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Clinopyroxene reveals recharge events in the generation of magmas for the "Millennium Eruption" of Changbaishan Tianchi volcano, NE China

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Among Cenozoic intraplate volcano fields in Northeast China, Changbaishan Volcano Field uniquely produces trachyte and peralkaline rhyolite alongside basalt. It has hosted at least three major explosive eruptions since ~50 ka, most recently the mid-10th century VEI 6-7 "Millennium Eruption" (ME) at Tianchi volcano, which ejected 7-9 km^3 each of comenditic and trachytic magmas with minor mafic material. Elucidating the formation of ME trachyte and comendite is crucial not only for the understanding of the genesis and eruption of peralkaline magmas, but also for the monitoring and assessment of potential future magmatic activities. While previous models attributed ME silicic magmas to protracted fractional crystallization, the potential roles of recharge and mixing in this long-lived system remain poorly constrained.

Clinopyroxene (Cpx) is an excellent recorder of magmatic events that are otherwise obscured in whole-rock compositions, owing to its wide stability field and moderate cation diffusion rates. Here, we use in-situ chemical compositions of Cpx combined with unsupervised clustering analysis to track the magmatic evolution following the penultimate eruption.

ME Cpx exhibit marked textural and compositional heterogeneity. Hierarchical clustering of Cpx major elements revealed five groups linked to specific magmatic environments (Fig 1), facilitating the recognition of Cpx formed in similar environments but mixed in different rock types. Notably, Fe-rich Cpx found in comendite are separated into Na-rich and Na-poor groups. Mg-rich, Na-poor rims surrounding Na-rich cores reveal a recharge event in comendite (Fig 2A-B). Patchy Cpx, common in trachyte and associated with a cluster of intermediate Mg#, displays channel-like or chaotic Mg-rich zones enclosing Mg-poor areas (Fig 2C-D) accompanied by Al and trace element variations. Mg# of patchy zones match well with different groups of fayalite Mg#, implying the coeval formation of fayalite and patchy zones in Cpx during progressive recharge events. Our findings suggest that ME trachyte and low-Si comendite were not simply the products of mafic magma fractionation, but rather represent the cumulative result of multiple recharge events into evolved mushes. Magmatic processes recognized in this study may also provide petrological reference for the interpretation of geophysical signals observed during unrests at Tianchi in recent years.

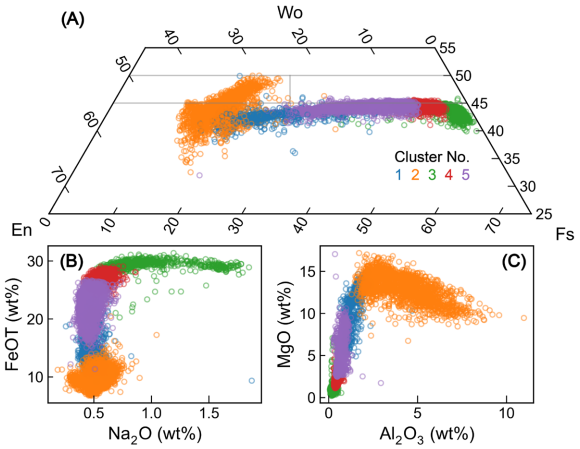


Fig 1. Hierarcical clustering results of ME Cpx compositions.

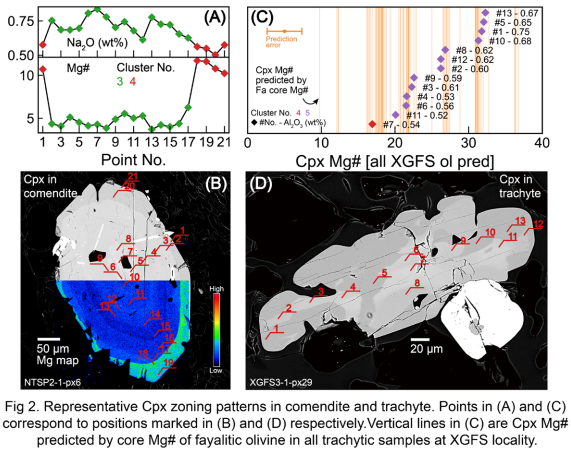


Fig 2. Representative Cpx zoning patterns in comendite and trachyte. Points in (A) and (C) correspond to positions marked in (B) and (D) respectively.Vertical lines in (C) are Cpx Mg# predicted by core Mg# of fayalitic olivine in all trachytic samples at XGFS locality.