

Phosphate saturation in ferrobasaltic magmas: The importance of iron content and oxidation state.

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Nelsonites are rocks made up of apatite and Fe-Ti oxides which are found associated with anorthosites and in extreme differentiates of some mafic layered intrusions, including the Bushveld complex. However, the petrogenetic processes which lead to their formation are poorly understood, although it is generally assumed that such rocks precipitated from liquids highly enriched in Fe, Ti and P. Two possibilities have been proposed in the literature to explain the formation of such liquids: a) immiscibility, or b) extreme magmatic differentiation. In the case of the latter hypothesis, this requires saturation of the magma in both Fe-Ti oxides and apatite to be suppressed as long as possible. In this respect it is of note that the presence of P in the liquid is known to retard magnetite saturation (*e.g.* [1]) and one may ask the question to what extent the presence of Fe³⁺ in the liquid retards phosphate saturation. If this were the case then Fe and P contents of liquids could increase to high levels until either magnetite or apatite finally appears on the liquidus, following which the other phase also precipitates in abundance.

In order to test the influence of ferric iron content on phosphate saturation we have performed crystallization experiments at 1 atmosphere using two different ferrobasaltic starting compositions (8 and 16wt% FeO*). Experiments were performed in the temperature range 1030 to 1075°C and oxygen fugacity from 1.5 log₁₀ units below to 5.5 log₁₀ units above the fayalite-magnetite-quartz (FMQ) buffer. Phosphorus was added (as P₂O₅) to all experiments in sufficient quantity to reach saturation in a phosphate mineral (generally whitlockite). In certain experiments liquid-liquid immiscibility was observed. However, this was only in experiments with additions of 10wt% P₂O₅ (note that experiments with additions of 5 wt% P₂O₅ did not show immiscibility) thus we do not imply that this observation has any direct relevance to natural systems. On the other hand, the presence of liquid-liquid immiscibility has the consequence that liquid compositions in equilibrium with whitlockite are extremely variable, for example with silica contents ranging from 10 to 75 wt%.

Our data, combined with those of phosphate saturated liquids from the literature,

have been used to assess the compositional controls on phosphate saturation. This analysis demonstrates that the principal factors affecting the P₂O₅ content of magmas at phosphate saturation are the SiO₂ and CaO content of the liquid, temperature playing a secondary role (in broad agreement with previous studies, *e.g.* [2]). On the other hand, no effect of either total iron content or ferric iron content could be discerned. These results infer that the variation of silica content as a function of differentiation may be more important than the variation of iron content when attempting to explain the origin of Nelsonites.

[1] TOPLIS, M. J., LIBOUREL, G. and CARROLL, M. R. (1994). *Geochim.Cosmochim. Acta*, 58 (2), 797-810. [2] WATSON, E.B. (1980) *Earth Planet. Sci. Lett.*, 51 , 322-335.