

SPECIAL COLLECTION: GLASSES, MELTS, AND FLUIDS, AS TOOLS FOR UNDERSTANDING VOLCANIC PROCESSES AND HAZARDS

Role of volatiles (S, Cl, H₂O) and silica activity on the crystallization of h a yne and nosean in phonolitic magmas (Eifel, Germany and Saghro, Morocco)†

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ABSTRACT

To constrain the crystallization of alkaline and volatile-rich lavas present in intraplate settings, we studied the petrological features and the geochemical composition of major, trace, and volatile elements of mineral and bulk-rock of two sodalite-bearing phonolites: (1) h a yne-plagioclase-bearing Si-K-rich phonolite from Laacher See (Germany) and (2) nosean-nepheline-bearing Si-poor phonolite from Saghro (Morocco). In h a yne-bearing phonolites (55–59 wt% SiO₂, K > Na, Na+K/Al = 0.96–1.08), we found that the low silica and low sodium activity promoted the early crystallization of S-rich h a yne (13.7–13.9 wt% SO₃, 0.4 wt% Cl) + S-rich apatite (0.7–0.9 wt% SO₃), titanite, and rare pyrrhotite followed by clinopyroxene-plagioclase-sanidine at relatively low pressure and temperature ($P = 250$ MPa and $T = 850$ °C) and oxidized condition ($\Delta\text{NNO} = +1$, where NNO is nickel-nickel oxide buffer). The crystallization of h a yne occurred at fluid-undersaturated conditions from a silicate melt with 6 wt% H₂O, 0.17–0.23 wt% Cl, 0.11–0.4 wt% S, and 0.07–0.14 wt% F. Nosean-bearing phonolites from Saghro are silica-poor and peralkaline (52–54 wt% SiO₂, Na > K, Na+K/Al = 1.2) and crystallized at higher P and T (300 MPa and 950 °C) and more reduced conditions (NNO) compared to h a yne-bearing phonolites. The incongruent reaction to form nosean requires high silica and Na₂O activity. The mineral assemblage and composition suggest early crystallization of nepheline followed by nosean (7.8–8.8 wt% SO₃; 1–1.1 wt% Cl). The sequence of crystallization is: clinopyroxene + nepheline + S-poor apatite (<0.04 wt% SO₃) + pyrrhotite followed by nosean and titanite. Nosean-bearing magmas are fluid-undersaturated with relatively low volatile content (4 wt% H₂O, <0.25 wt% Cl, <0.056 wt% S, 0.08–0.1 wt% F), although Cl may have exsolved during ascent and formed a fluid phase (NaCl-bearing).

Both h a yne- and nosean-bearing phonolites are last equilibrated at relatively low pressure and high temperature. H a yne and nosean crystallized at oxidized and volatile-rich pre-eruptive conditions. They record the volatile concentrations at depth and may be used as oxybarometer. The incongruent reactions involved to form h a yne and nosean suggest that phonolitic magmas became more oxidized during crystallization. The initial volatile concentrations in basanite/nephelinite magmas, from partial melting of volatile-bearing K₂O-rich mantle rock, should have been one important factor influencing the crystallization of h a yne-bearing Si-K-rich phonolite and nosean-bearing Si-poor phonolite in intracontinental setting.

Keywords: Phonolite, sodalite, h a yne, nosean, volatile elements, pre-eruptive conditions