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Preliminary Geologic Map of the McDermitt Caldera, Humboldt County, Nevada and Harney and Malheur Counties, Oregon

by

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INTRODUCTION

The McDermitt caldera of northern Nevada and southeastern Oregon is a large, 16.4 Ma volcanic center that is commonly recognized as the starting point of the Yellowstone hotspot, which migrated northeastward over time to the Yellowstone National Park area where volcanism continues to be intensely active (Pierce and Morgan, 1992, 2009). New geologic mapping and analytical studies by geologists with and working with the Nevada Bureau of Mines and Geology reveal the overall characteristics, dimensions, timing, and relation to mineralization of the caldera. The caldera formed when about 1000 km^3 (about 250 mi^3) of mostly rhyolite magma erupted from an underlying chamber. So much magma erupted that the overlying ground collapsed into the resulting void, leaving a giant depression–a caldera–that was about 40 km north-south by 22 to 30 km east-west. The giant eruption was preceded by additional volcanism that began about 16.85 Ma and was followed by volcanism that lasted episodically until about 14.9 Ma. Hydrothermal activity related to the volcanism generated numerous known and probable mineral deposits in and around the caldera, especially of the strategically important minerals lithium, uranium, and gallium. Additional, currently unknown areas and types of mineral deposits are likely.

MAJOR EVENTS: CENOZOIC VOLCANISM AND DEVELOPMENT OF THE MCDERMITT CALDERA

46.7 and 39.2 Ma. Two pulses of dacite to andesite lavas (Tv_1, Tv_2) were deposited along what became the western margin of the caldera.

≥16.69±0.02 Ma. Steens Basalt lavas (Tsb, Tb) began to erupt from unknown sources and flowed into what became the northwestern part of the caldera. Eruptions were nearly continuous until caldera formation. Lava flows became more silicic with time, progressing irregularly through icelandite (Tsi, Fe-rich andesite; Wallace et al, 1980) and anorthoclase-phyric rhyolite (Tra) to aphyric high-Si rhyolite (Tar). At least the more silicic rocks had local sources.

16.69±0.02 to 16.35±0.04 Ma. Silicic magmatism began based on the range of ages on sparsely anorthoclase-phyric rhyolite lavas from the lowest exposed unit underlying icelandites north of the caldera (Tral) to similar rhyolite lavas in the northern and eastern wall (Tra, Tra_2, Tram, Trau). At **16.65±0.01 Ma**, the anorthoclase-phyric ash-flow tuff (Tta) was emplaced along the western wall, possibly a pyroclastic eruption related to the lavas.

16.62±0.02 Ma. The first of three pulses of biotite-quartz-sanidine-plagioclase, metaluminous rhyolites was emplaced as lavas and lava domes of the Moonlight Mine (Tbr) along what became the southwestern margin of the caldera.

16.56±0.02 and 16.49±0.03 Ma. The tuffs of Oregon Canyon (Tto) and Trout Creek Mountains (Ttt),

widespread peralkaline ash-flow tuffs, flowed into the area from the northwest or west.

16.49±0.02 Ma. Biotite-hornblende-quartz-sanidine-plagioclase rhyolite of Mendi Suri was emplaced as two lava domes or shallow intrusions (Tbrm) 5 km northeast of the caldera.

16.40±0.02 Ma. Deposition of one or more sanidine-quartz±sodic amphibole-phyric peralkaline rhyolite lavas around the western, southwestern, and southeastern margins of caldera (Tprw, Tprs, Tpre).

~16.60-16.40 Ma. Numerous aphyric rhyolites (Tar) were emplaced around most of the caldera except in the area that became the western and northwestern margins.

16.38±0.07 to 16.36±0.02 Ma. Eruption of at least three biotite-sanidine-quartz-plagioclase rhyolite flows of Hoppin Peaks (Tbrh) outside of what was to become the eastern margin of the caldera.

16.35±0.03 Ma (n = 5). Eruption of the McDermitt Tuff (Tmt, our proposed new name) and formation of the McDermitt caldera. The tuff is strongly zoned from peralkaline, aphyric high-Si rhyolite to anorthoclase-rich, Fe-rich dacite and icelandite. Intense rheomorphic flow intimately intermixed these rock types in the caldera. Most of the McDermitt Tuff ponded in the caldera. Thin outflow (mostly ≤50 m thick) was deposited north, west, and south of the caldera.

16.34±0.06 Ma. Hydrothermal activity that generated the Moonlight U deposit, adjacent U mineralization along the western margin of the caldera, and possibly other widespread areas of U mineralization.

16.4-16.1 Ma. A large area of post-collapse resurgent uplift formed in the caldera. Intra-caldera volcanism consisting dominantly of icelandite lavas (Til, Tia) with lesser dacitic to rhyolitic lavas (Trm) were extruded widely in the caldera, including two major vent areas (Tiv, Round Mountain and Black Mountain) on the resurgent dome. As much as 200 m of tuffaceous lacustrine sedimentary deposits (Tis) accumulated in the caldera.

15.67±0.05 Ma. Eruption of the tuff of Whitehorse Creek and formation of the Whitehorse Creek caldera (Rytuba and McKee, 1984) 22 km northwest of the McDermitt caldera.

14.90±0.74 Ma. Emplacement of late basaltic (Tbl, high-alumina olivine tholeiite) lavas in the southeastern part of the caldera and a small plug in the northern part.

14.87±0.05 Ma. Formation of K feldspar spatially and probably temporally related to Li mineralization in tuffaceous sedimentary deposits.

KEY POINTS

1. The McDermitt caldera is a single volcanic-collapse structure resulting from eruption of one major ash-flow tuff (the McDermitt Tuff of this study) at 16.35 Ma. We find no evidence for four other proposed calderas nested with the McDermitt caldera (Rytuba and McKee, 1984).

2. The caldera is areally large (30 x 40 km), but collapse seems to have been relatively "thin". The caldera is highly visible on satellite images, particularly along its northern margin. Intracaldera tuff is as much as 600 m thick where a complete section from pre-collapse rocks to moat sediments is exposed along the western margin by basin-and-range faulting and may reach as much as 800 m thick. This thickness is remarkably less than the commonly 2 to 4 km thicknesses of intracaldera tuffs in calderas related to the 37–19 Ma ignimbrite flareup (Henry and John, 2013).

3. Total erupted volume of the McDermitt Tuff is ~600 to as much as 1000 km^3, of which at least 50% and possibly as much as 85% ponded in the caldera. Outflow tuff crops out up to 12 km south of the southern caldera margin and up to 20 km north of the northern margin but was probably never much more extensive. Except where it filled local topographic lows, the outflow tuff is no more than ~50 m thick, and outflow volume was likely <270 km^3.

4. Collapse is expressed in different ways around the caldera margin, although a narrow structural boundary separating thick intracaldera rocks from the caldera wall is ubiquitous. The structural margin is a mix of a single ring fault, a major ring fault with parallel lesser faults, and both with downwarp toward the caldera between faults. The eastern margin contains a complex series of major north- to north-northeast-striking faults that are bounded on the north by an east-northeast fault that may have reactivated an older structure (e.g. near the Cordero Mine).

5. Abundant basaltic (Steens Basalt) volcanism began possibly 500 ka earlier than eruption of the McDermitt Tuff and caldera collapse, and silicic lavas began to erupt as early as 16.69 Ma.

6. Middle Miocene magmatism around McDermitt was predominantly alkaline and peralkaline but included three, major, spatially and temporally overlapping pulses of biotite-bearing, metaluminous rhyolite lavas, lava domes, or shallow intrusions.

7. Abundant mineralization in and around the McDermitt caldera includes Hg, Ga, Mo, U, Zr, Li, and Au (Yates, 1942; Fisk, 1968; Wallace and Roper, 1981; Roper and Wallace, 1981; Rytuba and Glanzman, 1979; Castor and Henry, 2000; Rytuba et al., 2003; Western Lithium NI43-101, 2014). All were likely related to caldera formation and development. Adularia in U-Zr±Mo±Au±Ag deposits in the western part of the caldera is 16.34±0.06 Ma, indistiguishable from the age of the McDermitt Tuff, but younger based on field relations. Geochemically different U enrichment in the north part of the caldera may have taken place at about the same time. The Hg deposits in the north and northeast part of the caldera, mined for many years, were deposited at 15.7±0.4 Ma on the basis of K-Ar dated adularia at the Cordero or McDermitt Mine (Noble et al., 1988). Lithium deposits in tuffaceous intracaldera sediments probably formed at 14.87±0.05 Ma based on the age of spatially related K-feldspar.

UNIT DESCRIPTIONS

Quaternary Deposits

Qm Mine dumps

Qa Alluvium

Qf Alluvial fan deposits

Qls Landslide deposits

Qc Colluvium and talus

Qb Beach deposits

Qfo Older alluvial fan deposits

Postcaldera Rocks

Tbl Late basaltic lavas (high-alumina olivine tholeiite) Overlying or interbedded with the uppermost parts of the intracaldera sedimentary deposits (Tis) in the southern part and a small plug intruded into Tis in the northern part of the caldera. Aphyric to moderately porphyritic with phenocrysts of plagioclase, clinopyroxene, and olivine. One analyzed sample is high-alumina olivine tholeiite. $^{40}Ar/^{39}Ar$ date: 14.90±0.74 Ma (matrix, WLC67-13.5)

Tis Intracaldera sedimentary deposits (moat sediments) Poorly to locally well exposed, variably lithified, predominantly tuffaceous sedimentary rocks. Generally coarsens upward from silicified conglomerate and breccia to well-bedded, tuffaceous sandstone, siltstone, and mudstone. Largely covered by Quaternary deposits in eastern and southern parts of caldera. Predominant host for lithium mineralization, both where it crops out and where covered.

Late icelandite vents and lavas Locally interbedded with lowest Tis. Definite vents (Tiv) at Black and Round Mountains consist of rims of dense, locally glassy icelandite surrounding agglutinated scoria. Lavas (Til) from these and probably other sources are sparsely to moderately porphyritic with plagioclase, (anorthoclase in the most silicic rocks), clinopyroxene, and fayalite. Aurora lavas (Tia) are a distinctive set of flows in the northern part of the caldera. $^{40}Ar/^{39}Ar$ dates: 16.08±0.10 Ma (plagioclase, Til, 09-McD-53), 16.41±0.02 Ma (anorthoclase, Tia)

Tiv Vent complex

Til Lavas

Tia Aurora lavas

Trm Rhyolite of McDermitt Creek (Greene, 1972, 1976). Group of low-SiO_2 rhyolite lavas that crop out in the northeastern part of the caldera. Moderately to abundantly porphyritic with phenocrysts of anorthoclase (plagioclase in least silicic rocks), clinopyroxene, and locally a trace of fayalite. $^{40}Ar/^{39}Ar$ dates: 16.42±0.02 Ma (anorthoclase, H04-55), 16.39±0.10 Ma (anorthoclase, 10-McD-225)

Tlm Late mesobreccia A thick sequence of matrix-supported breccia with clasts up to 80 cm in diameter that caps intracaldera McDermitt Tuff (Tmt) in the southwestern part of the caldera was mapped separately (Castor et al., 1982) because it is not overlain by more tuff.

McDermitt Tuff

Tmt McDermitt Tuff Main ash-flow tuff sequence. Zoned, peralkaline, aphyric, high-SiO_2 rhyolite to non-peralkaline, abundantly anorthoclase-phyric, high-SiO_2 trachydacite and icelandite. Phenocrysts are anorthoclase with sparse clinopyroxene and fayalite. Filled McDermitt caldera to possibly as much as 800 m thick, where it is generally strongly rheomorphic. Also spread as outflow as much as 25 km to the north and west (Rytuba et al., 1983; Minor, 1986) and 13 km to the south, where it is locally rheomorphic where it flowed over steep topography.

Tmtu Late intracaldera tuff Sparsely anorthoclase-phyric, moderately rheomorphic ash-flow tuff that overlies mesobreccia and caps the section above the Moonlight Mine.

Tmb Megabreccia blocks and mesobreccia Blocks of precaldera rocks, mostly biotite rhyolite of Moonlight Mine (Tbr) up to 30 m in diameter, surrounded by intracaldera McDermitt Tuff (Tmt). Mesobreccia layer in upper part of Moonlight Mine section has clasts of peralkaline rhyolite (Tprw), biotite rhyolite (Tbr), and Steens Basalt (Tsb). Best exposed in complete sections above Moonlight Mine and in Horse Canyon.

Tmv Vitrophyric tuff dikes Densely welded, abundantly anorthoclase-phyric, low-SiO_2 rhyolite and high-SiO_2 trachydacite form a series of generally northeast-striking vitrophyric dikes, especially south of Calavera Canyon where they cut intracaldera McDermitt Tuff (Tmt). Also present as a more irregular dike that cuts Steens Basalt (Tb) south of Little Peak. Probably feeders to late eruptions of McDermitt Tuff.

Precaldera Rocks

Western Caldera Wall

Tprw Peralkaline rhyolite lava Moderately porphyritic, peralkaline rhyolite crops out in the western, southern, and eastern caldera walls, as either a single, discontinuously exposed flow or similar separate flows. Phenocrysts consist of chatoyant sanidine, smoky quartz, clinopyroxene, arfvedsonite (possibly vapor phase), aenigmatite, and monazite. $^{40}Ar/^{39}Ar$ date on Tprw: 16.40±0.02 Ma (sanidine, C95-107).

Tbr Biotite rhyolite lavas and domes of the Moonlight Mine Series of lavas and/or lava domes that crop out at the Moonlight Mine and south to Thacker Pass and commonly form lithics in McDermitt Tuff. Contains phenocrysts of plagioclase (generally altered), sanidine, biotite, and minor quartz. $^{40}Ar/^{39}Ar$ date: 16.62±0.02 Ma (sanidine, C95-103A).

Traw Sparsely anorthoclase-phyric rhyolite lava Single rhyolite lava interbedded with unit Tsi in Horse Canyon. Similar to units Tra_2, Tra, Trau, and Tram.

Tta Anorthoclase-phyric tuff Crops out in a 2 km north-south band along the caldera wall north of Horse Canyon. Phenocrysts consist of anorthoclase as the only feldspar, which distinguishes it from other pre-caldera tuffs all of which contain sanidine, clinopyroxene, and a trace of quartz. Oldest known middle Miocene tuff in the region. $^{40}Ar/^{39}Ar$ date: 16.65±0.01 Ma (anorthoclase, C05-280).

Steens Basalt (Tsb, Ts) and Steens-type (Tsi) rocks Steens Basalt crops out around the northwestern wall of the caldera as far south as Horse Canyon and especially at Disaster Peak and along Orevada View, but may exist elsewhere in the subsurface beneath Steens-type rock. Steens-type rock is widely distributed around the western, northern, and eastern caldera wall.

Tsi Steens-type mafic to intermediate lavas Steens geochemical type consists of mafic to intermediate aphyric to sparsely plagioclase-phyric lavas, including icelandite, that overlie the tuffs of Oregon Canyon or Trout Creek Mountains.

Ts Steens basalt Predominantly aphyric basalt flows. Division between Ts and Tsb is placed at the top of observed coarsely plagioclase-phyric lavas.

Tsb Steens basalt Numerous, thin (≥2 m) basalt to basaltic andesite lavas that include both aphyric lavas and the coarsely plagioclase-phyric lavas common to the Steens Basalt. Porphyritic varieties contain phenocrysts of plagioclase up to 6 cm long, as well as 2–3 mm diameter olivine and clinopyroxene. $^{40}Ar/^{39}Ar$ date: 16.69±0.02 Ma (anorthoclase, H05-26 on anorthoclase rhyolite lava interbedded with unit Tsb northeast of map area). Overall timing of Steens Basalt ~16.85 to ~16.56 or 16.49 Ma (ages of the tuffs of Oregon Canyon and Trout Creek mountains) based on this study and Camp et al. (2013).

Tvs Volcaniclastic sedimentary deposits Consists of conglomerate, sandstone, mudstone, and siltstone that crops out in Horse Canyon beneath Steens Basalt. Conglomerate contains clasts of granitic rock, probable Eocene volcanic rocks, and possible Miocene volcanic rocks (≤10 cm, mostly ≤1 cm). Presence of accretionary lapilli, shard- and biotite-bearing ash beds in the upper part of the unit, and fining-upward bed sets indicate deposition during active volcanism, which was probably the earliest part of middle Miocene activity.

Northern Caldera Wall

Tra_2 Sparsely anorthoclase-phyric rhyolite lava Similar to units Traw, Tra, Trau, and Tram. Underlies outflow McDermitt Tuff in the northeastern caldera wall. $^{40}Ar/^{39}Ar$ date: 16.46±0.02 Ma (anorthoclase, C04-07).

Ttt Tuff of Trout Creek Mountains Regional, strongly peralkaline, rhyolite ash-flow tuff containing phenocrysts of sanidine, quartz, arfvedsonite, aegirine-augite, and aenigmatite. Crops out as a continuous ledge below outflow McDermitt Tuff in the northwestern wall of the caldera and discontinuously eastward to ~2 km east of the Bretz Mine, where it pinches out. $^{40}Ar/^{39}Ar$ dates: 16.49±0.03 Ma (sanidine, mean of 4).

Tbrm Biotite rhyolite lava domes of Mendi Suri Two, light colored, ~1.5 km wide and ≥140 m thick lava domes at the northeastern corner of the map area where they are overlain by Steens-type rocks (Tsi). Phenocrysts consist of sanidine, plagioclase, quartz, biotite, and a trace of hornblende. $^{40}Ar/^{39}Ar$ date: 16.49±0.02 Ma (sanidine, H05-28)

Tsi Steens-type lavas mostly icelandite (see description of Tsi in western caldera wall)

Tra Sparsely anorthoclase-phyric rhyolite lavas Crop out in and around Cottonwood Canyon. Similar to units Traw, Tra_2, Trau, and Tram.

Tsi Steens-type lavas (see description of Tsi in western caldera wall).

Tvu Volcanic rocks undivided Probably consists of rocks of units Tsi, Tra, in areas not mapped in detail.

Tto Tuff of Oregon Canyon Regional moderately peralkaline, rhyolite ash-flow tuff containing phenocrysts of sanidine, quartz, clinopyroxene, and aenigmatite. Crops out discontinuously beneath younger rocks in the northern wall. $^{40}Ar/^{39}Ar$ date: 16.56±0.02 Ma (sanidine, mean of 4).

Taro Older aphyric rhyolite lavas Series of rhyolite lavas that underlie and are partly interbedded with Steens-type rocks (Tsi) in the northeastern wall. Probably the oldest aphyric rhyolites in the area.

Tarv Older aphyric rhyolite vent Subcircular area ~1 km in diameter with inward-dipping layers of massive to highly pumiceous, aphyric rhyolite and breccia. Probably vent for adjacent aphyric rhyolite lavas.

Tral – Sparsely anorthoclase-phyric rhyolite lava (north of map area)

Ts, Tsb Steens Basalt (see descriptions of units in western caldera wall).

Eastern Caldera Wall

$Tbrh_{1-3}$ Biotite rhyolite lavas of Hoppin Peaks Sequence of three biotite-bearing rhyolite lavas, commonly with basal vitrophyres and breccias, that cap Hoppin Peaks. Phenocrysts consist of quartz, sanidine, plagioclase, biotite, and a trace of clinopyroxene. $^{40}Ar/^{39}Ar$ dates: 16.36±0.02 and 16.38±0.07 Ma (sanidine on uppermost and lowermost of lavas, H04-53 and H04-51, respectively).

Trau Sparsely anorthoclase-phyric rhyolite lavas Series of lavas that underlie biotite rhyolite of Hoppin Peaks (Tbrh) and overlie Steens-type rocks (Tsi). Probably continues farther south along west side of Long Canyon than mapped. Similar to units Traw, Tra_2, Tra, and Tram. $^{40}Ar/^{39}Ar$ date: 16.40±0.06 Ma (anorthoclase, H04-49).

Tar Aphyric rhyolite lavas Series of aphyric rhyolite lavas that make up most of the southeastern and southern caldera walls.

Tpre Peralkaline rhyolite lava Similar to Tprw in phenocryst assemblage and composition and possibly same flow. Crops out along ~1 km of the southeastern caldera wall north of Pole Creek where it underlies aphyric rhyolite lavas (Tar) and overlies an icelandite (Tsi). See description in western caldera wall.

Tram Sparsely anorthoclase-phyric rhyolite lava Same as rhyolite of McConnell Canyon of Greene (1972, 1976). $^{40}Ar/^{39}Ar$ date: 16.49±0.08 Ma (anorthoclase, 09-McD-33)

Tsi Steens-type lavas (see description of Tsi in western caldera wall).

Southern Caldera Wall

Tar Aphyric rhyolite lavas Thick unit that makes up most of the southern caldera wall, where it underlies outflow McDermitt Tuff.

Tprs Peralkaline rhyolite lava Similar to Tprw in phenocryst assemblage, composition, and age and possibly same flow. See description in western caldera wall. $^{40}Ar/^{39}Ar$ date: 16.40±0.02 Ma (sanidine, 11-McD-290).

Tvu Volcanic rocks, undivided Probably consists mostly of aphyric rhyolite or other lavas in areas not mapped in detail.

Eocene Volcanic Rocks

Tv_2 39 Ma andesite Sequence of andesite lava flows with phenocrysts of plagioclase, biotite, and clinopyroxene that is poorly exposed along the western wall of the caldera. $^{40}Ar/^{39}Ar$ date: 39.18±0.12 Ma (plagioclase, 11-McD-311).

Tv_1 47 Ma dacite and andesite Porphyritic dacite to andesite lavas and minor dikes containing phenocrysts of plagioclase, biotite, and hornblende that crop out along the western wall of the caldera. Interbedded volcaniclastic rocks contain angular to rounded blocks of the volcanic rocks and sparse granitic rocks to 40 cm in diameter. Rests

on Cretaceous granodiorite (Kg). $^{40}Ar/^{39}Ar$ date: 46.74±0.41 Ma (plagioclase, MD-6).

Cretaceous Granodiorite

Kg Granodiorite and related intrusive rocks Main intrusion composed of quartz, plagioclase, orthoclase, biotite, and hornblende. Cut by irregular bodies of diorite and felsic to mafic dikes. Cretaceous, possibly ~101 or 94 Ma based on U-Pb zircon dates in the Santa Rosa Range to the east (Brown and Hart, 2013).

All cited $^{40}Ar/^{39}Ar$ dates are in table 1.

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TABLE 1

$^{40}Ar/^{39}Ar$ Dates of Igneous Rocks and Mineralization, McDermitt Caldera, Nevada and Oregon.

Area[1]	Sample	Unit	Mineral	Age (Ma)	±2s	K/Ca	±2s	n[3]	Latitude	Longitude	Mass Spec
Single Crystal Analyses				wtd mean[2]					NAD27		
Postcaldera rocks											
NW	MD-8	tuff of Whitehorse Creek	sanidine	**15.67**	0.05	49.8	125.6	18	42.20254	-118.18473	MAP-215-50
N	H11-199	Tia, Aurora lava, icelandite	anorthoclase	**16.410**	0.020	4.1	3.1	13	42.02541	-117.92870	Argus VI
NE	H04-55	Trm, rhyolite of McDermitt Creek (Greene, 1976)	anorthoclase	**16.417**	0.018	1.3	1.0	15	41.96699	-117.83488	Argus VI
NE	10-McD-225	Trm, rhyolite of McDermitt Creek (Greene, 1976)	plag-anorthoclase	**16.39**	0.10	0.8	0.9	9/15	42.00636	-117.86027	MAP-215-50
McDermitt Tuff		Mean of 5 McDermitt Tuff		**16.35**	0.03						
NW	H12-259	Tmv, northwestern tuff dike	anorthoclase	**16.374**	0.008	6.8	5.3	12	41.93443	-118.17275	Argus VI
N	H05-23P	Tmt, northern outflow	anorthoclase	**16.386**	0.008	6.0	3.3	12	42.06038	-117.86914	Argus VI
N	H04-40	Tmt, northern intracaldera, highly rheomorphic	anorthoclase	**16.348**	0.014	6.4	1.9	14	42.01573	-117.94867	Argus VI
W	H95-103	Tmv, western tuff dike	anorthoclase	**16.301**	0.024	4.3	3.4	15	41.78900	-118.14500	Argus VI
S	H07-191	Tmt, southern outflow	anorthoclase	**16.346**	0.010	7.4	5.1	8	41.55587	-118.05610	Argus VI
Precaldera rocks											
N	H04-39	Tra, anorthoclase rhyolite lava	anorthoclase	**16.35**	0.04	7.0	4.4	15	42.05767	-117.91479	MAP-215-50
E	H04-53	Tbrh, biotite rhyolite lava of Hoppin Peak, highest	sanidine	**16.362**	0.024	24.6	3.7	14	41.85060	-117.81474	Argus VI
E	H04-51	Tbrh, biotite rhyolite lava of Hoppin Peak, lowest	sanidine	**16.384**	0.069	24.4	13.3	15	41.87344	-117.83797	Argus VI
E	H04-49	Trau, anorthoclase rhyolite lava	anorthoclase	**16.397**	0.061	7.4	4.4	14	41.89883	-117.81177	Argus VI
W	C95-107	Tprw, peralkaline rhyolite lava, Moonlight Mine	sanidine	**16.399**	0.016	133	159	12	41.78833	-118.15333	Argus VI
SW	11-McD-290	Tprs, peralkaline rhyolite lava	sanidine	**16.404**	0.018	256	743	7	41.63468	-118.10511	Argus VI
NE	H04-47	Tra, anorthoclase rhyolite lava, Oregon Canyon	anorthoclase	**16.40**	0.04	10	17.2	19	42.23777	-117.98662	MAP-215-50
N	C04-07	Tra_2, anorthoclase rhyolite lava	anorthoclase	**16.462**	0.018	6.3	1.4	12	42.04817	-117.87184	Argus VI
NE	H05-28	Tbrm, biotite rhyolite dome of Mendi Suri	sanidine	**16.487**	0.015	83.2	47.7	3/3	42.09532	-117.87168	Argus VI
E	09-McD-33	Tram, anorthoclase rhyolite lava (McConnell Canyon)	anorthoclase	**16.49**	0.08	2.5	2.4	13	41.88367	-117.87946	Argus VI
N	mean of 4	Ttt, tuff of Trout Creek Mts	sanidine	**16.49**	0.03	~500					MAP-215-50
N	mean of 4	Tto, tuff of Oregon Canyon	sanidine	**16.56**	0.02	144	27				MAP-215-50
W	C95-103A	Tbr, biotite rhyolite dome, Moonlight Mine	sanidine	**16.619**	0.020	26.7	13.4	13	41.78833	-118.15417	Argus VI
W	C05-280	Tta, anorthoclase-phyric tuff	anorthoclase	**16.651**	0.008	8.8	4.3		41.90204	-118.16437	Argus VI
NE	H05-26	Tral, anorthoclase rhyolite lava	anorthoclase	**16.691**	0.021	5.9	1.9	11	42.18131	-117.91709	Argus VI

Step Heating Analyses				Ages (Ma)												
				plateau	±2s	$\%^{39}Ar$[4]	steps[4]	isochron	±2s	$^{40}Ar/^{36}Ar_i$	±2s	total gas	±2s			
Mineralization																
S	WLC43-180.2	K-feldspar alteration in Li deposits	K feldspar	**14.87**	0.05	54.4	7/16	**15.24**	0.26	172.9	78.1	14.92	0.03	41.70949	-118.06058	Argus VI
W	C95-105	adularia, Moonlight Mine U mineralization	adularia	**16.34**	0.06	94.9	9/13					16.38	0.12	41.7880	-118.1597	MAP-215-50
Postcaldera rocks																
SE	WLC67-13.5	Tbl, late basalt (high-alumina olivine tholeiite)	matrix	**14.90**	0.74	92.5	11/13	**15.89**	1.1	291.6	5.5	15.18	1.16	41.71017	-118.07190	Argus VI
SW	09-McD-53	Til, late icelandite lava	plagioclase	**16.08**	0.10	93.8	9/10	**16.12**	0.03	273	13	15.76	0.10	41.74001	-118.10789	Argus VI
Miocene precaldera rocks																
N	C04-06	Tsi, Steens-type icelandite lava	plagioclase	**16.53**	0.16	80.6	8/10	**16.53**	0.19	295.0	11.5	16.57	0.17	42.04800	-117.87212	MAP-215-50
Eocene volcanic rocks																
W	11-McD-311	Tv_2, andesite lava	plagioclase	**39.18**	0.12	94.2	9/10	**39.09**	0.22	319.6	86.8	39.02	0.17	41.87447	-118.15990	Argus VI
W	MD-6	Tv_1, dacite lava	plagioclase	**46.74**	0.41	80.4	8/10	**46.90**	0.27	277.0	14.7	46.30	0.28	41.91674	-118.18456	MAP-215-50

Ages in bold are best estimates of emplacement or deposition age. All $^{40}Ar/^{39}Ar$ analyses done at the New Mexico Geochronological Research Laboratory (methodology in McIntosh et al., 2003). Neutron flux monitor Fish Canyon Tuff sanidine (FC-1) with assigned age = 28.201 Ma (Kuiper et al., 2008). Minerals were separated from crushed, sieved samples by standard magnetic and density techniques, feldspars were leached with dilute HF to remove matrix, and all were handpicked.

Decay constants after Min et al. (2000); $l_{total} = 5.463 \times 10^{-10}\ yr^{-1}$. Isotopic abundances after Steiger and Jäger (1977); $^{40}K/K = 1.167 \times 10^{-4}$

1 Area of caldera or caldera wall, N = north, etc. Italics = outside map area.

2 wtd mn = weighted mean. Weighted mean $^{40}Ar/^{39}Ar$ ages of feldspars calculated by the method of Samson and Alexander (1987).

3 number of single grains used in age calculation/total number of grains analyzed.

4 $\%^{39}Ar$ = percentage of ^{39}Ar used to define plateau age. steps = number of steps in plateau/total number of steps