Fe-Ti-V-P deposits in anorthosite complexes; the bearing of the parental magma composition and crystallization conditions on the economic value

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Fe-Ti-V-P deposits in anorthosite complexes: the bearing of parental magma composition and crystallization conditions on the economic value.

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Recent experimental data (Fram & Longhi 1992; Longhi et al. 1993; Vander Auwera & Longhi 1994; Vander Auwera et al. 1998; Longhi et al. 1999) indicate that parental magmas of the anorthosite-mangerite-charnockite (AMC) suite probably encompass a large continuum of compositions ranging from high-Al basalts (HLCA, Table 1) to more ferroan and potassic compositions, represented by the primitive jotunites (hypersthene-bearing monzodiorites)(TJ, Table 1).

Table 1 Endmember composition of the norite series

	TJ	**HLCA**
	Vander Auwera & Longhi, CMP 1994	Fram & Longhi, Am Min 1992
SiO_2	49.39	50.02
TiO_2	3.67	1.85
Al_2O_3	15.81	17.51
FeO	13.11	10.97
MgO	4.54	6.67
MnO	0.13	0.15
CaO	6.87	8.78
K_2O	0.96	0.44
Na_2O	3.50	2.93
P_2O_5	0.71	0.16

Experimental phase equilibria show that both endmember magmas can account for the norite series which fractionates at 3-5 kb to silica-enriched liquids (Longhi et al. 1999).

In Rogaland (Fig. 1), comparison between phases experimentally obtained on TJ primitive jotunite (i.e. plag An47 and orthopyroxene En66, Vander Auwera & Longhi 1994) and natural phases from the anorthosite massifs (i.e. An49 and En74 in the Åna-Sira anorthosite massif and An57 and En75 for the Egersund-Ogna anorthosite massif) and from the Bjerkreim-Sokndal layered intrusion (An52 and En77) suggests that a liquid generally similar to this primitive jotunite was parental to both types of intrusions.

Interestingly, Fe-Ti-V-P deposits have been recognized in massive anorthosites and in the Bjerkreim-Sogndal layered intrusion (Duchesne 1999). In massive anorthosites, the ore-bodies occur as (deformed) dykes or pods ranging in composition from pure hemo-ilmenite (Jerneld) to ilmenite norite (Tellnes, Storgangen). Polybaric fractional crystallization and synemplacement deformation in rising anorthosite diapirs lead to relatively Mg- and Cr-rich ilmenite (± V-magnetite) deposits. The high contents in Cr and Mg are deleterious for the new chlorination process that tends to substitute to the classical sulfatation process used in the TiO_2 pigment industry. On the other hand fractional crystallization of jotunite magmas in layered magma chambers, such as the Bjerkreim-Sokndal inytrusion, gives rise to voluminous "disseminated" mineralizations, containing low Mg and Cr ilmenite + Ti-magnetite ± REE-rich apatite, more adequate to the chlorination process but still of sub-economic value. Immiscibility is not the controlling mechanism, except maybe in some rare nelsonites (Hesnes).

Subsolidus re-equilibration leads to a thorough change in the oxide mineral composition towards an

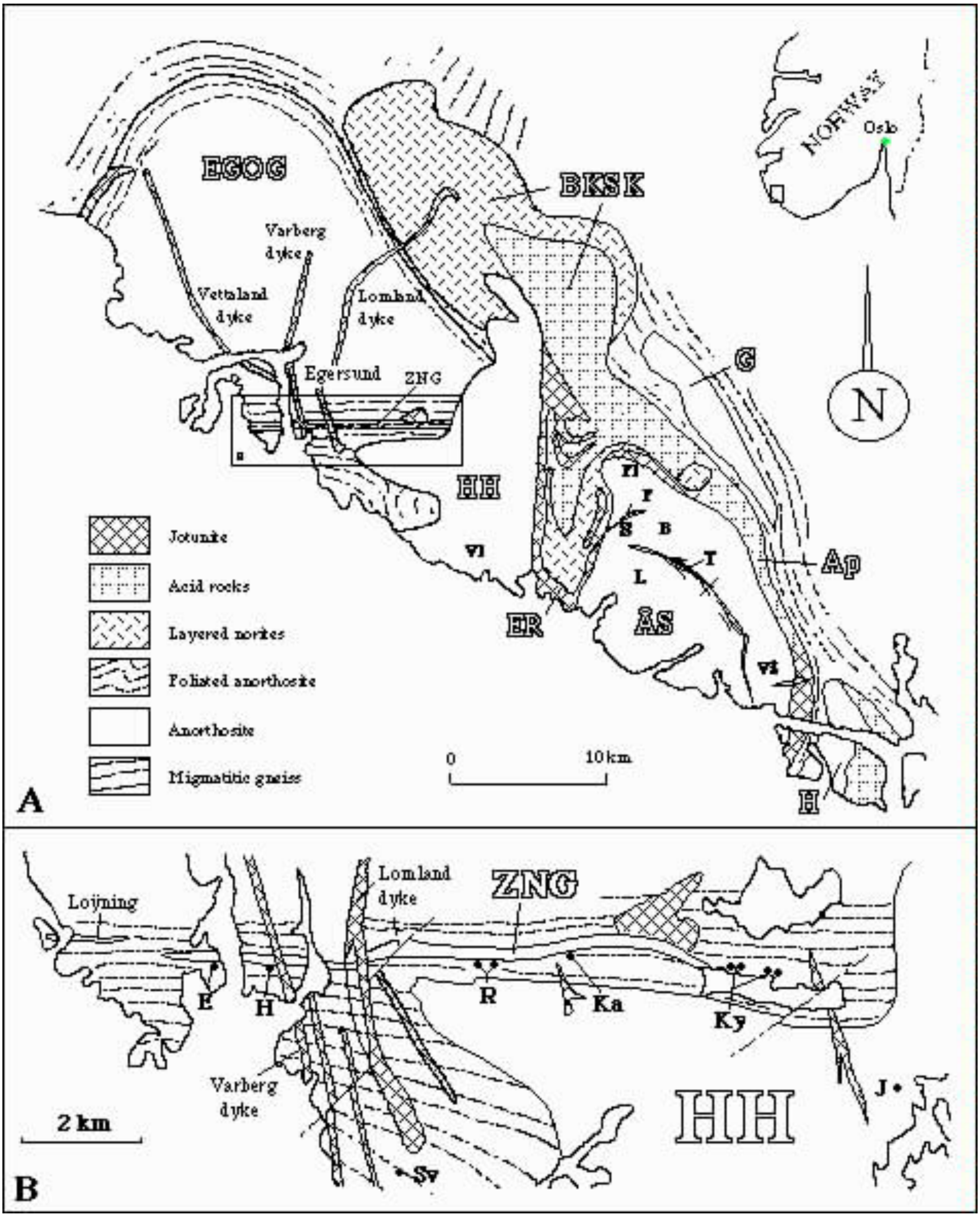

Figure 1 (after Duchesne and Schiellerup, 2001).

A. Schematic geological map of the Rogaland anorthosite province Main geological units: EGOG, Egersund-Ogna massif; HH: Håland-Helleren massif; ÅS: Åna-Sira massif; H: Hidra massif; BKSK: Bjerkreim-Sokndal intrusion; Ap: Apophysis; G: Garsaknat massif; ER: Eia-Rekefjord intrusion. Fe-Ti deposits: B: Blåfjell; F: Flordalen; Fl: Frøtlog; L: Laksedal; S: Storgangen; T: Tellnes; Vl: Vatland.

B. Schematic geological map of the contact zone between the Egersund-Ogna and Håland-Helleren massifs. Same shading as A. ZNG: Norito-granitic Zone; Fe-Ti deposits: E: Eigerøy; H: Hesnes; J: Jerneld; Ka: Kagnuden; Ky: Kydlansvatn; R: Rødemyr; Sv: Svånes enrichment in end-member compositions. Reactions between the oxide minerals leave conspicuous microscopical evidence : zoning of the hematite exsolution content in the ilmenite grain towards

the contact with a (Ti-) magnetite grain and development of a subcontinuous rim of Al spinel-bearing ilmenite inside magnetite at the contact.. The reactions regularly lower the hematite content of the ilmenite solid solution and the Ti- and Al-spinel contents of the magnetite solid solution. The Mg content of ilmenite also decreases subsolidus, particularly in the Bjerkreim-Sokndal intrusion (Duchesne and Schiellerup, 2001), possibly through reactions with pyroxenes, but no reaction rims can be observed.

References

Duchesne, J.C. 1970. Microstructures o Fe-Ti oxide minerals in the South Rogaland anorthositic complex (Norway). Ann. Soc. Géol. Belg. 93: 527-544.

Duchesne, J.C. 1972. Fe-Ti oxide minerals in the Bjerkreim-Sogndal massif (Norway). J. Petrol. 13: 57-81.

Duchesne, J.C. 1999. Fe-Ti deposits in Rogaland anorthosites (South Norway): geochemical characteristics and problems of interpretation. Miner. Deposita 34: 182-198.

Duchesne, J.C. & Schiellerup, H. 2001. The Fe-Ti deposits. In J.C. Duchesne (ed.) The Rogaland intrusive massifs: an excursion guide. NGU Bulletin (in the press).

Fram, M. & Longhi, J. 1992. Phase equilibria of dikes associated with Proterozoic anorthosite complexes. Amer. Min. 77: 605-616.

Longhi, J., Fram, M., Vander Auwera, J., Montieth, J. 1993. Pressure effects, kinetics, and rheology of anorthositic and related magmas. Amer. Min. 78: 1016-1030.

Longhi, J., Vander Auwera, J., Fram, M. and Duchesne, J.C. 1999. Some phase quilibrium constraints on the origin of Proterozoic (Massif) anorthosites and related rocks. J. Petrol. 40: 339-362.

Vander Auwera, J. & Longhi, J. 1994. Experimental study of a jotunite (hypersthene monzodioite): constraints on the parent magma composition and crystallization conditions (P,T,fO_2) of the Bjerkreim-Sokndal layered intrusion. Contrib. Miner. Petrol. 118: 60-78.

Vander Auwera, J., Longhi, J. & Duchesne J.C., 1998. A liquid line of descent of the jotunite (hypersthene monzodiorite) suite. J. Petrol. 39: 439-468.