Controls on volcanism associated with the intrusion of the Redwell and Mount Emmons stocks, Crested Butte, Colorado: Implications for Climax-type porphyry Mo exploration

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Abstract & Background

The Miocene Mount Emmons complex (Crested Butte, Colorado) is a Climax-type porphyry Mo system that contains the Redwell and Mount Emmons stocks, which are ~600–1000 m apart but connected at depth. The complex also contains a volcanic breccia pipe that emanates from the top of the Redwell stock and likely breached the paleo-surface, but the Mount Emmons stock lacks a volcanic pipe. Three Climax-type deposits have preserved breccia units that are thought to have breached the paleo-surface: the Mount Emmons complex contains two stocks and one breccia pipe, the Cave Peak deposit in western Texas contains three stocks and three breccia pipes, and the Pine Grove deposit in Utah contains one stock and one breccia pipe.

Because the stocks at Mount Emmons are part of the same magmatic parent event, we can investigate local causes of volcanism without needing to compare deposits from different geologic settings or exposed at different erosional levels. Intrusive paleo-depth differences of the top of the stocks and the number of magma recharge events into the bottom of the two stocks are not likely controls on the occurrence of volcanism, although, the magma recharge rate into the Redwell stock may have played a role in volcanism. The presence of intersecting faults above the Redwell stock may have promoted development of the associated volcanism whereas these were lacking at the Mount Emmons stock.

This has important exploration implications because even though the Mo mineralization associated with the Redwell stock was discovered first due to the outcropping breccia, its two Mo orebodies contain 37% less Mo compared to the single Mo orebody associated with the Mount Emmons stock. In a magmatic arc environment, venting to surface during porphyry emplacement inhibits the formation of porphyry Cu orebodies due to the release of fluid and volatiles from an otherwise fertile magmatic-hydrothermal system; fluid that was channeled toward the surface but never breached the surface may promote porphyry Cu orebodies. This research suggests the same may hold true for Climax-type Mo deposits formed in extensional to transitional environments, and that for stocks with associated breccias that breached the paleo-surface, higher tonnage orebodies may be nearby (within 1 km), around stocks with no obvious volcanic vents. This is particularly important because Climax-type deposits are typified by multiple intrusive bodies.

Mechanisms for volcanism in a porphyry environment (Sillitoe, 1985)

Phreatic eruptions:
magmatic heating and expansion of meteoric pore fluids

Phreatomagmatic eruptions:
interaction of subsurface groundwater with magma

Magmatic-hydrothermal-volcanic eruptions:
release of magmatic-hydrothermal fluids from an intrusion during boiling or decompression; rapid decompression with surface venting

Magmatic-hydrothermal-volcanic eruptions can be pre- to post mineralization. Phreatomagmatic and phreatic eruptions are commonly post-mineralization.

Observed

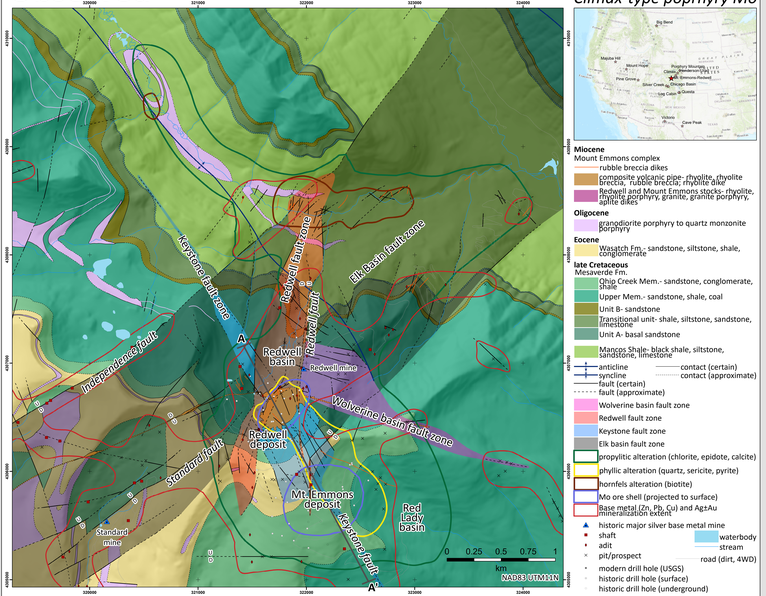


Figure 1- Map of the Mount Emmons-Redwell area. Modified after Gaskill et al. (1967), Galey (1978), and Sharp (1978).

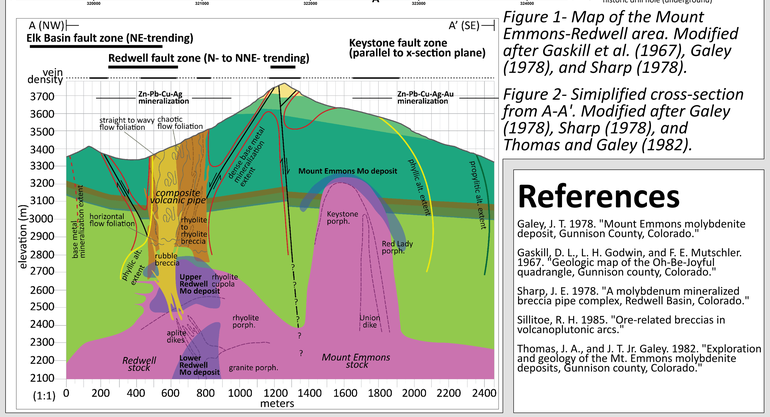


Figure 2- Simiplified cross-section from A-A'. Modified after Galey (1978), Sharp (1978), and Thomas and Galey (1982).

References

Galey, J. T. 1978. "Mount Emmons molybdenite deposit, Gunnison County, Colorado."

Gaskill, D. L., L. H. Godwin, and F. E. Mutschler. 1967. "Geologic map of the Oh-Be-Joyful quadrangle, Gunnison county, Colorado."

Sharp, J. E. 1978. "A molybdenum mineralized breccia pipe complex, Redwell Basin, Colorado."

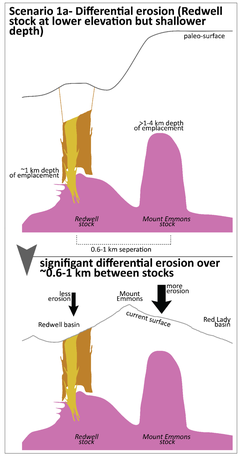
Sillitoe, R. H. 1985. "Ore-related breccias in volcanoplutonic arcs."

Thomas, J. A., and J. T. Jr. Galey. 1982. "Exploration and geology of the Mt. Emmons molybdenite deposits, Gunnison county, Colorado."

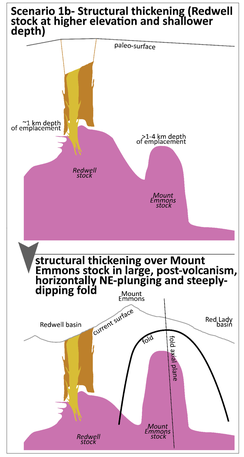
Controls on volcanism

Scenario 1 Assumes that the shallower stock will preferentially undergo a magmatic-hydrothermal- volcanic eruption and/or a phreatic/phreatomagmatic eruption due to a higher chance of decompression and/or groundwater interaction with melt.

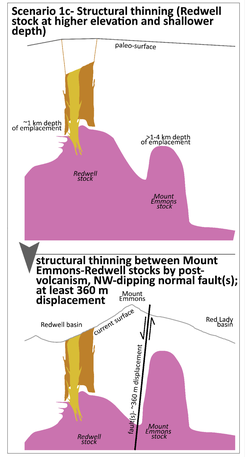
Scenario 2 Assumes that the stock with a higher rate and/or volume of melt recharge will preferentially undergo a magmatic-hydrothermal- volcanic eruption due to a higher chance of catastrophically breaching porphyry confining pressure.



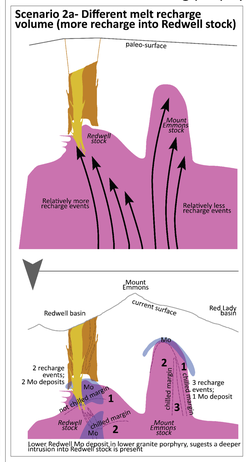
Hard to prove or disprove; but volcanic pipe is more competent than surrounding sedimentary rocks



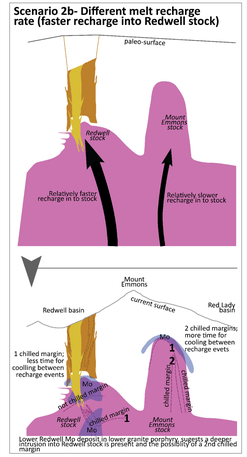
Not observed; no folds trending NE in field area; pipe not tilted with respect to Mt. Emmons stock



Not observed; no faults in-between stocks dipping NW; no fault or fault zones with ~360 m of displacement in field area

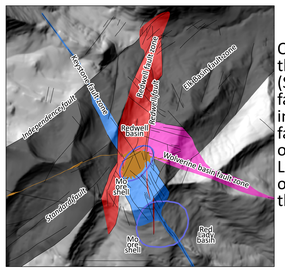


Similar to less melt volume into Redwell stock vs. Mt. Emmons stock based on known distinct phases



Possibly larger melt recharge rate into Redwell stock vs. Mt. Emmons stock based on known chilled margins

Scenario 3 Assumes that the stock located in a more structurally complex area will preferentially undergo a magmatic-hydrothermal-volcanic eruption and/or a phreatic/phreatomagmatic eruption due to a higher chance of decompression and/or groundwater interaction.



Observed; intersection of three of the four largest fault (Standard, Keystone, Redwell faults) in Redwell basin; intersection of four brittle fault zones in Redwell basin, only one fault zone in Red Lady basin; volcanic pipe occurs at the intersection of the large faults and fault zones

Discussion & Conclusion

Scenario 3 is most likely based on observed geology. The stock associated with the intersection of major faults likely had a higher chance to rapidly decompress, resulting in an eruption. The overprinting rubble breccia pipe, which cuts the Upper Redwell deposit, may have been a result of increased groundwater flow within the fault intersection and previous eruption zone, resulting in a second phreatomagmatic eruption.

Scenario 2b is also viable if the number of chilled margins is a rough indicator of melt injection rate into the base of the stocks (higher rate of melt injection preventing full cooling of previous melt). A higher rate is more likely to produce a pressure differential at the porphyry boundary with wallrock, increasing the likelihood of a catastrophic rupture, rapid decompression, and subsequent eruption.

Scenario 1a is somewhat viable because rhyolite of the volcanic pipe is more competent than the surrounding sedimentary rocks. If true, this scenario was likely not the main reason for localization of volcanism over one stock.

From an exploration perspective, the breccia pipe is larger and easier to identify on the surface, but the loss of volatiles during at least two eruptions and the overprinting of one of the ore zones resulted in a lower resource for that stock. A larger resource may be nearby.