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ARE OCEANIC PLAGIOGRANITES GENERATED BY PARTIAL MELTING OF GABBROS?

INTRODUCTION

Layer 3 of the oceanic crust, the plutonic section, consists of generally gabbroic rocks. Included in the gabbroic section are small, but ubiquitous amounts of leucocratic, evolved rocks composed of quartz diorites, tonalites, trondjhemites, so-called oceanic plagiogranites. Such rocks were drilled in several legs of the Ocean Drilling Program ("ODP", e.g., Southwest Indian Ridge, SWIR, Leg 176) and are also present in the plutonic sections of most ophiolites. For the genesis of oceanic plagiogranites at mid-ocean spreading systems, two models are under discussion: (1) Late-stage differentiation of a MORB-type melt and (2) partial melting of pre-existing gabbros within high-temperature shear zones. In this study, we have applied recent experimental data of the experimental lab in Hannover to the plagiogranite petrogenesis in order to test both models. The role of water during the genesis of these rocks (presence of amphibole as mafic phase in natural plagiogranites) was assessed by including water to the systems.

METHODS OF INVESTIGATION

Crystallization experiments were performed in a MORB system doped with different water contents at different redox conditions at 200 MPa (Berndt 2002), and hydrous partial melting experiments were performed at 200 MPa on typical oceanic gabbros (Koepke et al. 2003 in press). For the experiments we have used an internally heated pressure vessel (IHPV) for high temperatures (up to 1250^{0}C) equipped with a rapid-quench system and a hydrogen membrane for controlling the oxygen fugacity.

RESULTS

Liquid lines of descent obtained via crystallization experiments are mainly controlled by oxygen fugacity and only to a little extent by water activity. SiO_2–rich residual melts can be obtained under both oxidizing and reducing redox condition at low temperatures, but at least one fractionation step is required to reach high-silicic plagiogranites (SiO_2 > 70 wt%). The partial melting of typical oceanic gabbro leads at

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low temperatures also to plagiogranitic melts. At 940^{0}C, the normalized SiO_2 contents of the experimental melts range between 60 and 61 wt%, and at 900^{0}C from 63 and 68 wt% (based on 3 different oceanic gabbros from ODP Legs 176 and 153 as starting material). These melts coexist with orthopyroxene, amphibole, plagioclase and in one sample also with olivine. The experimental melt compositions are compared with those of natural plagiogranites of different tectonic settings and show in general a broad compositional overlap with those. Our experiments imply, in concordance with the natural systems, that TiO_2 is a key parameter for discrimination between both processes: TiO_2 is low in anatectic plagiogranitic and high in those plagiogranites generated by differentiation (Fig. 1).

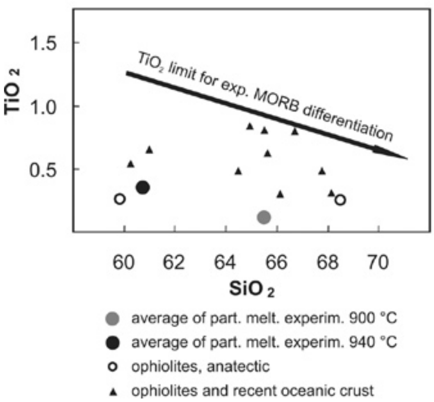

Fig. 1. Compositions of oceanic plagiogranites both from experiments and nature. The averages of the partial melting experiments on natural oceanic gabbros are based on 3 different compositions. The origin of those plagiogranites from ophiolites generated by anatexis is evidenced by field and textural relations. The curve of TiO_2-limit is based on crystallization experiments in a MORB system at low temperatures (with low melt fractions, Berndt 2002). All these experiments, even those under oxidizing conditions, lead to TiO_2 contents in the residual melts lying above this curve. References are given in Koepke et al. 2003 in press.

The ~1500 m long drilled gabbroic section of the Legs 118 and 176 from the Southwest Indian Ridge (SWIR) contains numerous felsic veins, most of them with a plagiogranitic composition. The compositions of the melts, observed in our experiments at low temperatures match those of natural SWIR-plagiogranites. This implies a model, that the felsic veins were generated by partial melting of gabbros. Further evidence is provided by high temperature microscopic veins within the SWIR gabbros, containing minerals which were formed by a water-rich fluid at temperatures up to 1000^{0}C. The othopyroxene and amphibole composition from the veins fit with the composition of crystals in our low temperature runs, indicating, that these minerals can be regarded as restitic minerals after removing of the coexisting (plagiogranitic) melt. Moreover, by carefully checking rocks from reference locations for oceanic gabbros (from East Pacific Rise, Mid-Atlantic Ridge, SWIR, and Oman ophiolite), we found nearly in every rock microstructures, which indicate that hydrous partial melting proceeded. This is manifested in plagioclase showing veins and irregular patterns that are significantly enriched in An, while clinopyroxene and olivine had reacted to orthopyroxene and pargasite. An-rich plagioclase, orthopyroxene, and pargasite are regarded as restitic crystals of a partial melting reaction. Striking is the compositional agreement with corresponding phases in our melting experiments on natural gabbro, indicating temperatures between 940 and 1000^{0}C, shallow pressures in the crustal level, high water-activities (probably water-saturated) and slightly oxidizing conditions (~ Ni-NiO oxygen buffer) for the partial melting reactions. The temperature estimations are confirmed by geothermometry on coexisting pargasites and An-rich plagioclases leading to temperatures between 900 and 1000^{0}C.

CONCLUSIONS

The experimental work shows that partial melting of oceanic gabbros has the potential to generate plagiogranitic melts, and the compositions of the experimental liquids fit with those of natural plagiogranites. Moreover we have observed nearly in all oceanic gabbros from reference locations the petrographical evidence that hydrous partial melting proceeded, indicating that hydrous partial melting is a "quite normal" processes occurring in the deep oceanic crust. The conclusion is that the oceanic plagiogranites typically found in the gabbroic oceanic crust may have generated by partial melting of gabbros and not by "extreme" differentiation of a MORB-type magma as assumed so far.

REFERENCES

BERNDT J., 2002: Differentiation of MOR Basalt at 200 MPa: Experimental techniques and influence of H_2O and fO_2 on phase relations and liquid line of descent. PhD Thesis, University of Hannover, 118 pp.

KOEPKE J., FEIG S.T., SNOW J., FREISE, M., 2003 in press: Petrogenesis of oceanic plagiogranites by partial melting of gabbros drilled by ODP cruises: An experimental study. Contrib. Mineral. Petrol.