

PETROGENESIS OF OLIVINE MELILITE AND KIMBERLITE AND MELTING OF PERIDOTITE - C - O - H

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A survey of worldwide occurrences of olivine nephelinites, olivine melilitites and kimberlites reveals that primary mantle - derived magmas of each class can be identified (Brey, 1977) and systematic chemical differences between and within each class can be attributed to different conditions of origin. Olivine nephelinites and melilitites can be closely linked genetically by different degrees of partial melting of a peridotitic composition and/or varying $H_2O : CO_2$ in the source region. Olivine melilitites become increasingly undersaturated ($CaO + MgO/SiO_2$ increases) with increasing distance from a rift zone and if the W - coast of southern Africa is viewed as a part of a rifted zone then the olivine melilitites disappear at some distance from the rifted zone and are replaced by kimberlites. Kimberlites are chemically continuous to the olivine melilitites except for a much higher MgO/CaO . This may be attributed to increasing depth of magma segregation.

A systematic study of the liquidus phase relationships of a natural primary olivine melilitite + $H_2O + CO_2$ at 30 kb (and more limited studies at other pressures) has established liquidus fields for olivine, garnet, clinopyroxene and orthopyroxene and furthermore that the particular olivine melilitite is a possible partial melting product of a four phase garnet lherzolite at 27 kb, 1160 - 1180°C, if the melt contains 7 - 8 wt % H_2O and 6 - 7 wt % CO_2 in solution (Brey and Green, 1977). Limited experiments with a modified olivine melilitite (higher $CaO + MgO/SiO_2$), matching the most undersaturated melilitites show that these rocks are derived from greater depth (~ 34 kb) by lower degrees of partial melting and/or higher CO_2/H_2O in the source region. A kimberlitic composition (36 % SiO_2 , 35 % MgO , 8.7 % $CaO + 20$ % FeO , alkalis) with 15.3 % H_2O and 25 % CO_2 added has orthopyroxene and magnesite at its liquidus at 45 kb and 50 kb. Similar compositions may represent the melt near the solidus of carbonated peridotite at such high pressures. All these experiments were carried out under MH-buffered conditions which create oxygen fugacities probably too high for the actual conditions in the mantle. Oxygen fugacities in the region of the LVZ are more likely to be around or below those generated by a QFM buffer (Rosenhauer et al., this meeting ; Ryabchikov et al., in prep.). At these conditions carbon still shows high solubilities as carbonate ion in silicate melts (Ryabchikov et al., in prep.) and thus the above experiments are still applicable. Under these low oxygen fugacities however carbonates are not stable any longer under subsolidus conditions and graphite or diamond coexist with mantle silicate minerals (Ryabchikov et al., in prep. ; Rosenhauer et al., this meeting).

The oxidation state of carbon at subsolidus conditions has consequences on melting temperatures and the nature of first melts of peridotite - C - O - H. The melting of carbonated peridotite has found extensive coverage (e.g. Wyllie and Huang, 1976 and earlier papers ; Egglar, 1976 and earlier papers) and also is/was a matter of disagreement. CO_2

occurs in mantle peridotite at sufficiently high pressures and low temperatures in dolomite and at even higher pressures in magnesite. The composition of the first melts of carbonated peridotite (no H_2O present) is very Si - poor and especially CaO - rich and may be termed carbonatitic (Wyllie and Huang, 1976). Our own experiments with various mixes of olivine melilitite + increasing amounts of carbonate ($CC_{58}MC_{42}$) + CO_2 at 30 kb show that carbonates and silicates may be together at the liquidus for a composition somewhat Si - poorer than that found by Eggler (1976). In the presence of excess H_2O , but high enough CO_2/H_2O , the first melt will also be carbonatitic (Wyllie, 1977), a conclusion supported by our experiments on olivine melilitite + $CC_{58}MC_{42}$ + CO_2 + H_2O . The melting temperatures increase with increasing CO_2/H_2O in the vapor phase (Wyllie, 1977), but note that with increasing CO_2/H_2O in the vapor phase, peridotite is carbonated and clinopyroxene and olivine are eliminated. Most interesting for nature is probably the case where all CO_2 and H_2O present can be accommodated in carbonates (dolomite and magnesite at higher pressures) and amphibole and phlogopite resp. The carbonated and hydrated peridotite will melt at lower (and for all CO_2/H_2O in the system constant) temperatures as compared to the systems with only carbonates or hydrous phases) and the composition of the first melt will also be the same for all CO_2/H_2O . Holloway and Eggler (1976) investigated the melting in the stability field of phlogopite + dolomite and Brey (1976, unpublished Ph.D. thesis) for amphibole + dolomite at lower pressures. At present we attempt to establish the composition of the first melt at such conditions.

It is more likely that oxygen fugacities in the mantle are such that carbonates are not stable anymore and graphite or diamond are present at subsolidus conditions. For amounts of water in excess of what can be accommodated in hydrous phases a complex vapor phase consisting of H_2O , CO_2 , CH_4 ... will coexist with graphite or diamond. The solidus temperature depends on the composition of this vapor phase. If all the water in the system is present in hydrous phases, esp. amphibole and/or phlogopite, the melting temperature will be determined by the stability of the hydrous phase, e.g. as in the case for amphibole in pyrolite + $< .4\%$ H_2O (Green, 1973). Upon melting carbon will dissolve as the carbonate molecule in the resulting melts which still are highly undersaturated and probably resemble the most undersaturated olivine melilitites at lower pressures (~ 30 kb) and kimberlites (in the stability field of phlogopite) at higher pressures (> 30 kb, ~ 50 kb). The existence of the low - velocity zone is a consequence of interstitial melt of this type at depths beyond those at which amphibole is stable in peridotite compositions. Kimberlitic melts could, upon cooling at high enough pressures, precipitate diamonds.

References

- Brey, G., J. Volc. Geotherm. Res., in press
 Brey, G. and Green, D.H., Contrib.Mineral.Petrol., 61, 1977
 Eggler, D. H., Geology, 4, 1976
 Green, D.H., Earth Planet. Sci. Lett., 19, 1973
 Holloway, J. R. and Eggler, D. H., Ann. Rept. Dir. Geophys. Lab., Washington, 75, 1976
 Rosenhauer et al., this meeting
 Ryabchikov, I. D., Green, D. H., Brey, G., in prep.
 Wyllie, P. J., J. Geol., 85, 1977
 Wyllie, P. J. and Huang, Contrib. Mineral. Petrol., 54, 1976