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Title of article Lithophile-element mineralization associated with Late Cretaceous two-mica granites in the Great Basin

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Lithophile-element mineralization associated with Late Cretaceous two-mica granites in the Great Basin

Mark D. Barton

APPENDIX 1. SYNOPSIS OF GEOLOGIC AND GEOCHEMICAL DATA

Name	Birch Creek (BC)	Dawley Canyon (DC)	Kern Mountains (KM)
Feature			
IGNEOUS			
Major phases	two-mica granodiorite to two-mica monzogranite ²	two-mica monzogranite ¹	two-mica monzogranite or two-mica granodiorite ⁵
Extent	~15 km ² ¹	~10 km ² ⁵	~90 km ² ⁵
Mineralogy	Pc+Qz+Kspr(Mi)+Bi+Mu±Zir ±Ap±Fl±Ep ²	Kspr(Mi)+Alb+Qz+Bi +Mu±Ap±Gt±Be±Zir ¹	Qz+Pc+Kspr(Or)+Bi+Mu ±Ap±Zir ⁵
Textures/distribution	medium-grained (2-4 mm) with K-feldspar megacrysts, interstitial Mu ²	fine- to medium-grained equigranular ^{1,2}	coarse-grained, somewhat porphyritic (Mu+Kspr) ⁵
Minor phases	aprites and pegmatites ^{2,3}	pegmatites and aprites (albite granites) ²	aprites and pegmatites (aplitic border phase)
Extent	<5% ³	<5%	widespread, but sparse
Mineralogy	Qz+Kspr+Pc+Gt+Bi+Mu(?) ³	Qz+Kspr+Pc(Alb)+Bi+Gt±Be ±Tour±Ap±Columb±And±Sill ²	Qz+Kspr+Pc+Mu±Gt
Textures/distribution	aplitic to pegmatitic ³	complex pegmatitic/aplitic to quartz veins near top ²	aplitic, rarely pegmatitic, interior dikes and border zone
Age(s), (methods)	80 ± 4 (K-Ar, bi) ; 77 ± 2 (K-Ar, bi) ¹	83.9 ± 1.3 (Rb-Sr, w.r.) ¹	71 ± 6 (Rb-Sr, w.r.) ⁴ ; 75 ± 9 (U-Pb, zir) ³ ; 69 ± ? (Ar-Ar, mu) ⁶
Whole rock comp.(s)	yes ⁵	yes ¹	yes ⁵
Normative Al ₂ O ₃		3.0-4.3%	1.7 (0.5-5.7)%
δ ¹⁸ O	9.5‰ (w.r.) ⁵	13.4‰ (w.r.) ⁴ , 14.9‰ (qz) ¹	8.1‰ (mu) ¹ , 9.5‰ (w.r.) ²
δD			-62‰ (mu) ¹
(⁸⁷ Sr/ ⁸⁶ Sr) _{initial}	0.71285 ⁴	0.7372 ¹	0.719 ± 0.002 ^{5,4}
ε _{Nd}	-18.3 ⁴ (corrected to 80 Ma)	-9.7 ³	-19.1 ⁷
Pb			yes (suggest 1.97 ± Ga) ³
Rb/Sr	0.19 ⁴	3.0 ± 0.6 ¹	0.27 ± 0.03 ⁵
REE	La/Yb~30, Eu/Eu*~1 ⁵	La/Yb~12, Eu/Eu*~0.7 ¹	
Other Trace Elements	yes ⁵	yes ¹	
References	¹ McKee and Nash (1967) ² Nelson and Sylvester (1971) ³ Pickering and Barton (unpublished data) ⁴ V. Bennett (unpublished data) ⁵ Griffis (1986)	¹ Kistler et al. (1981) ² Olson and Hinrichs (1960) ³ Farmer and DePaolo (1983) ⁴ Estimated	¹ Lee et al. (1984b) ² Lee et al. (1981) ³ Lee et al. (1984c) ⁴ Lee et al. (1980) ⁵ Best et al. (1974) ⁶ P. Gans (pers. comm.) ⁷ Farmer and DePaolo (1983)

Lithophile-element mineralization associated with Late Cretaceous two-mica granites in the Great Basin

Mark D. Barton

Name	Lexington Creek (LC)	McCullough Butte (MB)	Mount Wheeler Mine (MW)
Feature			
IGNEOUS			
Major phases	two-mica granodiorite or monzogranite ¹	two-mica monzogranite ¹	
Extent	~6 km ² ²	<0.01 km ² ²	
Mineralogy	Qz+Pc+Kspr+Mu+Bi± Ap±Zir±Fl±Mt±Ep ¹	Qz+Pc+Kspr+Mu+Bi±monazite ±Nb-rich Ilm±Ap±Zir ¹	
Textures/distribution	medium-grained, equigranular, locally porphyritic	fine-grained (~1mm) porphyritic dikes and sills, Qz+Mu+Kspr+Pc phenocrysts ^{1,2}	
Minor phases	aprites	minor aprites, felsite dikes ¹	felsite dikes ¹
Extent	<5%	a few dikes, <2m thick ¹	a few dikes, <2m ¹
Mineralogy	Qz+Kspr+Pc+Mu±?	Chl+Carb+Qz+Py±Ser±Clays after feldspar, mafics	
Textures/distribution	aplitic commonly with pegmatitic centers	fine-grained, commonly porphyritic	fine grained, porphyritic
Age(s), (methods)	86.3, 82.2, 77.9 ± 1.9 (K-Ar, Mu) ⁴	83.8 ± 1.9, 76.3 ± 6.3, 73.1 ± 6.0 (K-Ar, Mu), 47.5 ± 1.0 (K-Ar, Bi) ⁵	
Whole rock comp.(s)	yes ¹	yes ¹	
Normative Al ₂ O ₃	2.7%	2.1% ¹	
δ ¹⁸ O	10.5‰ (w.r.), 8.9‰ (Mu) ⁷	13.2‰ (w.r.), 14.2‰ (Qz) ³	
δD	-75‰ (Mu) ⁷	-54‰ (Mu) ³	
(⁸⁷ Sr/ ⁸⁶ Sr) _{initial}	0.7114 ⁵	0.71077 ^{3,4}	
ε _{Nd}		-10.2 ³	
Pb	yes (suggests pC) ⁶		
Rb/Sr	0.17 ⁵	0.25 ± 0.01 ³	
REE		La/Yb~85, Eu/Eu*~1 ³	
Other Trace Elements		yes ¹	
References	¹ Lee et al. (1981) ² Whitebread (1969) ³ Barton (unpublished data) ⁴ Lee et al. (1980) ⁵ Lee et al. (1984a) ⁶ Lee et al. (1984c) ⁷ Lee et al. (1984b)	¹ Barton (in preparation) ² Barton (1982) ³ Barton et al. (in preparation) ⁴ V. Bennett (unpublished data) ⁵ Barton and Marvin (unpublished data)	¹ Barton (unpublished data)

Lithophile-element mineralization associated with Late Cretaceous two-mica granites in the Great Basin

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Name	Pole Canyon (PC)	Rocky Canyon (RC)	Toana Range (TR)
Feature			
IGNEOUS			
Major phases	two-mica monzogranite, minor two-mica granodiorite ³	two-mica monzogranite ¹	two-mica monzogranite ²
Extent	~10 km ²	seen only in drill core	~10 km ² ⁵
Mineralogy	Qz+Pc+Kspr+Mu+Bi±Ap ±Zir±Mon±Allanite ²	Qz+Pc+Kspr(Mi)+Bi +Mu±? ¹	Qz+Pc+Kspr(Or)+Mu+Bi ±Ap±Zir ²
Textures/distribution	coarse-grained (>5 mm) with Kspr and Mu phenocrysts ³	fine--grained (~1 mm); Qz and Kspr phenocrysts (2-4 mm)	coarse-grained granite, Mu phenocrysts
Minor phases	aprites ± pegmatite dikes (<2m thick) ³		
Extent	<50% ³	<5%	widespread, but sparse
Mineralogy	Qz+Alkali fldspr+Mu±Gt±Fl ±Gahnite±Columbite±Beryl		
Textures/distribution	aprites in dikes; rarer micropegmatite		
Age(s), (methods)	79.5 (Rb-Sr, w.r.) ¹ ; aprites are reported to be 31 ³ , but are probably reset ⁵	83.8 ± 1.9 (K-Ar, Mu), 84 (Rb-Sr, Mu)	71.2 ± 2.0, 62.9 ± 1.9 75 ± 9 (K-Ar, Mu) ^{6,7} ; 128 (K-Ar, Bi) ⁷
Whole rock comp.(s)	yes ³		yes ²
Normative Al ₂ O ₃	1.7-3.5%		2.5%
δ ¹⁸ O	10.6-12.1‰ (w.r.) ²		9.1‰ (w.r.) ²
δD	-60‰ (Mu) ⁵		-62‰ (Mu) ¹
(⁸⁷ Sr/ ⁸⁶ Sr) _{initial}	0.7157 ¹		
ε _{Nd}	-16.9 ⁶		
Pb			
Rb/Sr	0.52 ± 0.05 ¹		
REE	La/Yb~40, Eu/Eu*~0.7 ⁴		
Other Trace Elements	yes ³		
References	¹ Lee et al. (1984a) ² Lee et al. (1982) ³ Lee and Van Loenen (1971) ⁴ Lee and Christiansen (1983) ⁵ Lee et al. (1984b) ⁶ Farmer and DePaolo (1983)	¹ Barton (unpublished data) ² Barton and Marvin (unpublished data)	¹ Lee et al. (1984b) ² Lee et al. (1981) ³ Lee et al. (1984a) ⁴ Lee et al. (1984c) ⁵ Stewart and Carlson (1978) ⁶ Lee and Marvin (1981) ⁷ Miller (1984)

Lithophile-element mineralization associated with Late Cretaceous two-mica granites in the Great Basin

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Name	Birch Creek (BC)	Dawley Canyon (DC)	Kern Mountains (KM)
Feature			
HOST			
Formation names and lithologies	mainly Reed dol; lesser Wyman ss, ls, sh; farther away Campito & Deep Spring (ss, ls) ¹	Prospect Mt. Quartzite; schists and quartzites (McCoy Creek equiv.); Granitoids	Nevada Fm., dolomite; Guilmotte Ls.; Pilot and Chainman Shales
Textures	massive clean dolomite, lesser quartzitic clastics ¹	quartzites and schists ¹	marbles to hornfels to tectonites ^{1,2}
Age(s)	late Precambrian to Cambrian ¹	late Precambrian to early Cambrian; Jurassic (?) granitoids ¹	Devonian to Mississippian to Pennsylvanian(?) ²
Pre-intrusion Metamorphism	in aureole of Beer Creek pluton, cuts across gradient ²	Bi+Gt±Sill grade forming schists and quartzites ²	none(?)
Extents	Beer Creek aureole extends across the BC area in Wyman and Reed ^{2,1}	pCsq on S, J(?) on W and N ¹	
Style of emplacement	forceful ¹	forceful(?) ^{1,2}	forceful ¹
References	¹ Nelson and Sylvester (1971) ² Gastil et al. (1967)	¹ Howard et al. (1979) ² Olson and Hinrichs (1960)	¹ Best et al. (1974) ² Hose and Blake (1976)

Lithophile-element mineralization associated with Late Cretaceous two-mica granites in the Great Basin

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Name	Lexington Creek (LC)	McCullough Butte (MB)	Mount Wheeler Mine (MW)
Feature			
HOST			
Formation names and lithologies	Pole Canyon Ls.; Pioche Sh. (sh and ls); Prospect Mt. Quartzite ¹	Pogonip Group (ls±dol); Eureka (ortho)Quartzite; Hanson Creek Fm. (dol) ^{1,2}	Pole Canyon Ls.; Pioche Sh. (sh and ls); Prospect Mt. Quartzite ^{1,3}
Textures	marble tectonites, ¹ contact is prob. S. Snake Range decoll.	micrites to sparites; ortho-quartzites to cc sandstones ²	quartz arenite, siltstone, argill. siltstone, rxllized ls ^{1,2,3}
Age(s)	Cambrian	Ordovician-Silurian ^{1,2}	Cambrian ¹
Pre-intrusion	not known	none? ²	chlorite grade(?) ²
Metamorphism			
Extents			regional in Cambrian and older rocks (?)
Style of emplacement	forceful (?)	?	
References	¹ Whitebread (1969)	¹ Barton (1982) ² Barton (in prep.)	¹ Whitebread (1969) ² E.L. Miller (1985, person. com ³ Whitebread and Lee (1961)

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Name	Pole Canyon (PC)	Rocky Canyon (RC)	Toana Range (TR)
Feature			
HOST			
Formation names and lithologies	Pole Canyon Ls.; Pioche Shale (sh and ls); Prospect Mt. Quartzite ¹	Secret Canyon Sh. (?); Geddes Ls.(?); Eldorado Dol.(?) ¹	Prospect Mountain Quartzite ¹
Textures	micaceous ss to siltstone to ls (marble) ¹	shale; calcareous shale; ls; dol ¹	
Age(s)	Cambrian	Cambrian	Cambrian; 75.6±2.1, 72.5±2.0 (K-Ar on metamorphic Mu) ²
Pre-intrusion	regional greenschist(?) ⁴ ; hbl	none(?), chlorite zone(?)	none(?)
Metamorphism	hnfls due to J pluton ²		
Extents	pluton intrudes Cpm with others nearby ¹	dikes in all three	
Style of emplacement	forceful ¹ ; lack of xenoliths, dips generally radiate	?	?
References	¹ Whitebread (1969)	¹ Barton (in prep.)	¹ Stewart and Carlson (1978) ² Lee et al. (1980)

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Name	Birch Creek (BC)	Dawley Canyon (DC)	Kern Mountains (KM)
Feature			
ALTERATION/ MINERALIZATION			
Igneous (types and sequence, including envelopes)	pegmatitic Qz veins; Qz veins with greisen envelopes; pervasive greisen in dikes ^{1,2}	pegmatites and quartz veins with be+tourm+colum etc.; albititized granite ²	Qz+Hb+Py+Fl+Triplite±Gn± Sph±Ccp veins w/ greisen env.; greisenization with beryl
Host (thermal)	progressive cc+dol+tc-->do+cc+tr -->do+cc+fo-->di+serp (veins) in Reed; marble, calc-hornfels in Wyman ¹	?	hornfels in pelitic units; coarse, low-Fe calcsilicates and hornfels in calcareous units with marble
Host (metasomatic; types and sequence, including envelopes)	Gt+Cpx+Id±Ep±Fl early skarn -->Ep(-->Czo)+Fl+Pc-->Chl veins w/ similar(?) envelopes-->Mu+Fl± Be±Qz veins w/ Fl envelopes--> Qz+sulfide veins-->silicified carbonate ²	intruded by pegmatites ²	stockwork of veins and skarn; associated with border aplite and related dikes; Gt+Id+Cpx±Ep± Hbl skarn; Pc+Czo+Fl veins w/ Bi envelopes; Mu+Fl vein; Qz+ Mu+Fl veins ³ ; Qz+Td+Fl+Sch veins in dol ²
Extent of thermal	up to 500 m; see (1) for details		>1000 m from contact
Extent of metasomatic	skarn concentrated on NW contact; widespread Qz-base-metal veins to N, W, and S ²	pegmatites extend < 200 m from contact ²	100-200 m from contact, anhydrous is closest in; veins >300m are <1m thick ³
Mineral compositions	Gt(Gr ₄₅ Ad ₅₀ -->Gr ₄₀ Ad ₅₀ , minor early Ad ₉₅) ²		
Isotopic compositions			C,O,H indicate magmatic
Fluid compositions	H ₂ O(CO ₂)≤moderate salinity fluid inclusions ²	H ₂ O(CO ₂)≤moderate salinity fluid inclusions in Qz and Be ¹	H ₂ O(CO ₂)≤moderate salinity fluid inclusions in Id, etc., sometimes with carbonate daughter ³
P (methods)	2 ± 1 kb ³ (strat. recon.)	>3 (strat. recon.) ³ ; ≥ 3.5 (mu breakdown) ⁴	1.5 - 2 kb (strat. recon.) ¹
T (ranges, methods)			
Elements added	Al,Fe,Si,F,Be,W,Cu, (Au,Ag,Pb,Zn,Sb)	(Be,Nb,Ta,B),Na	Si,Al,Fe,W,F,K,Na,Cu, Ag,Sb
Resource potential	~0.5 km ² of 5-10% stockwork skarn containing up to 60% Fl, 5% Sch, 2% Be, but averaging much less (10%, 0.1%, 0.05%?); small precious metal production ^{2,4}	a small amount of muscovite production; >20 small beryl- bearing pegmatites (≤0.1% BeO) ²	<20,000 tons of 0.5% WO ₃ from granite; stockwork skarn occurs sporadically along >3 km of contact containing <0.1% WO ₃
References	¹ Nelson and Sylvester (1971) ² Pickering and Barton (unpublished data) ³ estimated ⁴ Diggles and Blakely (1983)	¹ Barton (unpublished data) ² Olson and Hinrichs (1960) ³ estimated ⁴ Kistler et al. (1981)	¹ estimated ² Hose and Blake (1976) ³ Barton (unpublished data)

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Name	Lexington Creek (LC)	McCullough Butte (MB)	Mount Wheeler Mine (MW)
Feature			
ALTERATION/ MINERALIZATION			
Igneous (types and sequence, including envelopes)	abundant greisenization; deuteri- c alteration with Qz±Fl±Mu±Ep veins ^{1,2}	Qz and pegm. veins-->bleached and greisenized (Mu+Fl+Czo± Ap) envelopes ^{2,1}	
Host (thermal)	marble	progressive Tr-->Di-->Wo (± Tc in dol); mssv near Qtzite contacts, ab. marble nr center ^{1,2}	chlorite+biotite in Pioche, marble in Pole Canyon ls ¹
Host (metasomatic; types and sequence, including envelopes)	Gt+Cpx+Amph+Ep early skarn -->Qz+Mu+Fl veins ²	stockwork veins and skarn; Gt+ Cpx±Id±Fl-->Pc and/or Ep +Fl ±Chl±Sch±Py±Sph±Ap veins w/ Amph+Chl+Fl+... skarn-->Mu+ Fl±Be±Ap±Sph±Py±Carb vein w/ Fl+Phl±Act±Py±... skarn-->Qz+ Fl±Mu±Carb±Py veins-->Qz+ Carb±Bar±Ag sulfosalt veins ²	Mu+Fl±Be mineral±Sch veins w/ Phl±Fl envelopes w/ later Qz+Mu+Fl±Be±Ph±Bt±Sch± Carb±Wolf veins; Qz+Carb±Sch veins in marble; nearby base- metal silica veins ^{1,2}
Extent of thermal	?	>3000 m from center of system	?
Extent of metasomatic	?	Gt<800m; Pc<1200m; Mu<2000m; Qz<3000m; Ag>4000m; all but Qz and Ag in carb. ^{2,1}	>3 x 3 km ^{2 1}
Mineral compositions		yes ^{2,1} ; Gt(Gr ₈₅₋₄₅ Ad ₁₀₋₄₀); Cpx (Di ₄₅₋₅ Hd ₅₀₋₉₅); others	
Isotopic compositions		mostly magm. C,O,H; meteoric in late veins; heavy sulfur ^{3,1}	
Fluid compositions		H ₂ O(CO ₂)≤moderate salinity fluid inclusions often with carb. daughter ³	H ₂ O(CO ₂)≤moderate salinity fluid inclusions ¹
P (methods)	2.5 ± 0.5 kb ³ (strat. recon.)	2 ± 0.5 kb (strat. recon.) ²	2.5 ± 0.5 kb (strat. recon.) ³
T (ranges, methods)		>500(igneous, anhyd. skarn) to 400-500 (Pc-Ep-Amph) to <350 (Mu,Qz); isotope and phase ³	
Elements added	Al,Fe,Si,F,W(?)	Si,Al,F,Fe,K,Na,Be,W,Sn, Zn,Ag,Bi,Cu,Mo	Si,Al,F,Be,W,Sn,Ag,Pb
Resource potential	abundant greisen in pluton; minor skarn containing only Fl on one side (the contact is mostly a fault) ²	>110 M tons of >10% CaF ₂ ; probably ~10 ⁹ tons skarn with >5% CaF ₂ , ~1% Zn, 100-1000 ppm W, 20-200 ppm Be,Mo,Sn	>>100 K tons 20% CaF ₂ , 0.5% WO ₃ , 0.7% BeO; poss. >10 M tons in the area, much is mineralized, but unexplored
References	¹ Whitebread (1969) ² Barton (unpublished data) ³ estimated	¹ Barton (1982) ² Barton (in prep.) ³ Barton et al. (in prep.)	¹ Barton (unpublished data) ² Stager (1960) ³ estimated

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Name	Pole Canyon (PC)	Rocky Canyon (RC)	Toana Range (TR)
Feature			
ALTERATION/ MINERALIZATION			
Igneous (types and sequence, including envelopes)	aprites and pegmatites; Qz veins w/ Py+Mol+Mu w/ greisenized/ argillized envelopes ¹	Qz+Py+Mu+Fl veins in greisenized granite ¹	
Host (thermal)	marble and coarse mica schists (perhaps due in part to the Snake Creek pluton) ¹	calc-silicate hornfels (domin. Cz+Tr+Di) in Secret Canyon Shale ¹	schists with Late Cretaceous K-Ar ages ¹
Host (metasomatic; types and sequence, including envelopes)	skarn veins w/ envelopes in carb. Gt±Cpx±Wo±Fl assoc. w/ dikes of aprite in some cases-->Ep and/ or Pc +Fl±Chl ... veins w/ Fl- rich envelopes-->rare Mu+Fl±Be ±Py-->massive Qz veins ±Mu± Py±Carb±Be (sparse) ¹	Cpx±Gt±Id±Fl skarn-->Qz+Fl +... veins in Amph±Tr+Mt±Py ±Sch±Mol+Fl+Qz±Cc skarn	?
Extent of thermal	>400 m (?) ¹	>400 m ¹	?
Extent of metasomatic	>400 m (?) ¹	>400 m ¹	
Mineral compositions			
Isotopic compositions			
Fluid compositions	H ₂ O(CO ₂)≤moderate salinity fluid inclusions with carbonate daughter minerals ¹	H ₂ O(CO ₂)≤moderate salinity fluid inclusions ²	
P (methods)	2.5 ± 0.5 kb (strat. recon.) ²	2.0 ± 0.5 kb (strat. recon.) ¹	2.5 ± 0.5 kb (strat. recon.) ²
T (ranges, methods)			
Elements added	Si,Al,F,Fe,Be,Na,K	F,S,W,Mo	
Resource potential	<5% veins+skarn in marble along >200m of Pole Canyon/ Pioche contact; only small amounts of Sch and Be seen ¹	abundant stockwork skarn veins in hornfels(?) exposed in 430 m drill hole; known over area >200 x 600 m ¹	?
References	¹ Barton (unpublished data) ² estimated	¹ Barton (in prep.) ² Barton (unpublished data)	¹ Lee et al. (1980) ² estimated

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