

Effects of redox variation on kimberlite magma fractionation during ascent: an experimental study

ZAIRONG LIU¹, I-MING CHOU¹, KAIWEN TA²,
 ZHONGJUAN LI³, YU WANG⁴ AND STEPHAN KLEMME⁵

¹Institute of Deep-sea Science and Engineering, Chinese Academy of Sciences

²Institute of Deep Sea Science and Engineering, Chinese Academies of Sciences

³Hainan University

⁴Guangzhou Institute of Geochemistry, Chinese Academy of Sciences

⁵University of Münster

Kimberlite magmatism offers critical insights into deep mantle composition and geodynamic processes within the deep lithosphere and upper asthenosphere^[1], linking modern and ancient subductions with supercontinent cycles^[2]. However, knowledge of kimberlite magma fractionation with respect to different redox conditions is limited^[3], primarily due to ambiguities regarding the primary magma composition and the complexities of experimental studies. To address this, we conducted experiments at 3–2 GPa and 1200–900 °C under two oxygen fugacity conditions (C-saturated CCO and Ni-NiO redox buffer pairs), using the average compositions of near-primary Group I kimberlites as the starting melt composition^[4]. As displayed in Fig. 1, our results show that olivine is the most stable mineral phase across all conditions. The stability of orthopyroxene and magnesian ilmenite is confined to specific oxygen fugacities: orthopyroxene is stable only under the carbon-saturated CCO buffer at 3 GPa, while magnesian ilmenite predominantly forms under Ni-NiO conditions. Additionally, carbonates and apatite are stabilized only under Ni-NiO-controlled conditions at the expense of the melt. The residual melt remains carbonatitic and evolves into a silicate-poor carbonatitic composition as the temperature decreases. Overall, our experiments suggest that an increase in oxygen fugacity promotes the crystallization of kimberlite magmas, providing new constraints on the redox-controlled fractionation processes during kimberlite magma ascent.

References

- [1] Sun, C. & Dasgupta, R. (2020). *Earth and Planetary Science Letters*, **550**, 116549.
- [2] Gernon, T.M., Jones, S.M., Brune, S., Hincks, T.K., Palmer, M.R., Schumacher, J.C., Primiceri, R.M., Field, M., Griffin, W.L., and O'Reilly, S.Y. (2023). *Nature*, **620**, 344–350.
- [3] Giuliani, A., Schmidt, M. W., Torsvik, T. H. & Fedortchouk, Y. (2023). *Nature Reviews Earth & Environment*, **4**, 738–753.
- [4] Becker, M. & Roex, A. P. L. (2006). *Journal of Petrology*, **47**, 673–703.

Fig. 1 Stability fields of phases under the P-T conditions of our experiments buffered by CCO (a) and NNO (b). Filled symbols indicates the presence of a phase. Abbreviations: Ol =

olivine, Cpx = clinopyroxene, Opx = orthopyroxene, Mg-Ilm = magnesian-ilmenite, Rt-rutile, Carb = carboantes (include dolomite and magnesite, Phl = phlogopite, Apt = apatite.

