Magmas responsible for porphyry Cu-Au mineralization at Dizon mine in the ancestral Pinatubo volcano, Philippines

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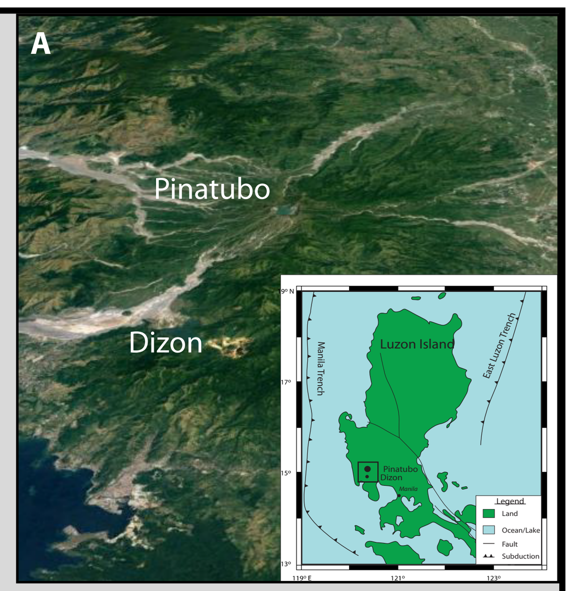
Introduction

Dizon porphyry Cu-Au mine is located on the flank of Mount Pinatubo, 19 km south of the current summit. The mine produced 0.67 Mt Cu and 140 t Au until its closure in 1997. The mineralization is hosted by quartz diorite (~2.5 Ma) which intruded Late Miocene volcanics of intermediate composition. Rocks from Dizon were characterised to examine the magmas responsible for mineralization at Dizon and the evolution of Pinatubo magmas throughout the past 3 m.y.



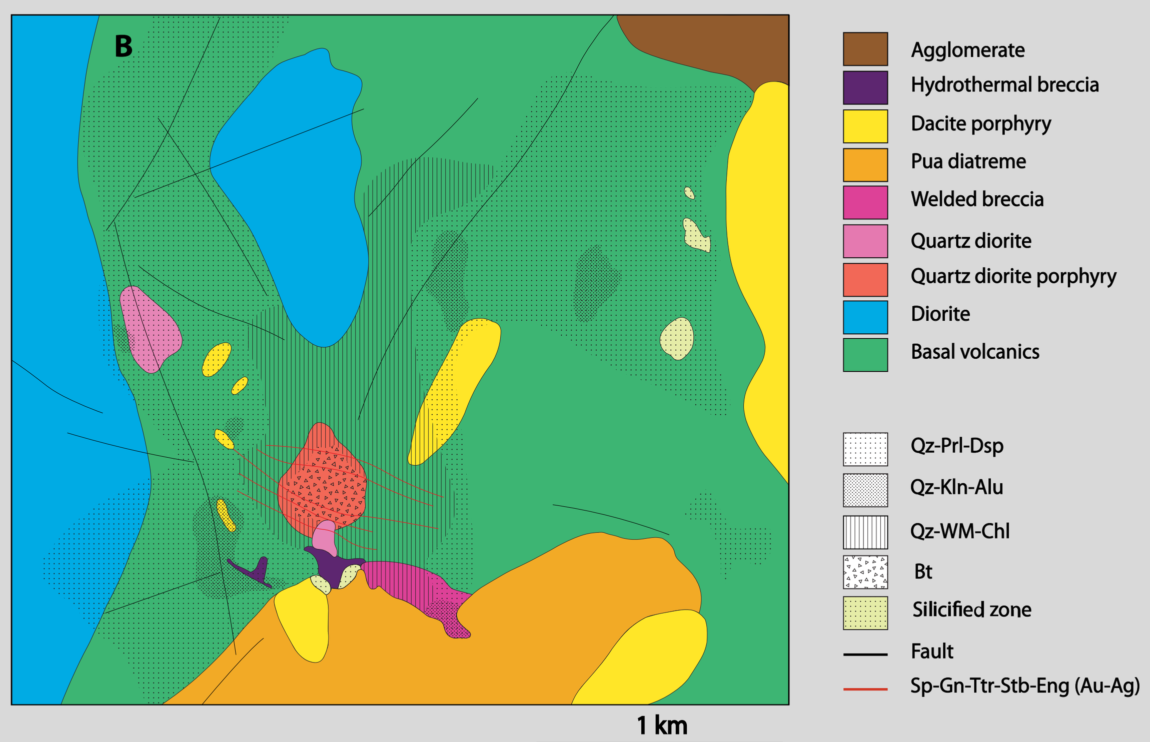
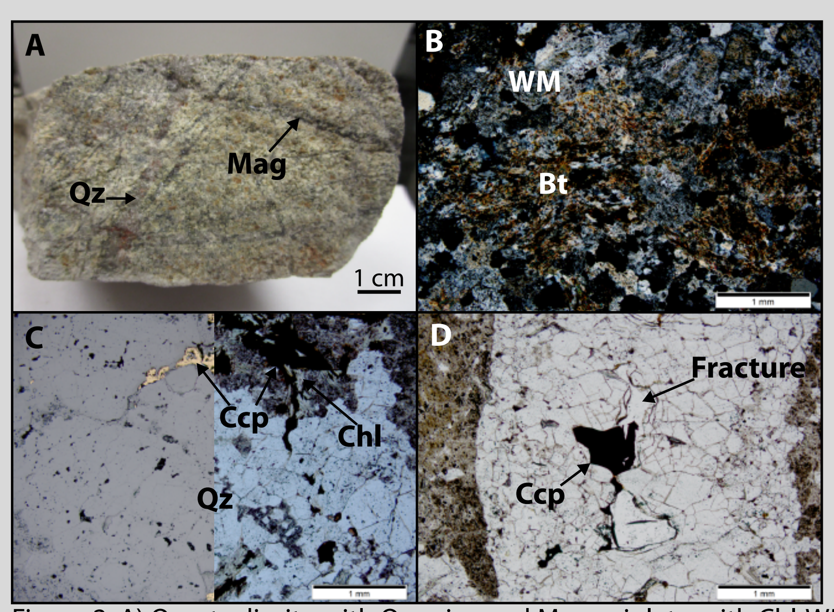


Figure 1. A) Maps displaying Pinatubo, Dizon and active subduction zones. B) Geologic map of Dizon mine displaying the different lithologies, alteration zonation and structures. There is advanced argillic alteration with quartz/pyrophyllite/diaspore and quartz/kaolinite/alunite, white mica-chlorite alteration, biotite alteration and veins containing sphalerite, galena, tetrahedrite, stibnite, enargite, gold and silver. Modified after Imai (2005).

Lithology and Alteration

The main orebody at Dizon is centered on the quartz diorite porphyry. Chalcopyrite and minor bornite are the Cu minerals. The rocks in the ore zone are characterised by biotite alteration. Quartz and magnetite veins host the Cu. Chalcopyrite is commonly found in fractured quartz veins.



The biotite alteration zone is surrounded by extensive chlorite-white mica alteration. The margins of the intrusion , along with the surrounding volcanic rocks are most affected by Chl-WM alteration. It is characterised by decreasing Cu grades and higher pyrite content. A seperate phase of Chl alteration features Cal, no WM. WM alteration surrounds Chl-WM zone.

Figure 2. A) Quartz diorite with Qz veins and Mag veinlets, with Chl-WM surrounding veins. B) Fine grained Bt alteration, illitized plagioclase. C) Fractured Qz veins containing Ccp with Chl halo. D) Fractured Qz vein with Ccp.

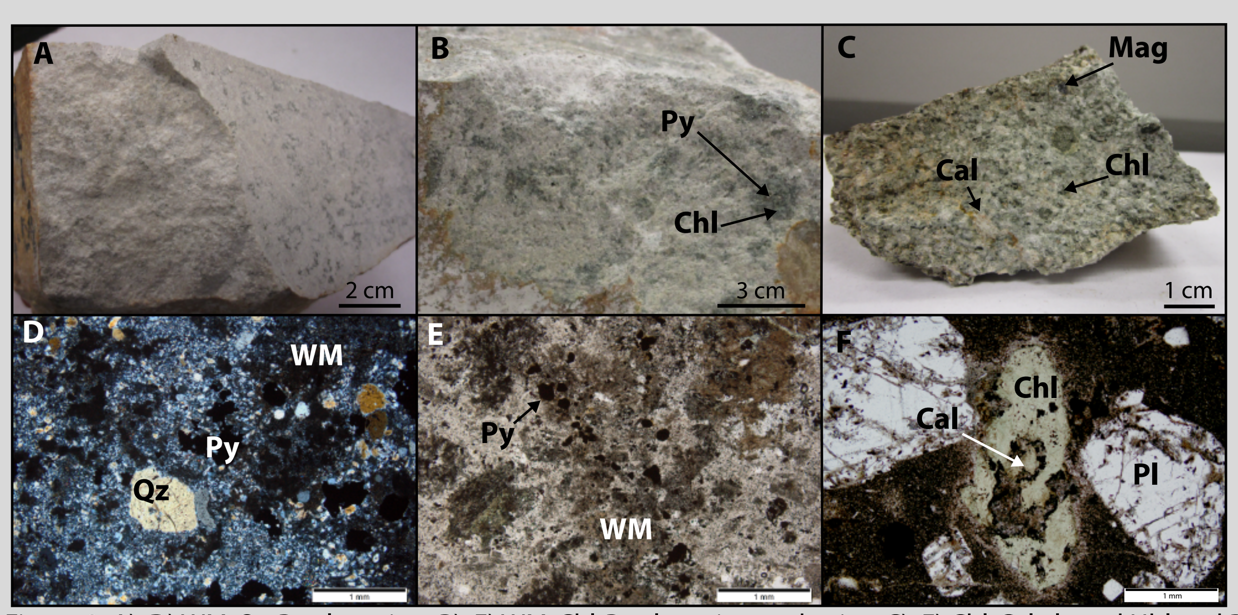


Figure 3. A), D) WM-Qz-Py alteration. B), E) WM-Chl-Py alteration and veins. C), F) Chl-Cal altered Hbl and Pl in porphyritic andesite.

Results

Porphyritic andesite and pyroxene-hornblende-diorite samples are unaltered and contain igneous amphibole. Andesite contains Fe-Ti oxides.

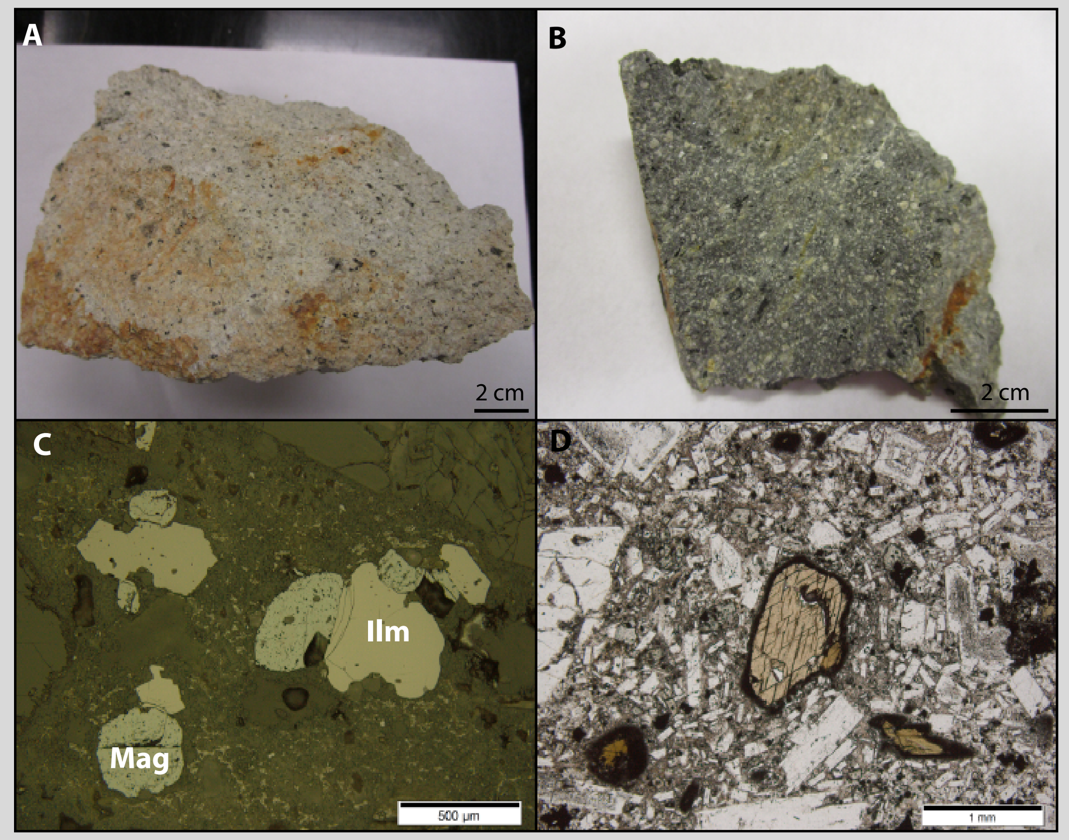
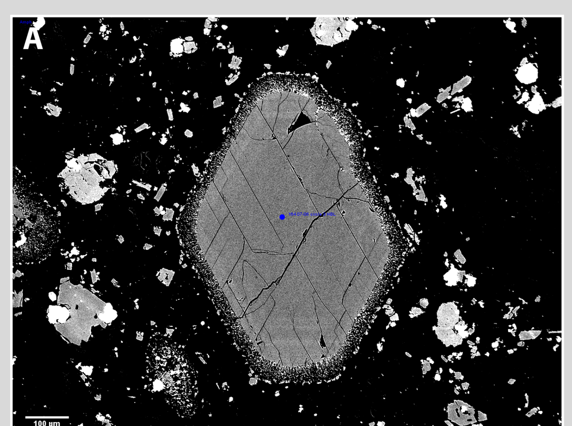


Figure 4. A) Porphyritic andesite. B) Hornblende-pyroxene-diorite. C) Ilm (pink) and Mag (grey) in andesite. D) Amphibole grain in diorite.

SEM and EPMA



Some amphibole grains show zoning (Fig. 5). The core yielded similar compositions to grains without zoning. The compositions of hornblende and Fe-Ti oxides were obtained with EPMA after examining them with SEM-EDS. Compositions of magnetite and ilmenite are in equilibrium following the Mg/Mn partitioning test by Bacon & Hirschmann (1988) (Fig. 6).

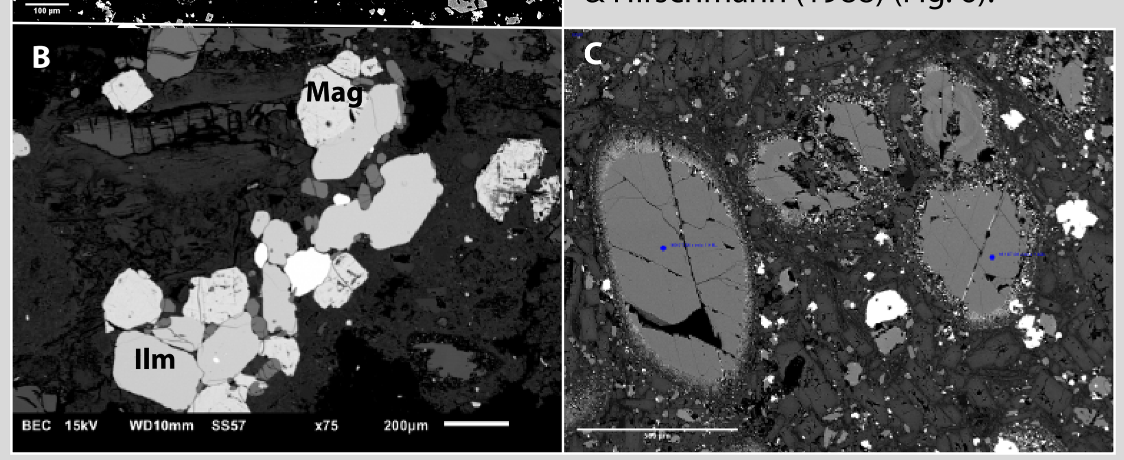


Figure 5. A) Zoned magnesio-hastingsite. B) Ilm and Mag (brighter) in andesite. C) Zonation is less pronounced in some amphibole grains.

Mg/Mn Partitioning in Fe-Ti Oxides

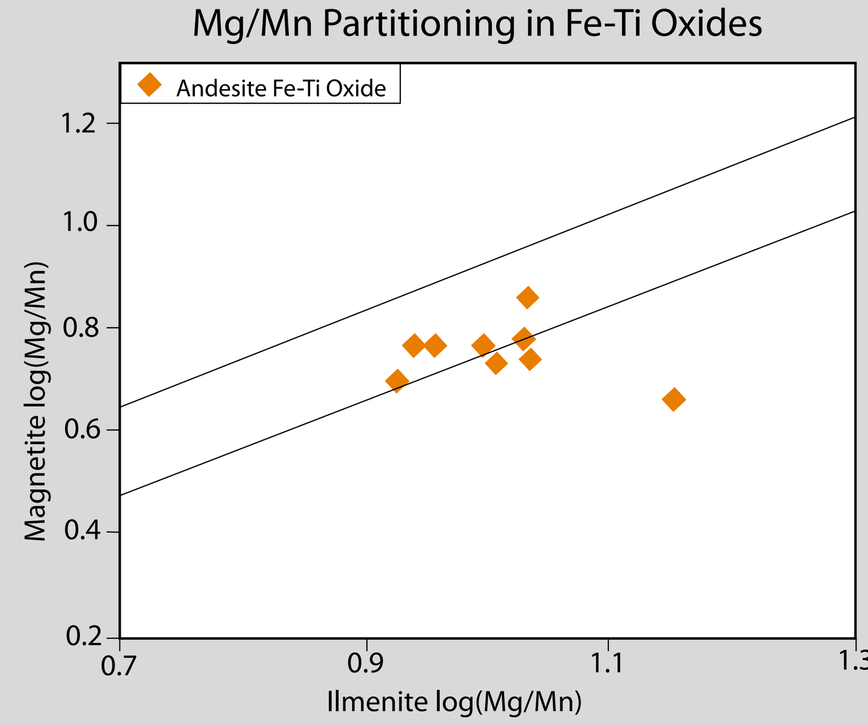
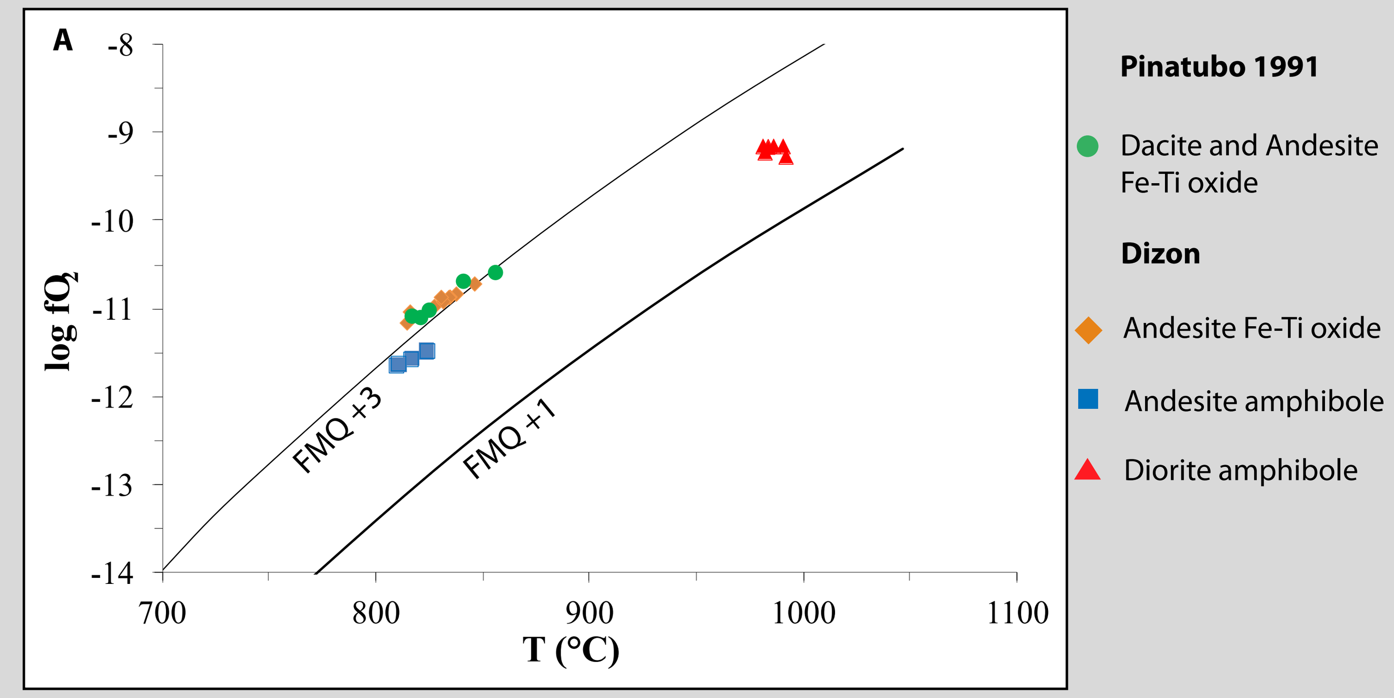


Figure 6. Test for Mg/Mn (atomic) partitioning of Fe-Ti oxides in the porphyritic andesite. The solid lines represent an error envelope, oxide pairs should plot near or within the lines.

Oxidation State, Temperature and Water Content

Dizon andesite oxidation conditions overlap with 1991 Pinatubo eruption products, at ~FMQ +3. Dizon diorite (amphibole) yields ~FMQ +2 with temperature ~980 °C.



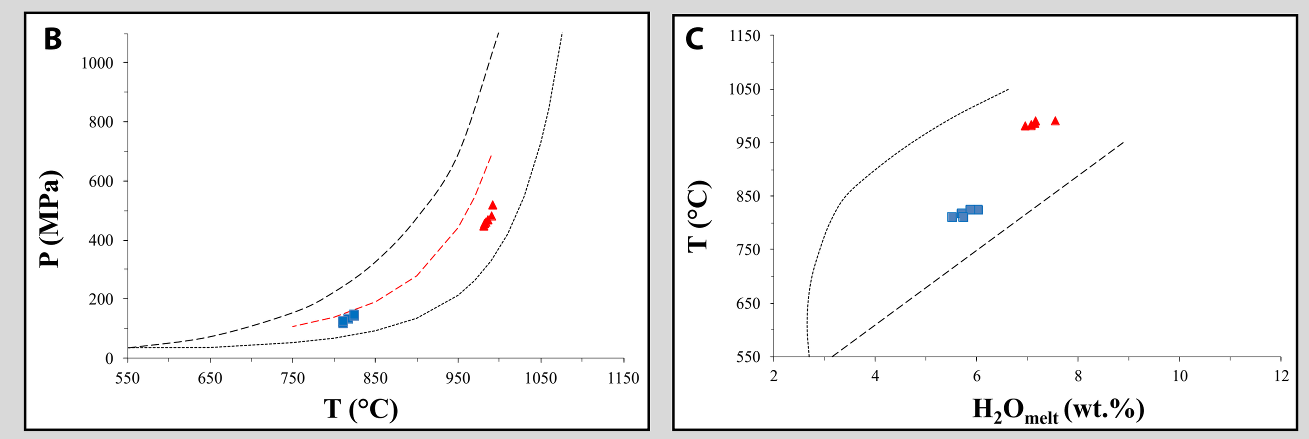
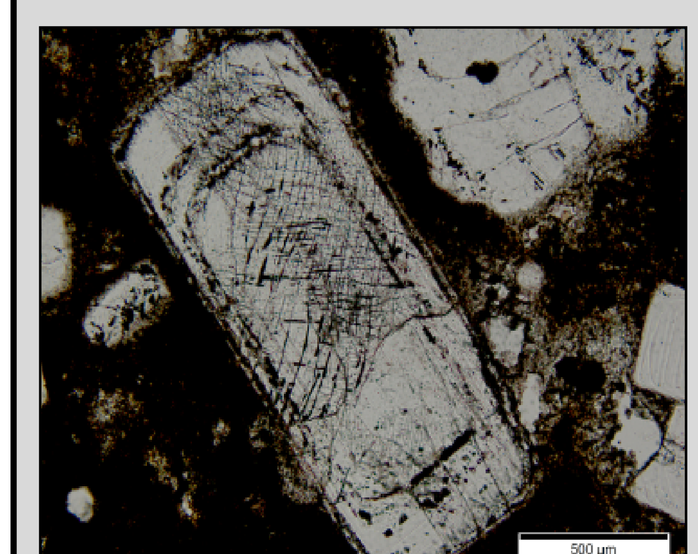


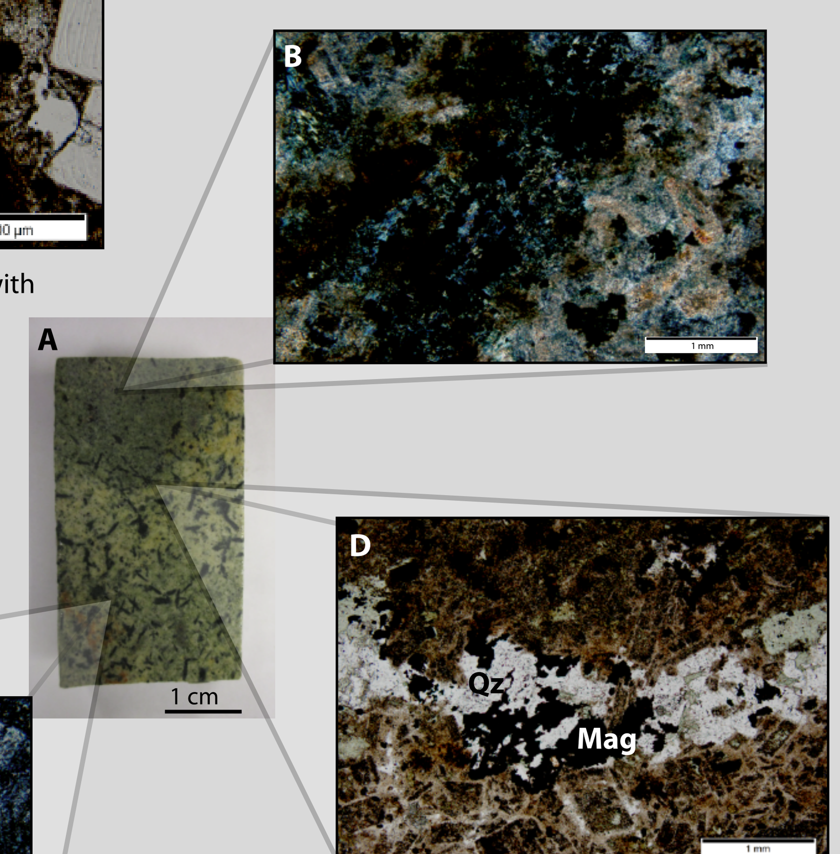
Figure 7. Calculations from Ridolfi et al. (2010). A) Temperature and oxygen fugacity of Dizon andesite, diorite and the 1991 Pinatubo dacite eruption products (Hattori, 1993). B) Pressure and temperature as indicated by amphibole in andesite and diorite. C) H_2O wt.% as indicated by amphibole in andesite and diorite.

Injection of Mafic Magma



Plagioclase crystals in andesite show dusty zones surrounded by overgrowths, suggesting heating events during crystal growth. There are basalt enclaves within andesite, which suggests basaltic magmas were contemporaneous.

Figure 8. Plagioclase displaying dusty zones with overgrowth.



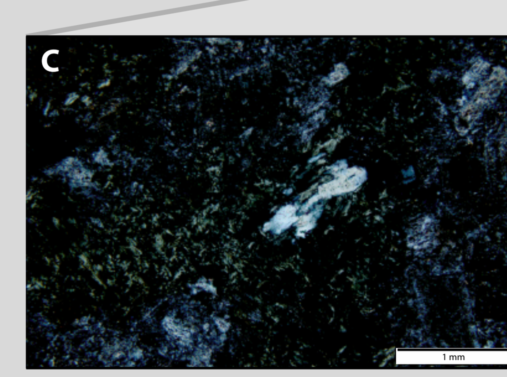


Figure 9. A) Andesite with basalt enclave. B) Fe-chlorite in basalt. C) Mg-chlorite in andesite. D) Andesite (bottom) and basalt (top) seperated by Qz and Mag.

Magma Oxidation Conditions

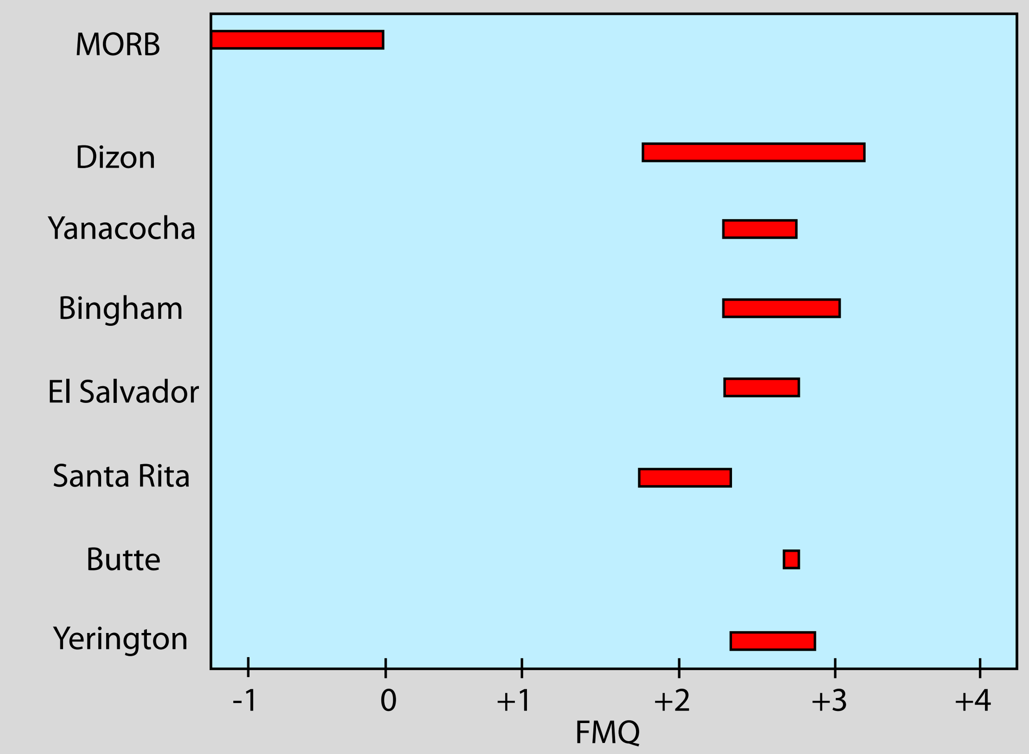


Figure 10. The oxidation conditions of MORBs and magmas responsible for porphyry Cu deposits are compared to amphibole and Fe-Ti oxide results from this study. Data sources: Dilles et al. (2015) and Hattori (2018).

Conclusion

1. Oxidation conditions of magmas at Mount Pinatubo have remained high, over FMQ +3 for 3 m.y.

2. Magmas at Dizon had high water content, ~6 wt% in andesite and ~7 wt% in diorite.

3. Basalt enclaves and destabilized plagioclase in andesite indicate injection of mafic magma.

4. The oxidation conditions for magmas responsible for mineralization at Dizon are similar to those for large porphyry Cu deposits around the world.

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