the Black Peak batholith is considerably older than the 90-Ma hornblende age reported by McGroder and Miller (1989). The biotite age of this sample--about 72 Ma (No. 44)--apparently records uplift and cooling in this part of the batholith.

Tertiary plutons and dikes

Potassium-argon ages for the Golden Horn batholith (Nos. 45-47) fall within the range 44 to 47 Ma, which is generally consistent with potassium-argon ages reported by Engels and others (1976). Samples of the Cooper Mountain batholith (Nos. 48-51) form a tight cluster at 49 to 47 Ma, in good agreement with the 48-Ma ages obtained by Bunning (1990) and Wade (1988). These ages and those of dikes (Nos. 52-55) from various parts of the Methow basin represent the widespread

Eocene volcanic and plutonic magmatic episode that affected south-central British Columbia and northern Washington.

Volcanic rocks

Potassium-argon whole-rock ages of volcanic rocks of the undivided Newby Group and equivalents (Nos. 57-60) are minimum ages that probably represent resetting during the earliest Cretaceous and (or) Late Cretaceous thermal events that affected the Methow basin.

REFERENCES CITED

Barksdale, J.D., 1975, Geology of the Methow Valley, Okanogan County, Washington: Washington Division of Geology and Earth Resources Bulletin 68, 72 p., 1 plate.

Bunning, B.B., 1990, Geologic map of the east half of the Twisp 1:100,000-scale quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 90-9, 51 p.

Cremer, M.J., Klock, P.R., Neil, S.T., and Riviello, J., 1984, Chemical methods for analysis of rocks and minerals: U.S. Geological Survey Open-File Report 84-565, 149 p.

Dalrymple, G.B., and Lanphere, M.A., 1969, Potassium-argon dating: W.H. Freeman and Co., San Francisco, California, 258 p.

Engels, J.C., Tabor, R.W., Miller, F.K., and Obradovich, J.D., 1976, Summary of K-Ar, Rb-Sr, U-Pb, Pb-alpha, and fission-track ages for rocks from Washington State prior to 1975 (exclusive of Columbia Plateau basalts): U.S. Geological Survey Map MF-710.

Hurlow, H.A., and Nelson, B.K., 1993, U-Pb zircon and monazite ages for the Okanogan Range batholith, Washington: implications for the magmatic and tectonic evolution of the southern Canadian and northern United States Cordillera: Geological Society of America Bulletin, v. 105, no. 2, p. 231-240.

McGroder, M.F., and Miller, R.B., 1989, Geology of the eastern North Cascades, *in* Joseph, N.L., and others, eds., Geologic guidebook for Washington and adjacent areas: Washington Division of Geology and Earth Resources Information Circular 86, p. 97-118.

Riedell, K.B., 1979, Geology and porphyry copper mineralization of the Fawn Peak intrusive complex, Methow Valley, Washington: Seattle, University of Washington, M.S. thesis, 52 p.

Rinehart, C.D., 1981, Reconnaissance geochemical survey of gully and stream sediments, and geologic summary, in part of the Okanogan Range, Okanogan County, Washington: Washington Division of Geology and Earth Resources, Bulletin 74, 24 p., 3 plates.

Steiger, R.H., and Jager, E., 1977, Subcommission on geochronology: convention on the use of decay constants in geo- and cosmochronology: Earth and Planetary Science Letters, v. 36, p. 359-362.

Stoffel, K.L., and McGroder, M.F., 1989, Geologic map of the Robinson Mountain 1:100,000-scale quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 90-5, 39 p.

Streckeisen, A.L., 1973, Plutonic rocks classification and nomenclature recommended by the IUGS subcommission on the systematics of igneous rocks: Geotimes, v. 18, no. 10, p. 26-30.

Stull, R.J., 1969, The geochemistry of the southeastern portion of the Golden Horn batholith, northern Cascades, Washington: Seattle, University of Washington, Ph.D. thesis, 127 p.

Tabor, R.W., Mark, R.K., and Wilson, R.H., 1985, Reproducibility of the K-Ar ages of rocks and minerals: An empirical approach: U.S. Geological Survey Bulletin 1654, 5 p.

Todd, V.R., 1995a, Geology of the Doe Mountain quadrangle, Okanogan County, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-2306, scale 1:62,500.

__________, 1995b, Geology of part of the Mazama quadrangle, Okanogan County, Washington: U.S. Geological Survey Open-File Report OF 95-523, scale 1:62,500.

Wade, W.M., 1988, Geology of the northern part of the Cooper Mountain batholith, north-central Cascades, Washington: San Jose State University M.S. thesis, 88 p., 1 plate.