AGES AND GEOCHEMISTRY OF MAGMATIC HYDROTHERMAL ALUNITES IN THE GOLDFIELD DISTRICT, ESMERALDA CO., NEVADA

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ABSTRACT

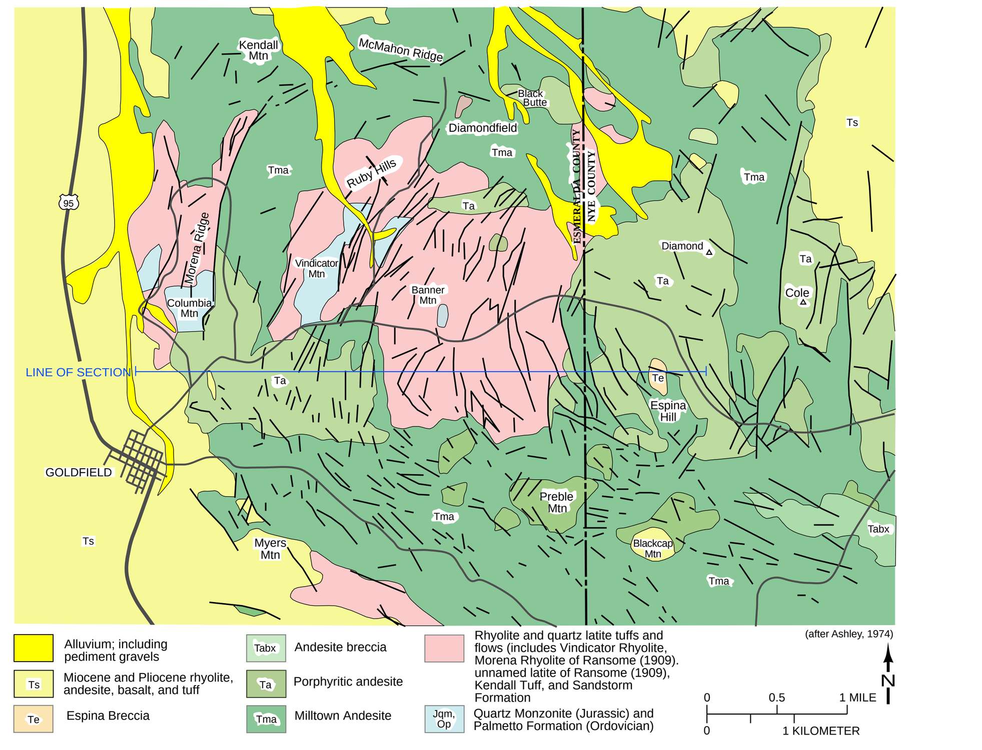
Hydrothermal mineral assemblages in the Goldfield district, Esmeralda County, NV, include several generations of quartz, alunite, kaolinite, and sulfide minerals that replaced and encrusted fragments and wall rocks of sub-linear tensional and shear fissures in Miocene andesites, rhyolites, and older rocks. Altered fissures weathered into resistant, discontinuous ledges, hundreds of which form an elliptical pattern within the 40 km^2 area of clay+pyrite alteration defining the district, but only a few percent contained minable quantities of Au, Cu and Ag. Mined ledges are distinguished by nested heterolithic breccias that display upward clast displacement, and multiple encrustation of clasts by quartz, alunite, kaolinite, Cu-As-Sb-Ag-Bi-Sn-Te-S minerals, and gold. Monolithic breccias and limited clast encrustation characterize many weakly mineralized and unmineralized ledges.

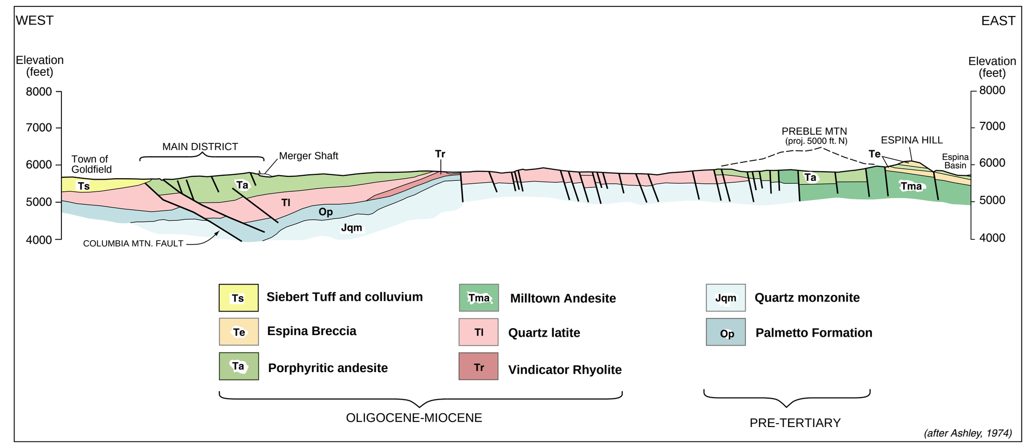
$^{40}Ar/^{39}Ar$ ages, and chemical and stable isotope compositions of magmatic hydrothermal (MH) alunites, associated sulfide minerals, and ledge host rocks, were evaluated along with ledge structure and breccia characteristics in an attempt to discriminate between gold-mineralized and unmineralized ledges. The oldest alunites (21.2 to 20.8 Ma) in the pre-alteration eruptive sequence of andesites (Milltown Andesite and porphyritic andesite; 22.4 to 21.8 Ma) and rhyolites (rhyolite of Wildhorse Spring, tuff of Chispa Hills, Sandstorm Rhyolite; 21.8 to 21.5 Ma), formed distally to subsequently formed ledges that were mined (alunite ages of 20.0 to 19.5 Ma) in the main district and Sandstorm-Kendall area. Alunite ages at Preble Mountain (20.4 to 19.5 Ma), a highly altered andesite edifice containing weakly mineralized tectonic breccias, fissures with fluidized textures, and pebble dikes, overlap those of mined ledges. The oldest recognized post-alteration eruptive rock is the 17.8 Ma Meda Rhyolite.

Magmatic hydrothermal alunites in mined ledges in the main district are predominantly K-rich (K/Na/Ca ≈ 8/1/1), while alunites formed in the same andesites at Preble Mountain have variable K/Na/Ca. Alunite-pyrite S-isotope equilibrium temperatures of 200-260 °C in ledge wall rocks contrast with unrealistically high disequilibrium S-isotope temperatures of >400 °C in fluidized fissures at Preble Mountain and in some mined ledge breccias. The high disequilibrium temperatures apparently resulted from disequilibrium between aqueous sulfur species in parent fluids because of elevated fluid flow velocities, and high flow rates may also have caused alunite cation variance. Stable isotope compositions of MH alunites and quartz fluid inclusions indicate that disproportionation of magmatic SO_2 in exchanged meteoric water led to wall rock replacement and ledge breccia fragment encrustation by alunite and pyrite. Exceptionally low $\delta^{18}O_{SO_4}$ and δD of some alunites indicates that much of the alteration occurred during a wet period in which the hydrothermal systems were "flooded" by exchanged meteoric water. Aerially extensive alteration and temporal correspondence of hydrothermal events to an eruption hiatus of at least 2 Ma, suggests protracted intrusion and degassing of sub-volcanic magmas throughout the district. Ages, chemical compositions, isotopic compositions, and crustification of alunites and sulfide minerals in mined ledge breccias reflect episodic and dynamic degassing from a magma chamber directly beneath the main district, perhaps presaged by injections of S-rich (basaltic?) magma. Multiple encrustations of hydrothermal minerals in mineralized ledge breccias are largely absent at Preble Mountain and in unmineralized ledges, and may reflect fewer magmatic mixing and degassing events outside of the main district.

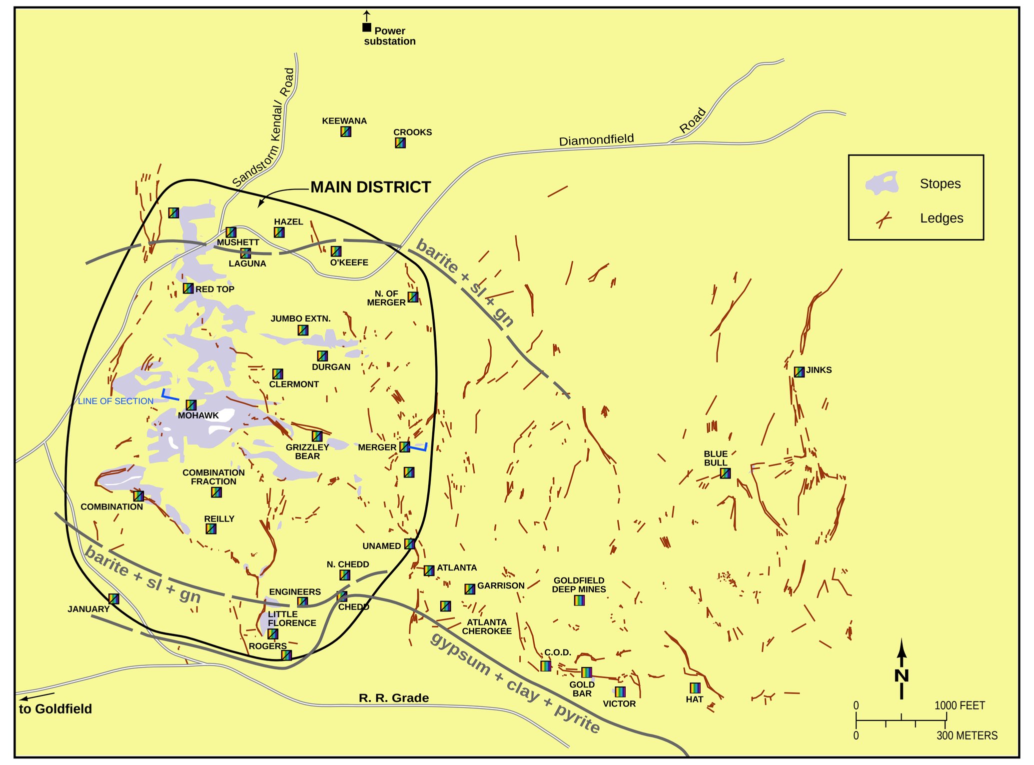
PURPOSE OF ALUNITE INVESTIGATION: Alunite $^{40}Ar/^{39}Ar$ ages, chemical compositions, and stable isotope compositions were determined across the district in order to assess relationships between alunite characteristics and mineralized ledges.

DISTRICT GEOLOGY

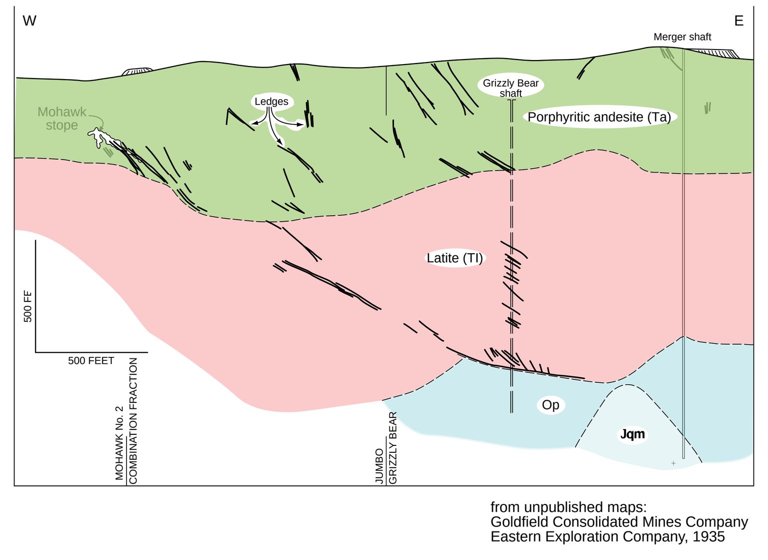




MAIN DISTRICT LEDGES



from unpublished maps:
Goldfield Consolidated Mines Company
Eastern Exploration Company, 1935



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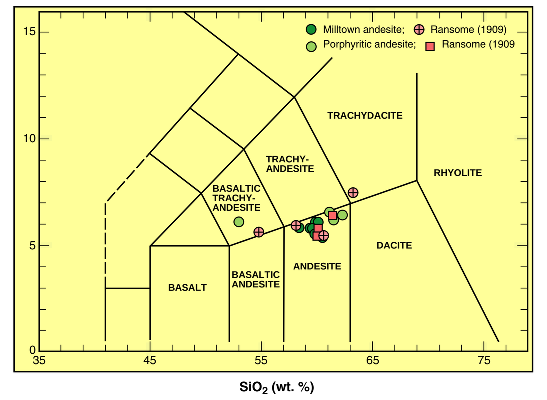
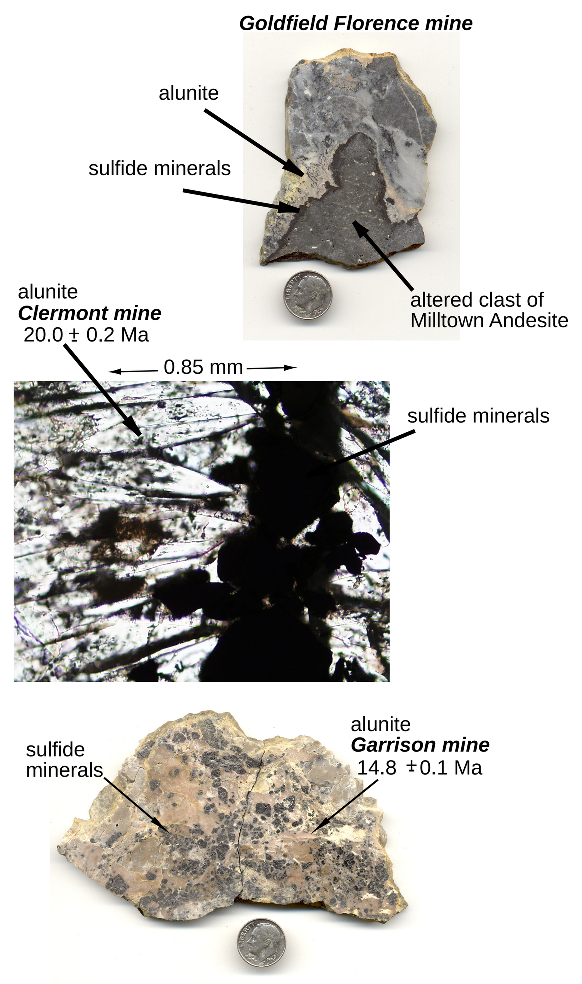
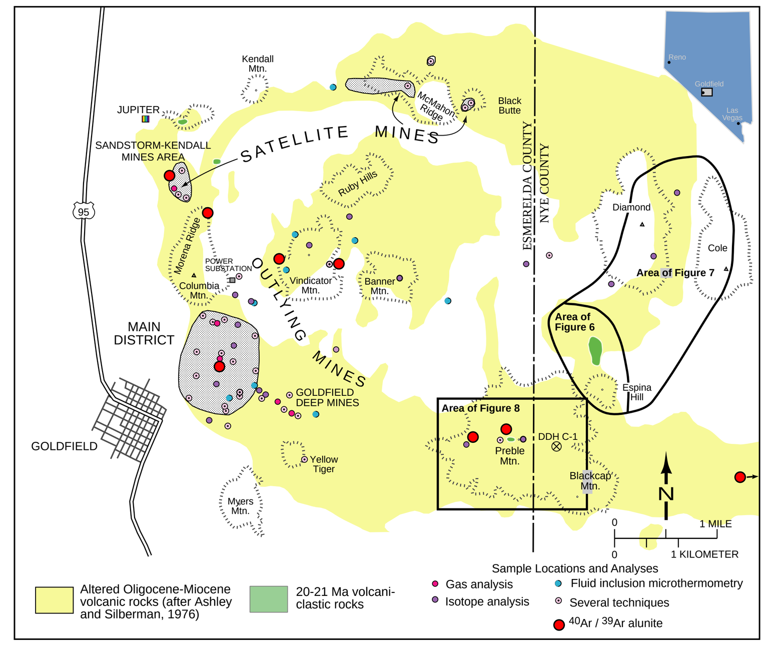
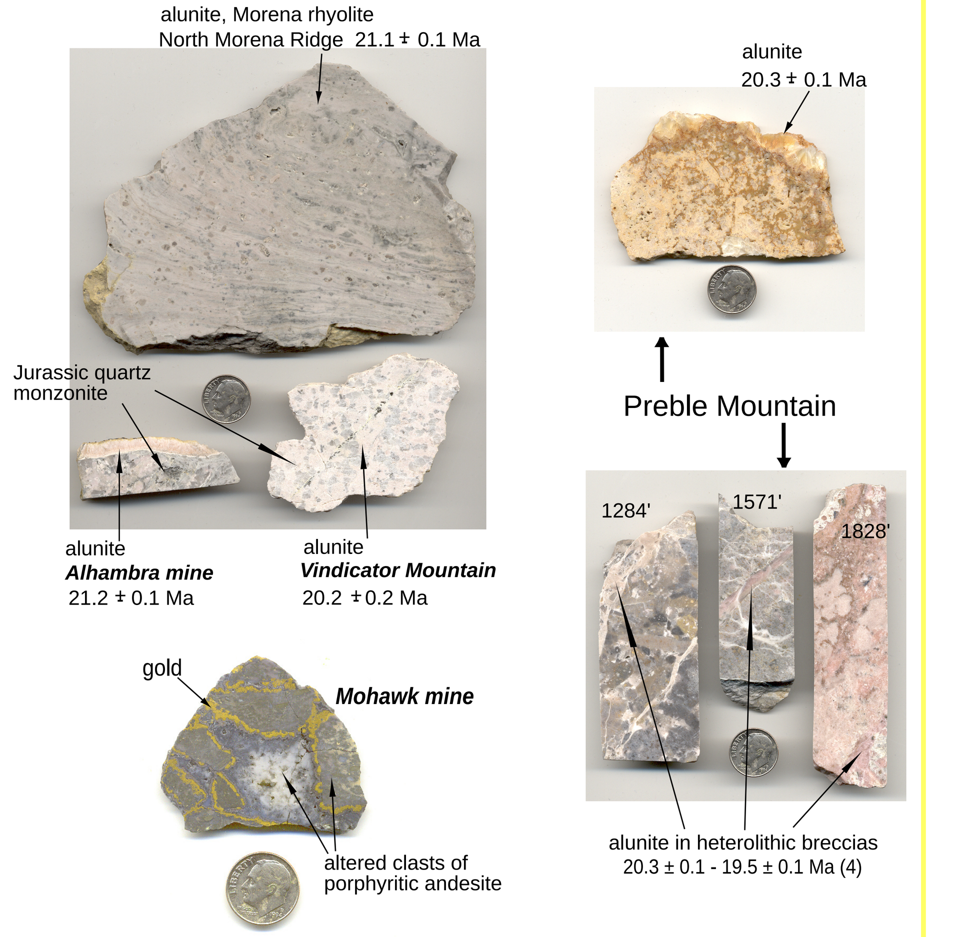


The Goldfield district, Esmeralda Co., Nevada, produced 4.2 Moz Au, 1.5 Moz Ag, and 3,800 tons Cu; most production occurred from 1904-1919. Prominent lithologies in the district, Miocene rhyolites, latites and andesites, overlie Mesozoic and Paleozoic granitic and sedimentary rocks. Most production came from silicified, sub-linear fissures, or ledges, in Milltown Andesite and porphyritic andesite (dacite of Ransome, 1909; porphyritic rhyodacite of Ashley, 1974). Ledges consist mainly of microcrystalline quartz that has replaced andesites. Internal breccias constituted most ore and consist of multiple generations of clasts encrusted and replaced by gold, pyrite, and a large number of Cu-As-Sb-Ag-Bi-Sn-Te-Se minerals (e.g., enargite-luzonite, famatinite, goldfieldite, bisthmuthinite, calverite), minor sphalerite, galena, and chalcopyrite, alunite, kaolinite, and pyrophyllite. Ledges commonly consist of en echelon segments that form a broadly elliptical pattern in the district. Contiguous ledge segments are generally meters to tens of meters in length by meters in width. Ledges are flanked by broad selvages of altered andesite consisting of proximal to distal quartz±alunite±kaolinite+pyrite, quartz+kaolinite+K-mica+pyrite, montmorillonite+pyrite, and, calcite+chlorite± pyrite, respectively. The abundance of ledges coupled with coalescing alteration selvages resulted in a very large volume (tens of km^3) of altered rocks in the district. More than 95% of district production came from a small area, the "main district", near the town of Goldfield.

ALUNITE LOCATIONS



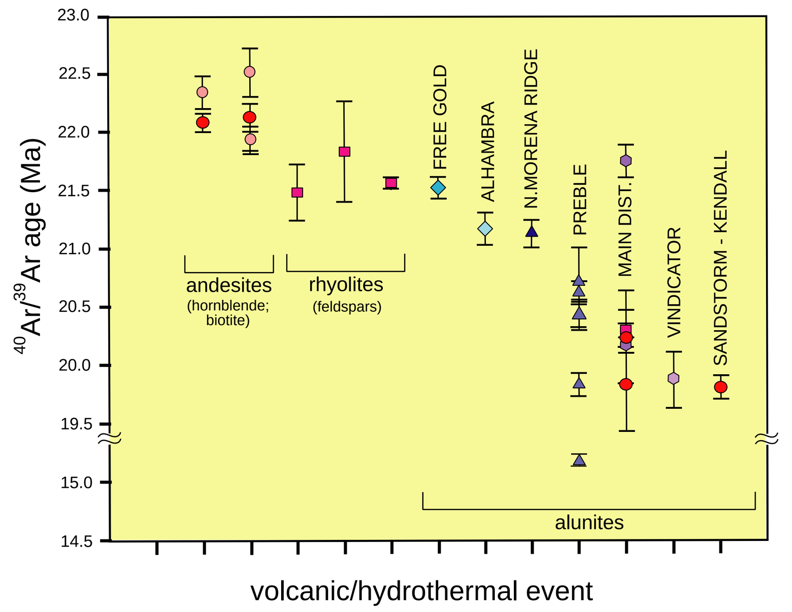




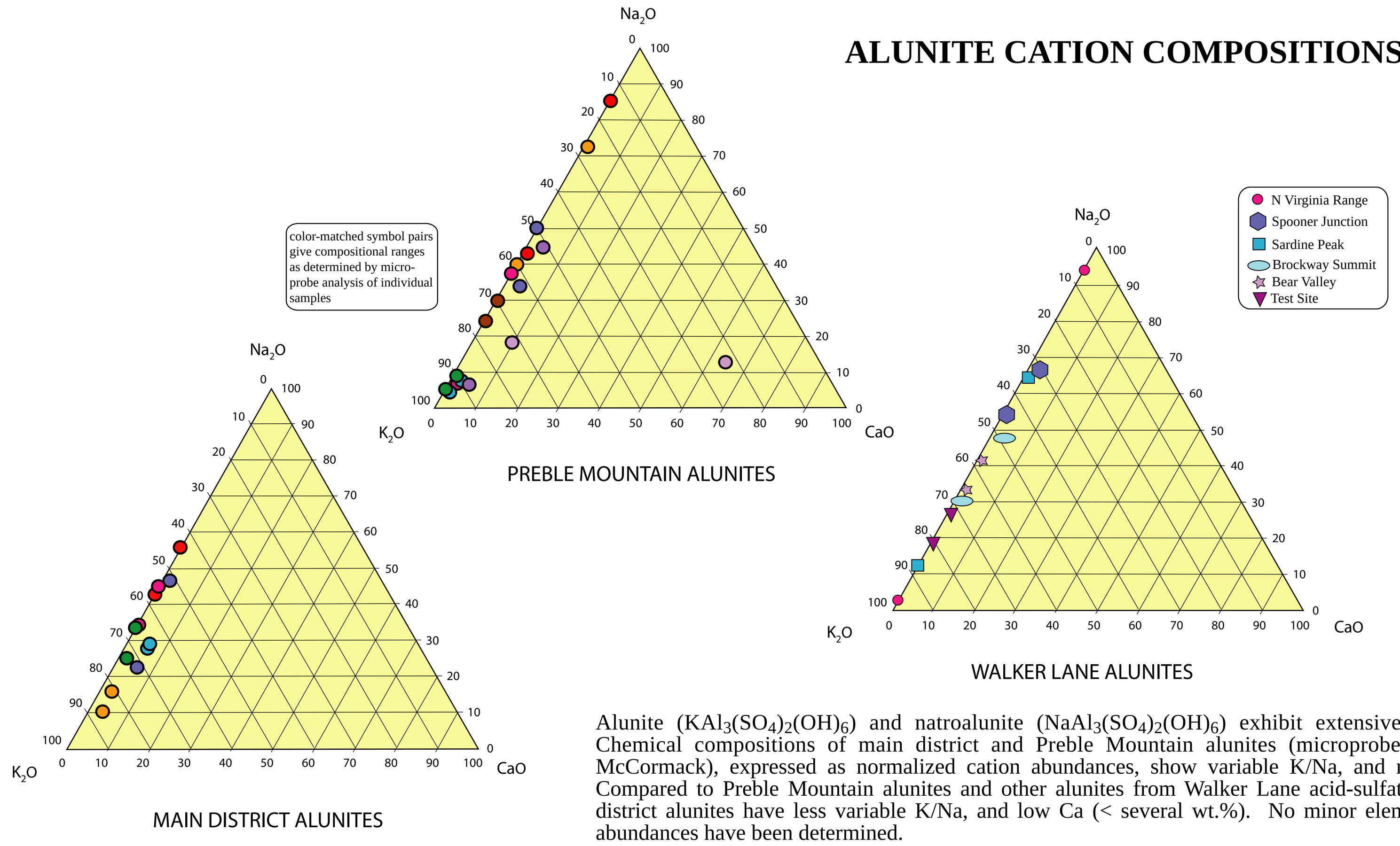
Alunite occurs in many mineralized and unmineralized ledges, and in adjacent wall rocks, throughout much of the district. In mineralized ledges it partially replaces early breccia clasts, occasionally forms clast crusts, more commonly is intergrown with quartz and sulfide-sulfosalt mineral encrustations, and occasionally dominates breccia matrices. In wall rocks alunite replaces phenocrysts and matrices and fills fractures.

ALUNITE AGES

$^{40}Ar/^{39}Ar$ ages of 13 alunites range from 21.5 to 15.2 Ma with 12 of the ages between 21.5 and 19.8 Ma. The oldest alunites (21.5 to 21.2 Ma) from wall rocks and small mines in the northern and eastern parts of the district, coincide in age with rhyolites (Sandstorm Formation, Rhyolite of Wild Horse Spring, and Tuff of Chispa Hills; Ransome, 1909; Ashley, 1974), and are as much as several hundred Ka younger than andesites. Main district, Preble Mountain, and Sandstorm-Kendall mine alunites range in age from 20.7 to 19.8 Ma. Most alunite ages are analytically indistinguishable, but some main district alunites are slightly younger than Preble Mountain alunites. Sandstorm-Kendall mine and Vindicator Mountain alunites, both distal to the main district, are among the youngest alunites. Alunite that cements sulfosalts in a main district ledge is 15.2 Ma.

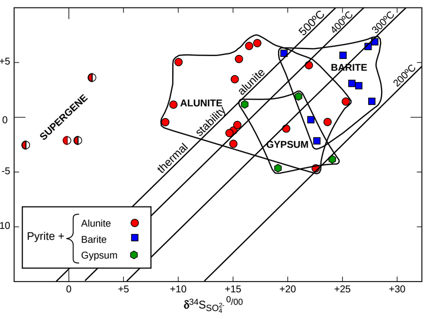


ALUNITE CATION COMPOSITIONS

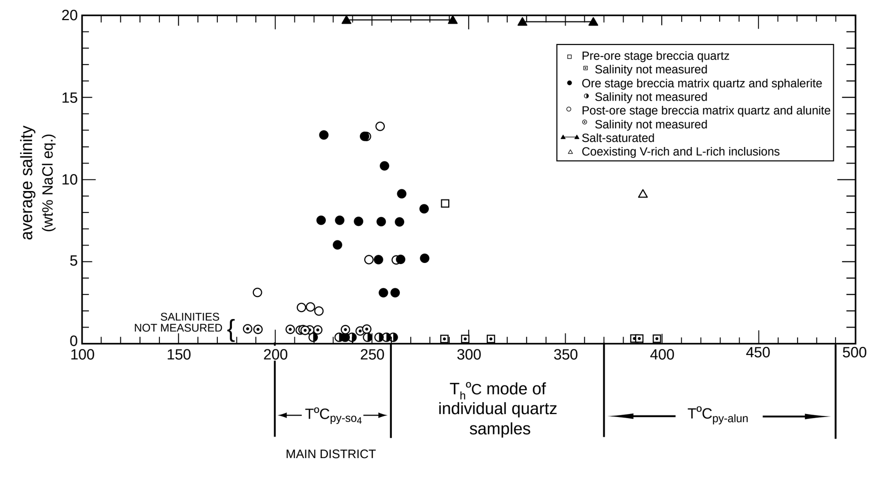


Alunite ($KAl_3(SO_4)_2(OH)_6$) and natroalunite ($NaAl_3(SO_4)_2(OH)_6$) exhibit extensive solid solution. Chemical compositions of main district and Preble Mountain alunites (microprobe analyses by J. McCormack), expressed as normalized cation abundances, show variable K/Na, and minor to no Ca. Compared to Preble Mountain alunites and other alunites from Walker Lane acid-sulfate systems, main district alunites have less variable K/Na, and low Ca (< several wt.%). No minor element and volatile abundances have been determined.

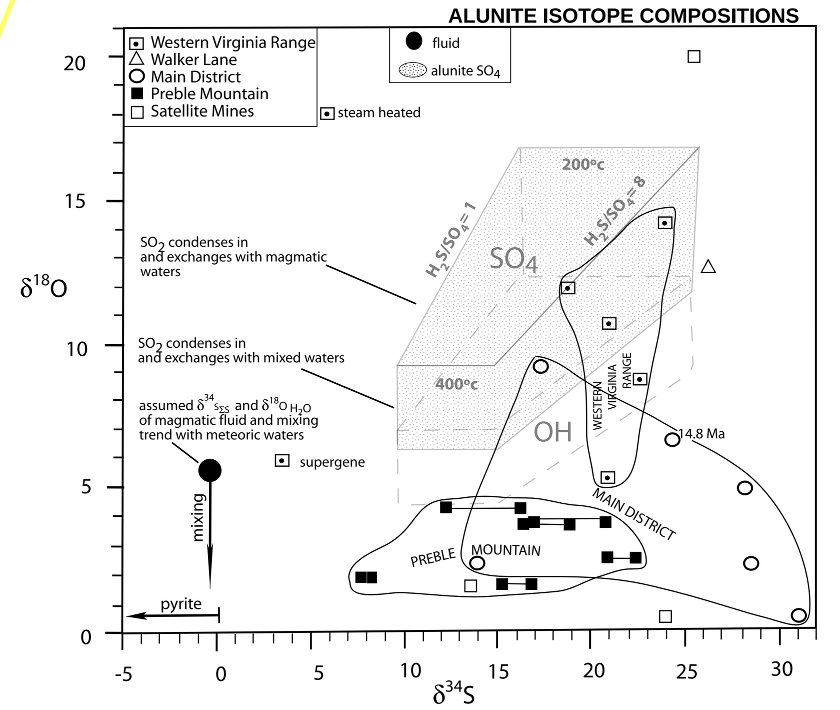
ALUNITE TEMPERATURES

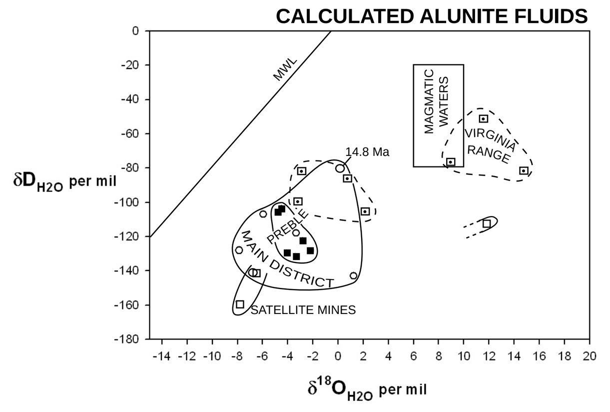


Sulfur isotope temperatures of ~400 °C for pyrite-alunite pairs in early ledge replacement quartz, and of ~200 to 260 °C for pyrite-alunite pairs in matrices of mineralized ledge breccias, are broadly similar to fluid inclusion homogenization temperature modes (T_h °C), suggesting sulfur isotope equilibrium in main district ledge fluids. Most pyrite-barite, and pyrite-gypsum sulfur isotope temperatures also are similar to (T_h °C). Isotope temperatures for Preble Mountain alunites are impossibly high, much greater than the upper thermal stabilities of alunite and natroalunite (480-490 °C; Rudolph et al, 2003) or the disproportionation temperature of SO_2, attesting to the isotopic disequilibrium among sulfur species apparently caused by high velocities of parent fluids. Analyzed pyrite and sulfate minerals from ledges are in physical contact in individual clast crusts, and are presumed to be paragenetically coeval. Pyrite and alunite from Preble Mountain also coxist, but several pairs are from breccia matrices with fluidized textures where simultaneous deposition of pyrite and alunite is less certain.



ALUNITE STABLE ISOTOPE COMPOSITIONS





The $\delta^{34}S$, $\delta^{18}O$, and δD values of main district alunites display a large variance relative to Preble Mountain and Walker Lane (Virginia Range) alunites. The large $\delta^{34}S$ values indicate that all of these alunites are magmatic hydrothermal (MH) in origin and derived from disproportionation of SO_2. Main district and Preble Mountain alunites were deposited during disproportionation of SO_2 in exchanged Miocene meteoric water, with possible unexchanged and condensed magmatic water components. The $\delta^{34}S$ of aqueous sulfate in the Preble system in particular was buffered by condensation in exchanged meteoric water with $\delta^{18}O$ of -4 ± 2 ‰. The calculated H and O isotope composition of the water in the parent alunite fluids was similar to the composition of quartz fluid inclusion waters (not shown). Magmatic water alunites and mixed magmatic-exchanged meteoric water alunites from the western Virginia Range are shown for reference (Vikre, 1998) because they show a classical trend of $\delta^{18}O$ values of aqueous sulfate affected by condensation in various mixtures of exchanged meteoric and magmatic water. Reference fields on the S-O isotope diagram are from Rye et al., 1992.

CONCLUSIONS

1. Magmatic hydrothermal (MH) alunite resulting from the disproportionation of SO_2 is widespread in the Goldfield district, occurring as encrustations on main district high-grade ledge breccia clasts, replacing breccia clasts and wall rock minerals and forming veins and breccia matrices.

2. Main district and Preble Mountain MH alunite ages, 20.7 to 19.8 Ma, are mostly analytically indistinguishable; alunites from small mines and wall rocks peripheral to the main district and Preble Mountain are both older and younger. The duration of hydrothermal activity recorded by MH alunites at Goldfield is ~1.7 m.y. Ledge host rocks, 22.5 to 21.5 Ma, are either slightly older than or the same age as the oldest ledges.

3. Main district MH alunites have more homogeneous K/Na compositions than alunites from Preble Mountain and Walker Lane acid-sulfate systems. However, volatiles and minor elements have not been analyzed, and might discriminate between mineralized and non-mineralized ledges at Goldfield.

4. Sulfur isotope temperatures based on pyrite-alunite/barite/gypsum pairs mostly range from 400 to 200 °C and generally agree with fluid inclusion homogenization temperatures in main district mineralized ledges. Unrealistically high sulfur isotope temperatures for Preble Mountain alunite-pyrite pairs most likely reflect sulfur isotope disequilibrium between sulfur species because of high velocities of parent fluids. Some of the Preble Mountain alunites appear to be similar to the magmatic steam alunites classically described at Marysvale, UT (Rye et al., 1992).

5. Stable isotope compositions of main district and Preble Mountain alunites overlap, and their exceptionally low $\delta^{18}O_{SO_4}$ values indicate that magmatic SO_2 in parent fluids disproportionated in fluids dominated by exchanged meteoric water.

6. Chemical and isotope compositions of alunites at Goldfield only generally distinguish mineralized from unmineralized ledges. Small differences in ages and compositional ranges (K/Na; $\delta^{18}O$ – $\delta^{34}S$) may not be sustained by additional analyses. However, disequilibrium isotope temperatures in unmineralized ledges may be a significant discriminator. Besides gold, presence of multiple, mineralized ledges (multiple, nested breccias, Cu-As minerals in addition to pyrite, 200 to 260 °C sulfur isotope temperatures), characterize mineralized ledges.

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