Applications of a new Eu-in-plagioclase-clinopyroxene oxybarometer

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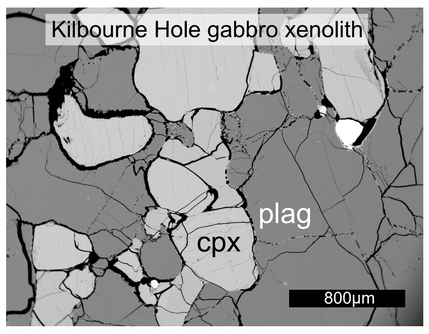
Summary: Oxygen fugacities (fO_2s) of intrusive reservoirs in planetary interiors are underconstrained. We developed a Eu-based oxybarometer that can be applied to plagioclase and clindopyroxene-bearing cumulate rocks, applicable to terrestrial, lunar and planetary systems. Here, we apply the oxybarometer to rocks from diverse settings to explore variations in fO_2.



Method

predicted: Dygert et al., 2020, GCA

$$D_{Eu}^{plag-cpx} = \frac{D_{Eu}^{plag-melt}}{D_{Eu}^{cpx-melt}} = \frac{\frac{c_{Eu}^{plag}}{c_{Eu}^{melt}}}{\frac{c_{Eu}^{cpx}}{c_{Eu}^{melt}}}$$

measured

predicted: this study

new divalent element partitioning model

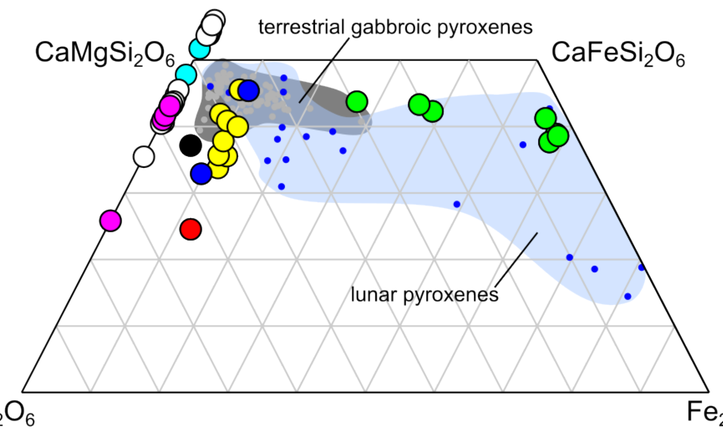
$$D_{Eu}^{mineral-melt} = \frac{K_{Eu}^{mineral-melt} \times D_{Eu^{2+}}^{mineral-melt} + D_{Eu^{3+}}^{mineral-melt} \times (fO_2)^{\frac{1}{4}}}{K_{Eu}^{mineral-melt} + (fO_2)^{\frac{1}{4}}}$$

newly constraintted

Sun and Liang, 2012 (Mg#>55) or Dygert et al., 2014 (Mg#<55)

fO_2 recovered numerically by equating measured and predicted Eu distribution

New divalent element partitioning model



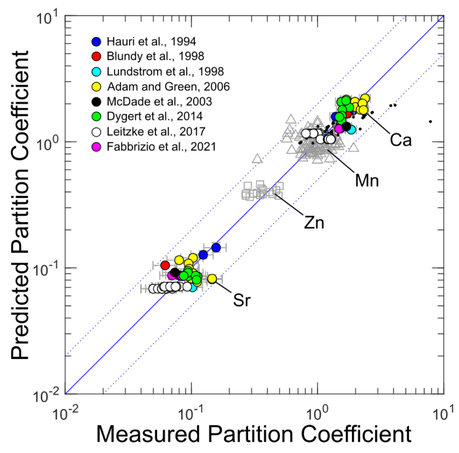
Calibrating data
- Hauri et al., 1994
- Blundy et al., 1998
- Lundstrom et al., 1998
- McDade et al., 2003
- Adam and Green, 2006
- Dygert et al., 2014
- Leitzke et al., 2017
- Fabbrizio et al., 2021

$$D = D_0 exp\left(\frac{-4\pi E N_A}{RT}\left(\frac{r_0}{2}(r_i - r_0)^2 + \frac{1}{3}(r_i - r_0)^3\right)\right)$$

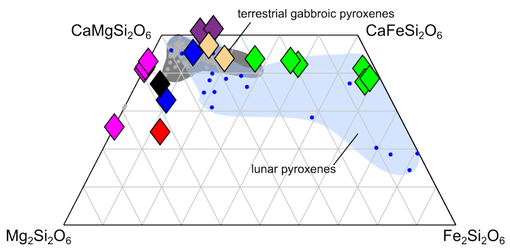
$$ln(D_0) = -1.68(\pm 0.50) + X_{Na} \times 3.82(\pm 0.47) - \frac{Mg}{(Mg + Fe)} \times 0.25(\pm 0.09) + \frac{10000 \times 2.89(\pm 0.56)}{RT}$$

$E = 212(\pm 6)$ GPa

$r_0 = 1.06$ Å

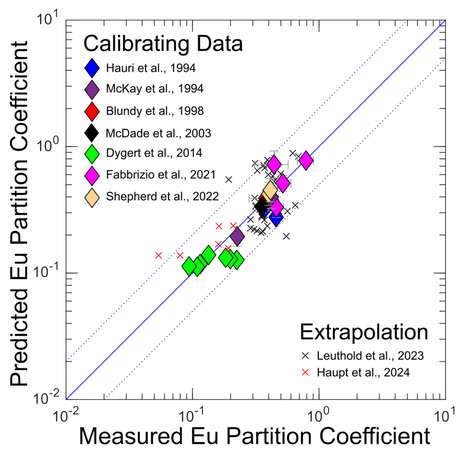


New fO_2-dependent cpx-melt Eu element partitioning model

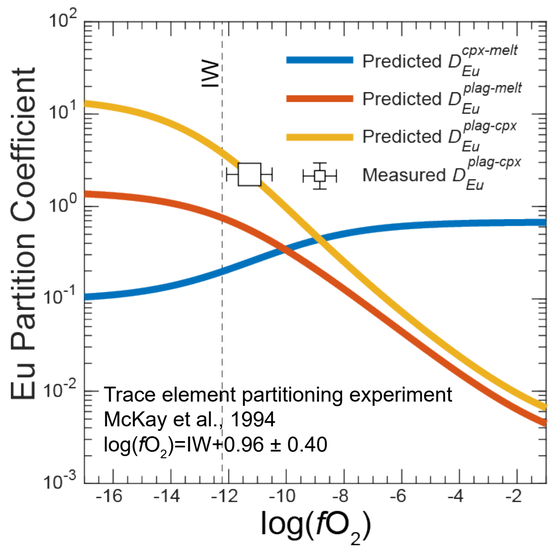


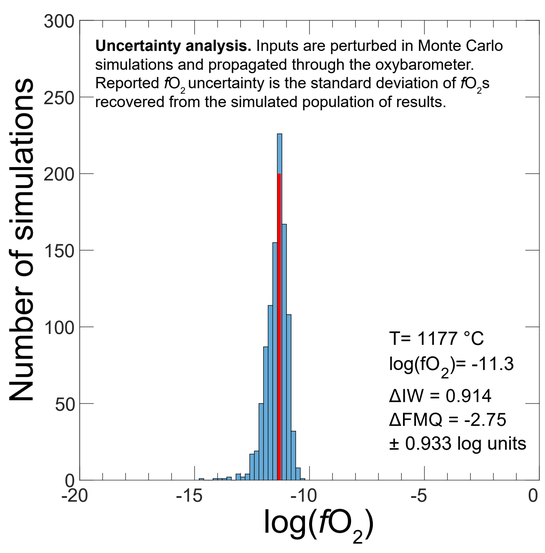
Calibrating data
Mg#: 100 to 5; T: 1080 to 1430°C; P: 0.0001 to 2.5 GPa; log(fO_2) -14.4 to 0.91

$$K_{Eu}^{cpx-melt} = 4.202(\pm 0.876) \times 10^{-3}$$



Model demonstration and uncertainty analysis



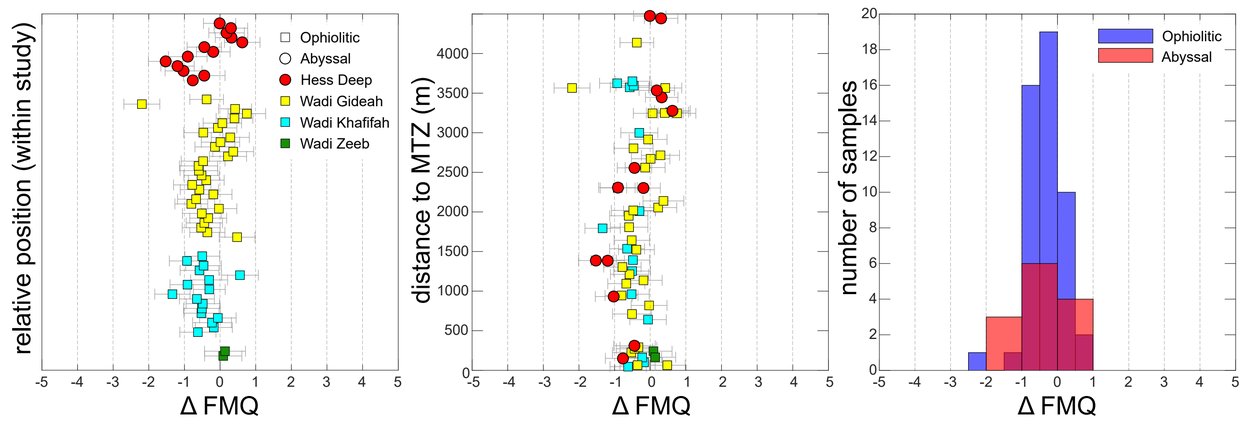


Reference and calculators

Dygert, N., Ji, D., Etheridge, E.N. (2025) A predictive model for divalent element partitioning between clinopyroxene and basaltic melt and a europium-in-plagioclase-clinopyroxene oxybarometer for cumulate rocks. Geochimica et Cosmochimica Acta 394, 148-163, https://doi.org/10.1016/j.gca.2025.02.003.

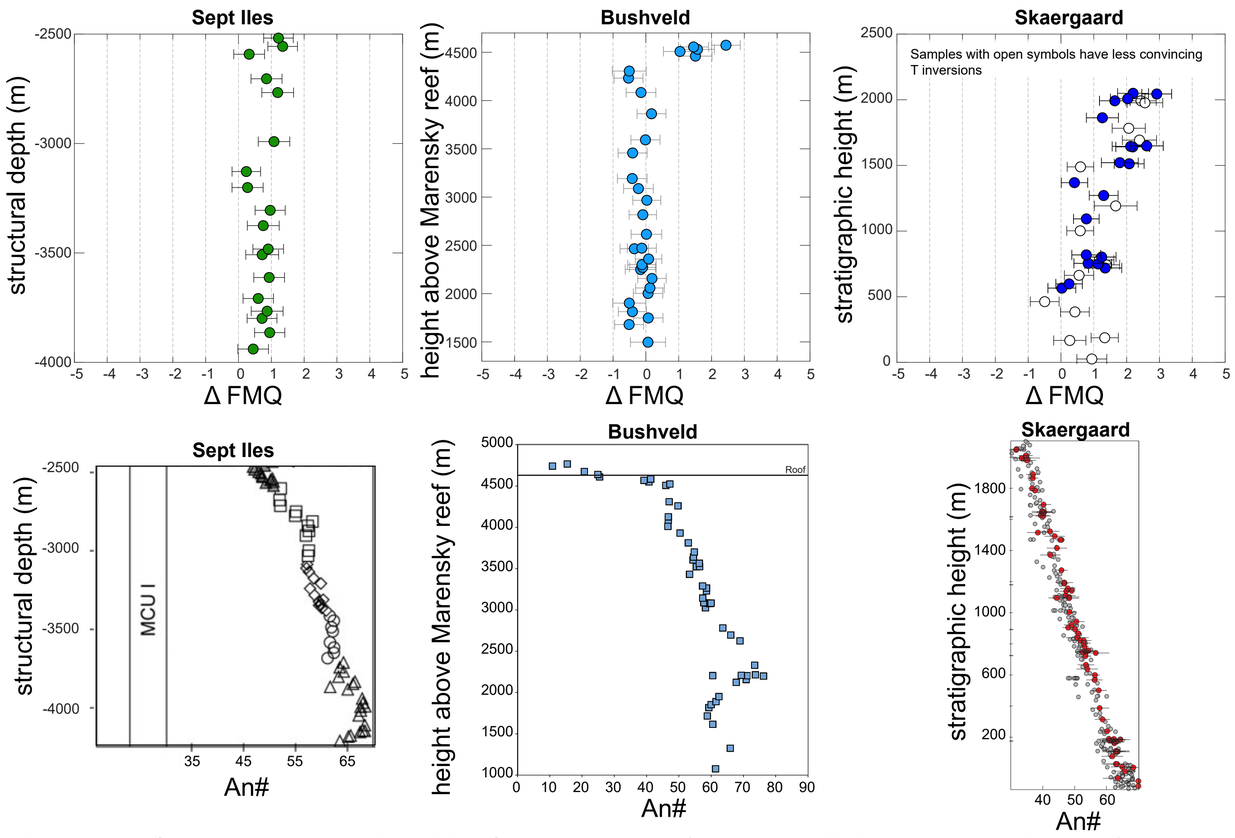
Calculators: https://doi.org/10.5281/zenodo.13882157.

Oceanic gabbros



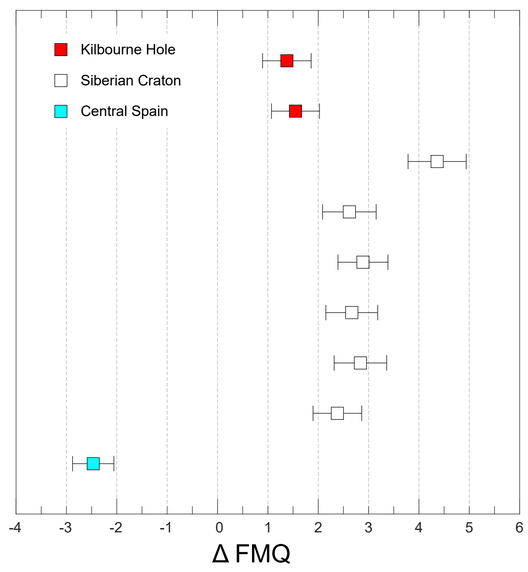
Data sources: **Hess Deep**, Sun & Lissenberg, 2018; **Wadi Khafifah**, **Oman**, VanTongeren et al., 2021, **Wadi Zeeb**, **Oman**, Grambling, Dygert, et al. 2022, **Wadi Gideah**, **Oman**, Müller et al., 2022

Layered intrusions



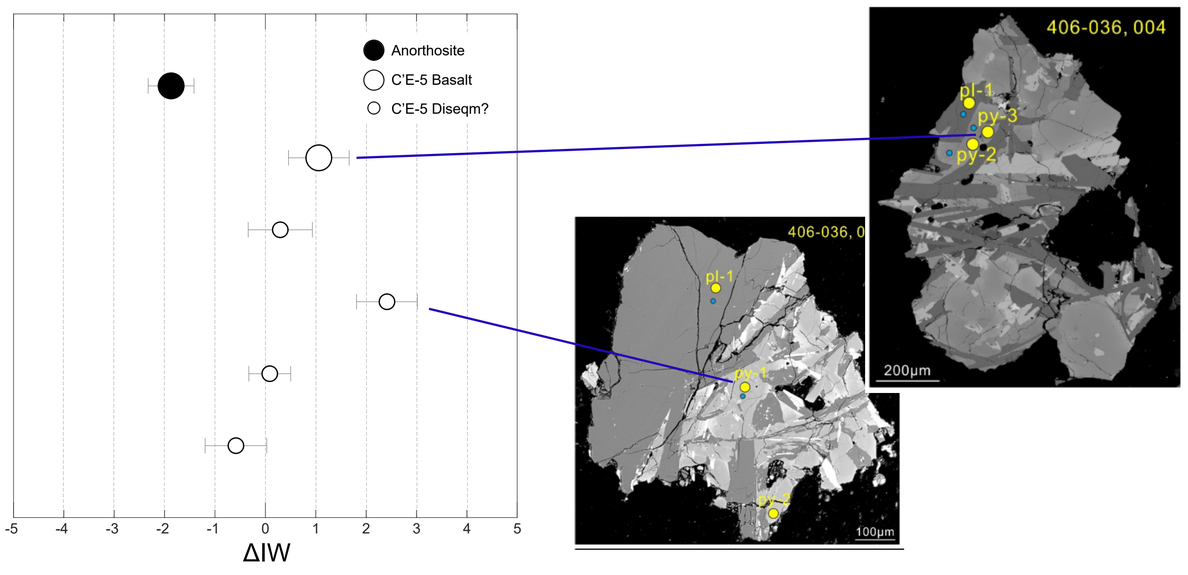
Data sources: **Sept Iles**, Namur et al., 2010; 2011, **Skaergaard**, Namur & Humphreys, 2018, **Bushveld**, VanTongeren & Mathez, 2012; Setera et al., 2018; VanTongeren et al., 2022;

Lower crustal xenoliths



Data sources: **Granultized mafic cumulate**, **central Spain**, Villaseca et al., 2007, **Granulites**, **Udachnaya**; **Kmosomolskaya**, **Siberian craton**, Koreshkova et al., 2011, **Gabbro**, **Kilbourne Hole**, new data

Lunar nearside basalt and anorthosite



Data sources: **Anorthositic breccia meteorite**, Ji & Dygert, 2023, **Nearside basalt (Chang'e-5)**, Tian et al., 2023

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