



Melting of hydrous-carbonated eclogite at 4–6 GPa and 900–1200°C: implications for the sources of diamond-forming fluids.

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Introduction

Eclogites play a significant role in geodynamic processes, transferring large amounts of basaltic material and volatiles (chiefly CO₂ and H₂O species) into the earth's mantle via subduction. They are also linked to formation of high density fluid inclusions in diamonds (HDF's). Previous studies on eclogite melting focused on two end member systems: either carbonated or hydrous eclogites. Here we focus on a hydrous carbonated eclogitic system in order to define the position of its solidus and determine the fluid and melt compositions at 4-6 GPa and 900-1200°C. In contrast to procedures commonly adopted in the past, we rely on direct measurements of the liquid phase (melt/fluid/supercritical liquid) compositions in determining the solidus location instead of relying on solid mineral compositions and/or textural criteria. The variations in the chemistry of the liquid phase enable us to discuss the role of eclogites in the sources and formation of HDFs found in diamond inclusions.

Analytical Results

All experiments contained garnet and clinopyroxene, representing an eclogitic assemblage and are in equilibrium with a H₂O and CO₂-rich fluid or melt. At 4-5 GPa and 900°C a large amount of H₂O and CO₂ in the liquid phase indicates the presence of an aqueous-carbonated fluid in equilibrium with the eclogite solid assemblage. A stepwise decrease in the H₂O and CO₂ contents of the liquid between 1000-1100°C is coupled with a stepwise increase in other oxides suggesting that the solidus is located at these conditions. At 6 GPa a smooth decrease in H₂O and CO₂ contents of the liquid phase with increasing temperature is observed. This smooth change indicates the existence of a supercritical fluid and the existence of a second critical end-point for the eclogite+H₂O+CO₂ system at ~5.5 GPa and ~1050°C.

Table 1: Determined liquid composition coexisting in equilibrium with eclogite as obtained in this study.

P (GPa)	4	4	4	4	5	5	5	5	6	6	6	6
T	900	1000	1100	1200	900	1000	1100	1200	900	1000	1100	1200
SiO ₂ ^a	81.09	43.84	47.53	44.43	68.52	39.64	39.84	42.76	69.25	50.6	48.83	36.35
TiO ₂	0.41	2.42	2.45	2.94	0.76	1.79	2.84	3.16	0.63	1.63	2.33	2.58
Al ₂ O ₃	4.79	3.31	6.2	6.82	1.33	3.71	5.26	9.1	2.23	2.54	3.21	4.96
FeO	0.53	10.5	9.95	11.97	9.24	12.92	14.47	12.42	4.3	6.43	7.48	14.28
MgO	0.58	10.41	9.93	12.01	5.54	9.89	15.09	12.69	3.69	7.15	8.22	15.25
CaO	4.07	19.43	19.03	18.14	9.56	24.28	19.25	17.25	13.53	27.5	27.12	17.03
Na ₂ O	6.73	8.93	4.56	3.39	3.1	7.03	3.27	2.32	4.73	3.22	2.37	8.93
K ₂ O	1.8	1.15	0.3	0.27	1.94	0.72	NA	0.22	1.61	0.91	0.41	0.59
Cr ₂ O ₃	0.005	0.03	0.05	0.04	0.02	0.02	NA	0.08	0.03	0.02	0.01	0.03
H ₂ O _{mole fraction} ^b	66.78	60.63	40.65	30.32	66.93	60.96	42.14	29.9	66.8	56.7	49.3	53.2
H ₂ O+CO ₂ _{mole fraction}	82.45	83.48	57.96	44.65	89.06	85.95	60.08	44.03	91.2	78	68.5	78.3

a. Calculated CO₂ and H₂O free basis normalized to 100%.

b. Mole fractions of H₂O and H₂O+CO₂ were calculated using the hydrous-carbonated fluid/melt compositions.

At 4-6 GPa and 900°C, the hydrous carbonated fluids we found are silica-rich and mostly consist of H₂O and CO₂ with very little carbonate content. They are not represented in the naturally occurring HDFs, but are similar in composition to recent thermodynamical computations done by Sverjensky and Haung (2015). They calculated, using a thermodynamic model, a hypothetical composition of a siliceous fluid after reaction with eclogite at 5 GPa and 900°C and predicted that such a fluid can contain significant amounts of CO₂ (47 wt% relative to ~34 wt% in this study).

At 4-6 GPa and 1000-1100°C the composition of the fluids reported here fall generally between those of silicic and low-Mg HDFs. The Al₂O₃, CaO, MgO and FeO content of the fluid increases with rise in temperature, while the Na₂O content remains relatively constant. At 1200°C, the composition of the determined melts is close to the bulk composition of the system (F=70%). As such, this composition is not representative of natural systems.

The fluid and near solidus melt compositions reported in this study indicate that the hydrous carbonated eclogite system is a possible source rock for HDFs whose composition is intermediate between low-Mg carbonatitic and silicic endmembers. We suggest that the silicic-carbonatitic array is not the result of continuous melting of an eclogite source, but rather, of variations in the H₂O/CO₂ ratio of the fluid.

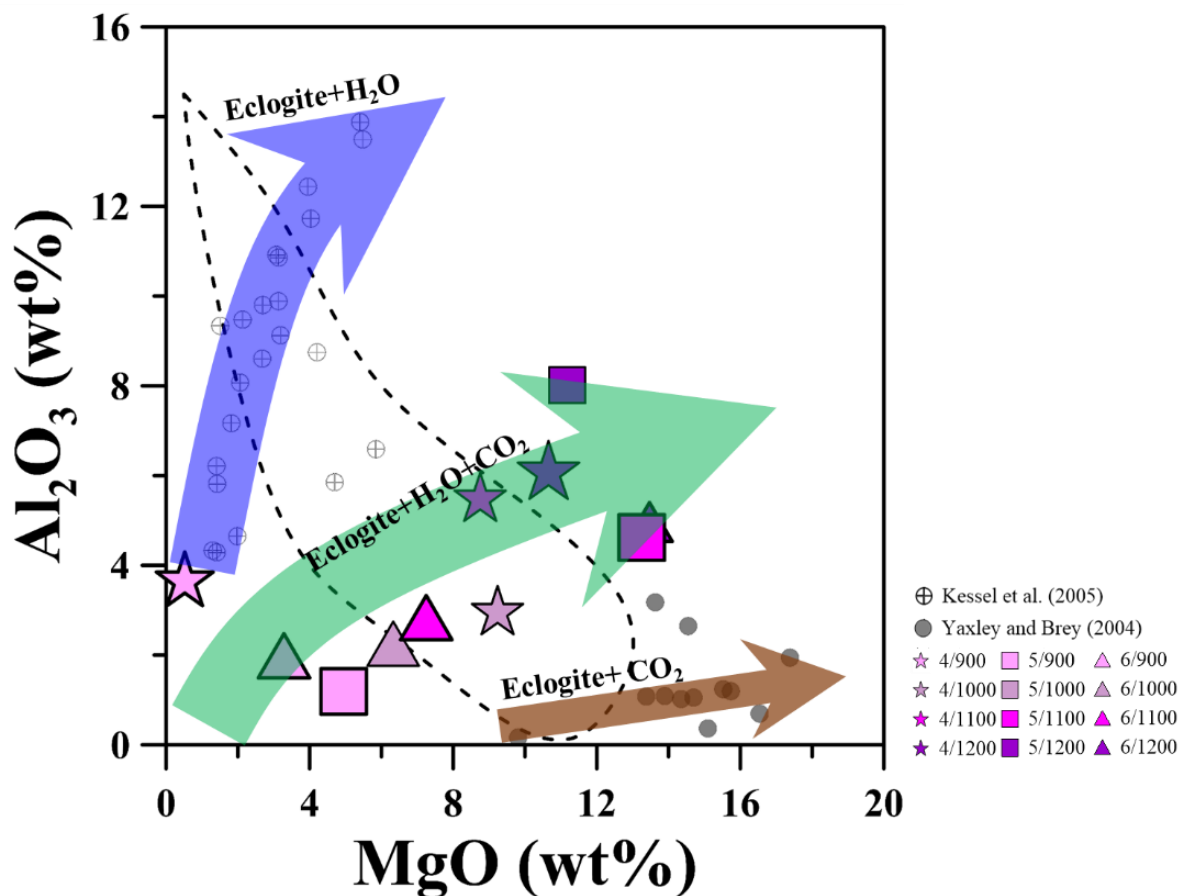


Fig 1: Al₂O₃ vs MgO variation diagram with liquid compositions from Kessel et al. (2005), Yaxley and Brey (2004) and this study (Water and CO₂-free compositions, corrected for lack of K₂O). Near solidus compositions in the eclogite+H₂O and eclogite+H₂O+CO₂ plot within the array charted by the low-Mg carbonatitic to silicic array (Wiess et al, 2009) suggesting that incipient melting of heterogeneous eclogitic sources as a possible mechanism for the production of the various HDF compositions.

References

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