Crystallization of sodalite-bearing phonolite (Eifel, Germany and Saghro, Morocco): Role of volatiles (S, Cl, H_2O) and silica activity

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In alkaline and silica undersaturated volcanic rocks, the presence of minerals of the sodalite group attest of the presence of volatile in magmas and possible deep magmatic fluids. To constrain the crystallization of alkaline and volatile-rich lavas, *w*e studied the petrological features and the geochemical composition of major, trace and volatile elements of mineral and bulk-rock of sodalite-bearing phonolites. We identified two groups depending on the presence of haüyne or nosean: (i) haüyne-plagioclase-bearing Si-K-rich phonolite (i.e Laacher See, Germany) and (ii) nosean-nepheline Si-poor phonolite (i.e. Saghro, Morocco).

Haüyne-bearing phonolites from Laacher See are Si-rich and slightly peralkaline (55-59 wt% SiO_2, K>Na, Na+K/Al =0.96-1.08). They crystallized at relatively low pressure and temperature (P=200 MPa and T=850°C) and oxidized conditions (ΔNNO-NNO+1). The sequence of crystallization is: S-rich haüyne (13.7-13.9 wt% SO_3, 0.4 wt% Cl), S-rich apatite followed by cpx, plagioclase and sanidine. The crystallization of haüyne occurred at fluid-undersaturated conditions from a silicate melt with 6 wt% H_2O, 0.17-0.55 wt% Cl, 0.11-0.4 wt% S and 0.07-0.14 wt% F.

Nosean-bearing phonolites from Saghro are Si-poor and peralkaline (52-54 wt% SiO_2, Na>K, Na+K/Al =1.2) and crystallized at higher P and T (300 MPa and 950°C) and more reduced conditions (close to NNO buffer) compared to haüyne-bearing phonolites. The mineral assemblage suggests an early crystallization of nepheline followed by nosean (7.8-8.8 wt% SO_3; 1-1.1 wt% Cl). This magma was fluid-undersaturated with relatively low volatile content (4 wt% H_2O, 0.25 wt% Cl, 0.056 wt% S, 0.08-0.1 wt% F).

Haüyne- and nosean-bearing phonolites are last equilibrated at low pressure. The low silica and sodium activity and the high volatile content in phonolites promoted early crystallisation of haüyne, whereas high silica activity and lower volatile content resulted in the crystallization of nepheline followed by nosean. Incongruent reactions suggest that phonolitic magmas became more oxidized during magma differentiation. The initial volatile concentrations in nephelinite magmas, from partial melting of volatile-bearing K_2O-rich mantle rock, should have been one important factor influencing the crystallization of haüyne-bearing Si-K-rich phonolite and nosean-bearing Si-poor phonolite in intracontinental setting.