DISTRIBUTIONS OF TRACE ELEMENTS IN THE EXTREME DIFFERENTIATES OF THE FONGEN-HYLLINGEN LAYERED COMPLEX: A POSSIBLE KREEP ANALOG.

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The Fongen-Hyllingen layered basic complex, Trondheim Region, Norway, consists of extremely differentiated, well-layered rocks, varying from dunites and troctolites through two-pyroxene gabbros to quartz-bearing alkali ferrosyenites. Although seven major episodes of magma replenishment are indicated by compositional reversals, it appears there was no loss of residual magma prior to or during the influx of fresh magma, but that extensive mixing of fresh and residual magmas occurred instead; smoothly varying compositional trends in the last 1500 meters of the upper Hyllingen sequence of the layered complex show that it must have crystallized as a closed system without further magma influx (1). A suite of twelve rocks from the upper part of the Hyllingen sequence, corresponding to the HUZe (Hyllingen Upper Zone) through HEZd (Hyllingen Extreme Zone) of Wilson et al. (1), have been analyzed by instrumental neutron activation analysis for REE and other incompatible elements. The lower rocks of this suite, diorites to quartz-bearing monzodiorites, show a moderately sloping REE pattern (the chondrite-normalized La/Yb ratio is about 3), with La enriched about 65 times OC (ordinary chondrites). The stratigraphically higher rocks, syenites to alkali syenites, have highly fractionated REE patterns; the OC-normalized La/Yb ratio reaches 37, and La is 1400 times OC for the most differentiated sample. As shown in Fig. 1, the REE patterns of the uppermost rocks are more similar to those of calc-alkaline suites, such as the charnockitic final differentiates of the Hidra Massif in southwest Norway (2), than they are to the moderately sloping patterns of the final differentiates of purely tholeiitic basic intrusions such as the Skaergaard (3). Wilson et al. (1) found corresponding major-element trends that suggested parallels with calc-alkaline intrusions, although the Fongen-Hyllingen parental magma is tholeiitic.

The REE fractionation is greatly controlled by the precipitation of REE-accepting accessory phases. Apatite is present throughout the upper Hyllingen sequence, and zircon, sphene, and allanite become important accessories as differentiation continues. One sample studied was stratigraphically below the first appearance of zircons, and it has a pattern which parallels the trend of the Skaergaard rocks; the LREE-enriched patterns of the stratigraphically higher samples are possibly due to the preferential acceptance of HREE by zircon and hornblende (4). The Th/U ratio also increases by a factor of 3.5 over the range of samples, consistent with effects expected from zircon crystallization.

One goal of our study was to examine the possibility that the final differentiates of the Fongen-Hyllingen complex are analogous to lunar KREEP. Fig. 2 shows representative Fongen-Hyllingen samples normalized to the KREEP component of Warren and Wasson (5). The less fractionated samples have KREEPy REE patterns, although KREEP is more highly enriched in REE by a factor of 3 to 10, while the uppermost rocks show a strong LREE/HREE fractionation, with LREE 5 times greater than KREEP and HREE 3 times less than KREEP. Because some commonly incompatible elements (e.g., the HREE) were readily accepted into minerals that were important accessory phases in the late Fongen-Hyllingen differentiates, their relative abundances are much lower than those of the LREE. Another contrast with the KREEPy magma is presence of appreciable of pH_2O in the Fongen-Hyllingen; hornblende and biotite are ubiquitous phases in the upper part of the complex. Despite these differences, the remarkable enhancement of the LREE and the closed-system crystallization in the upper zone appears to make the Fongen-Hyllingen a valuable KREEP analog worthy of extensive study.

References:
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(3) Haskin L.A. and Haskin M.A. (1968) GCA 32, 433-447.
(4) Petersen J.S. (1980) Contrib. Min. Petr. 73, 161-172.
(5) Warren P.H. and Wasson J.T. (1979) Rev. Geoph. Sp. Ph. 17, 73-88.

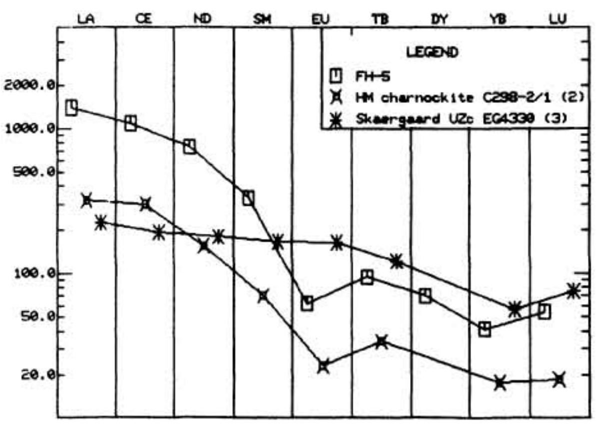

Fig. 1. Comparison of chondrite-normalized REE patterns from Forgen-Hyllingen (FH), Hidra Massif (HM) and Skaergaard.

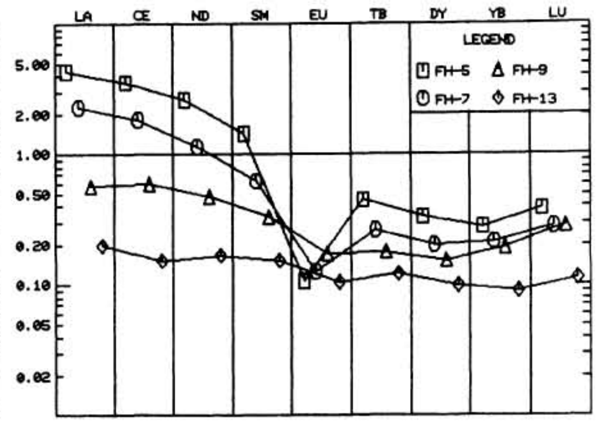

Fig. 2. KREEP-normalized REE patterns of representative Fongen-Hyllingen extreme differentiates.