Water in eclogitic garnet and clinopyroxene with oriented quartz and pargasite inclusions, W Norway

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Introduction

This study analyses 10 eclogites from an ultrahigh-pressure (UHP) metamorphic area in the Western Gneiss Region (WGR) of Norway. Each sample has oriented lamellar to acicular inclusions in clinopyroxene, which are either quartz with pargasite or quartz/albite without pargasite [1]. Oriented quartz in clinopyroxene is typically regarded to have formed by the consumption of vacancies in non-stoichiometric pyroxene, i.e. an isochemical breakdown of a Ca-Eskola component [2, 3]. If applicable then the close spatial association of quartz and pargasite suggests an isochemical origin for the pargasite inclusions too. The H_2O content of nominally anhydrous minerals (NAMs) was quantified and compared with petrological data to evaluate this hypothesis.

UHP rocks in the WGR

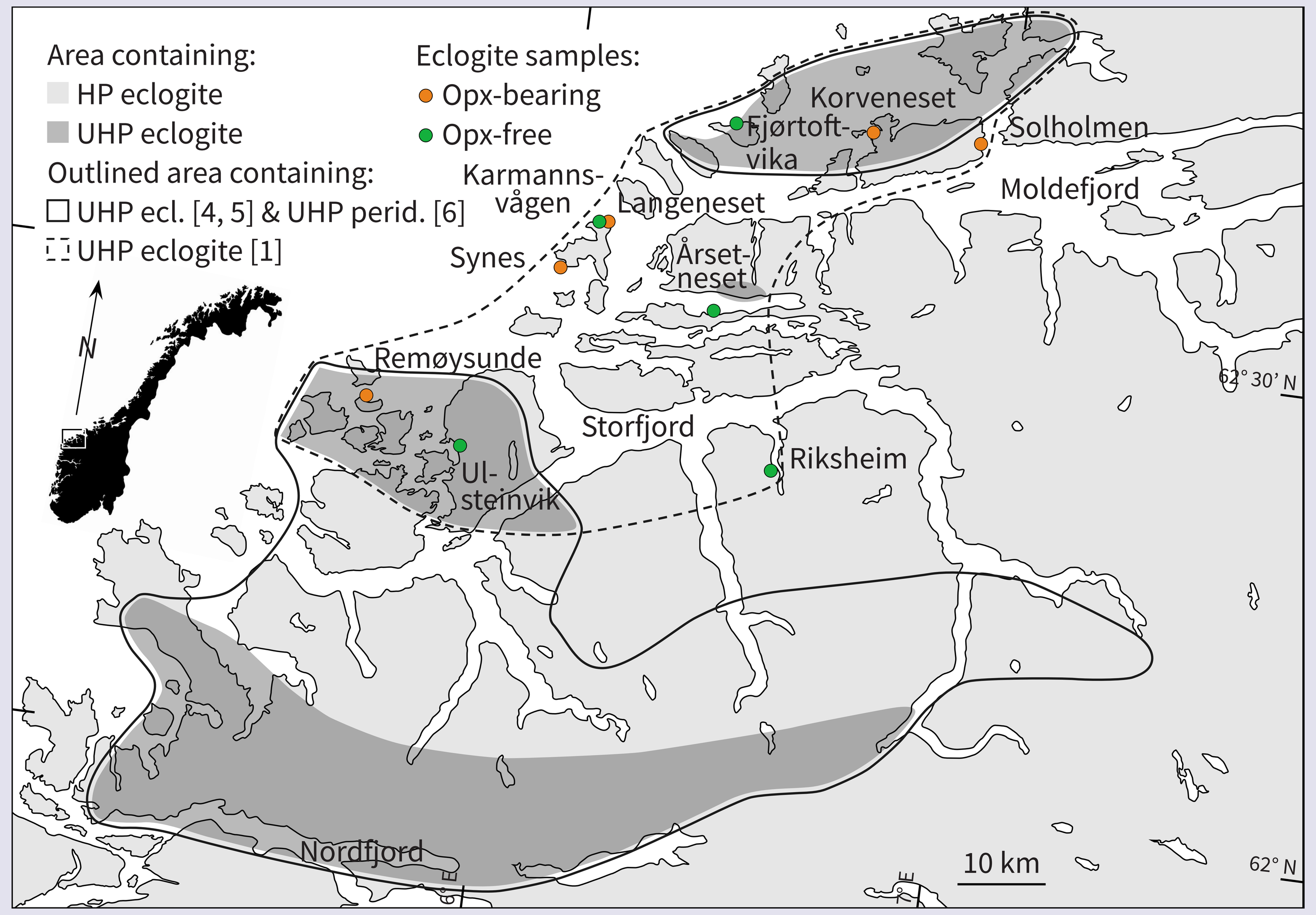

Fig. 1: Simplified map of the WGR that shows sample locations and known areas of UHP metamorphism from eclogite [1, 4, 5] and peridotite [6].

Mafic rocks (eclogite) define three large UHP domains that spread along the coast (shaded in Fig. 1). Ultramafic rocks (garnet pyroxenite enclosed in orogenic garnet peridotite) define UHP exposure that partially overlaps that of eclogite and partially fills the space in between (solid outline). Eclogite of the current sample set (dots) fills the gap between Storfjord and Moldefjord and has recently been shown to bear evidence for UHP metamorphism (dashed outline).

Petrography of oriented inclusions

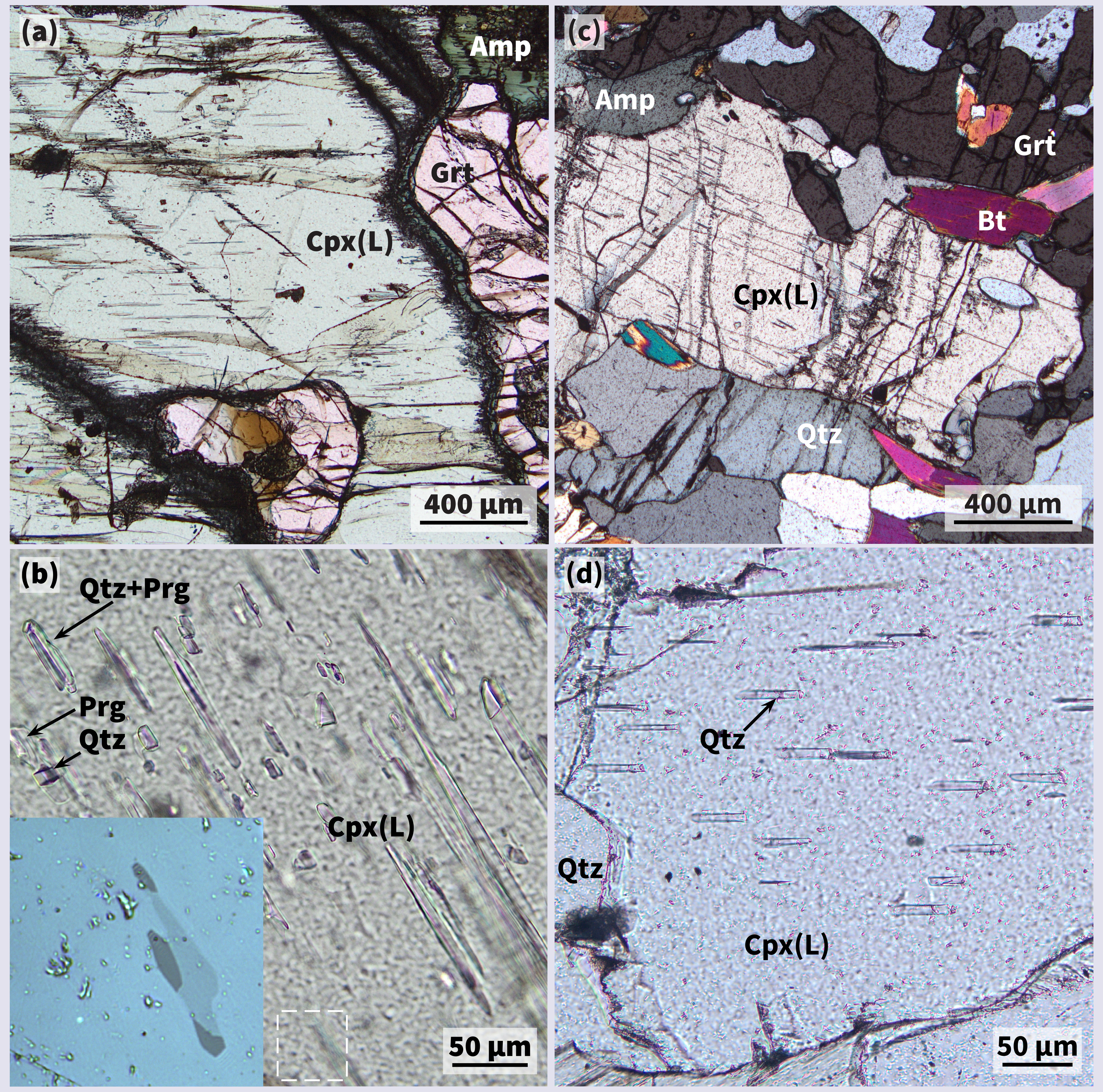

Fig. 2: Inclusions in clinopyroxene. (a, b) Bimineralic needles (PPL, Synes eclogite). Dashed frame shows the position of the inset (reflected light). (c, d) Monomineralic needles (c – PPL, d – nearly XPL, Årsetneset eclogite).

Spectra deconvolution

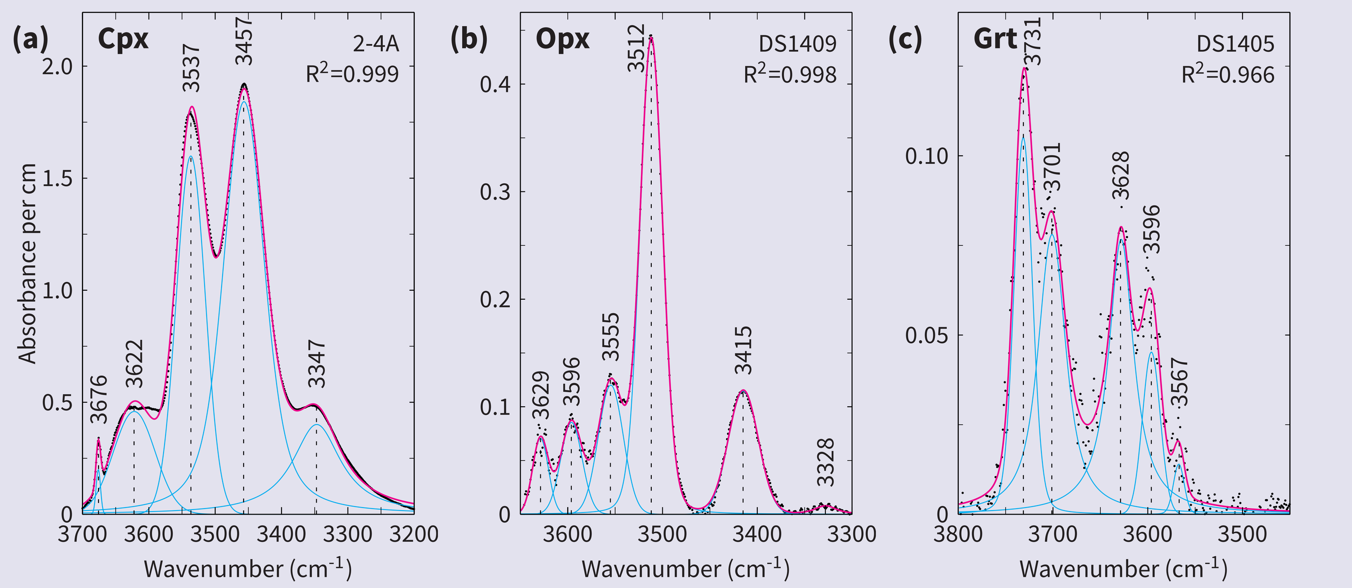

Fig. 4: Baseline corrected and deconvoluted spectra normalised to 1 cm.

FTIR absoption spectra

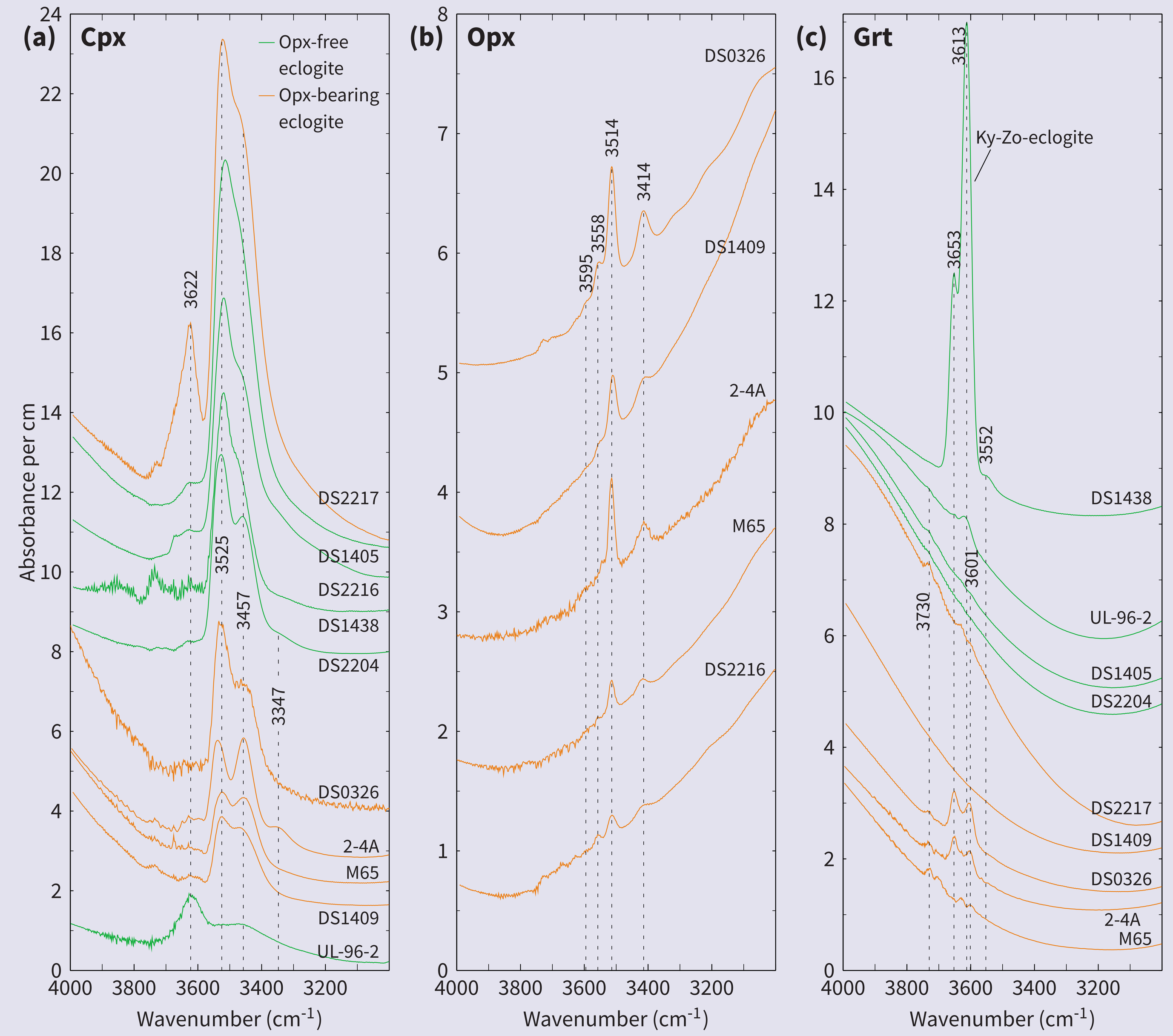

Fig. 3: Representative unpolarised FTIR spectra of (a) clinopyroxene, (b) orthopyroxene and (c) garnet (labels = sample numbers) in the O–H stretching frequency range normalised to 1 cm thickness and offset along the ordinate. Dashed lines indicate the position of selected peaks. Absorption in clinopyroxene with peak positions greater 3550 cm^{-1} (band III of [7]) may relate to sheet silicate inclusions and were excluded from the quantification.

Quantified H_2O contents

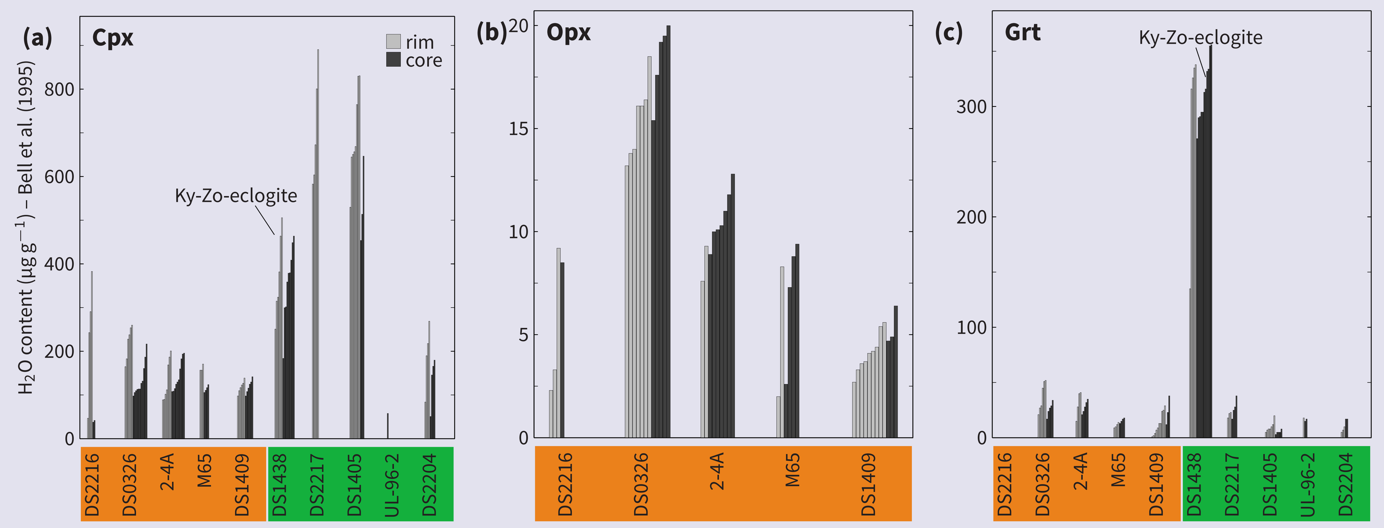

Fig. 5: Water contents in the grain interior (core) and the outermost 200 µm (rim) quantified using individual FTIR spectra and the calibration of [8].

Discussion

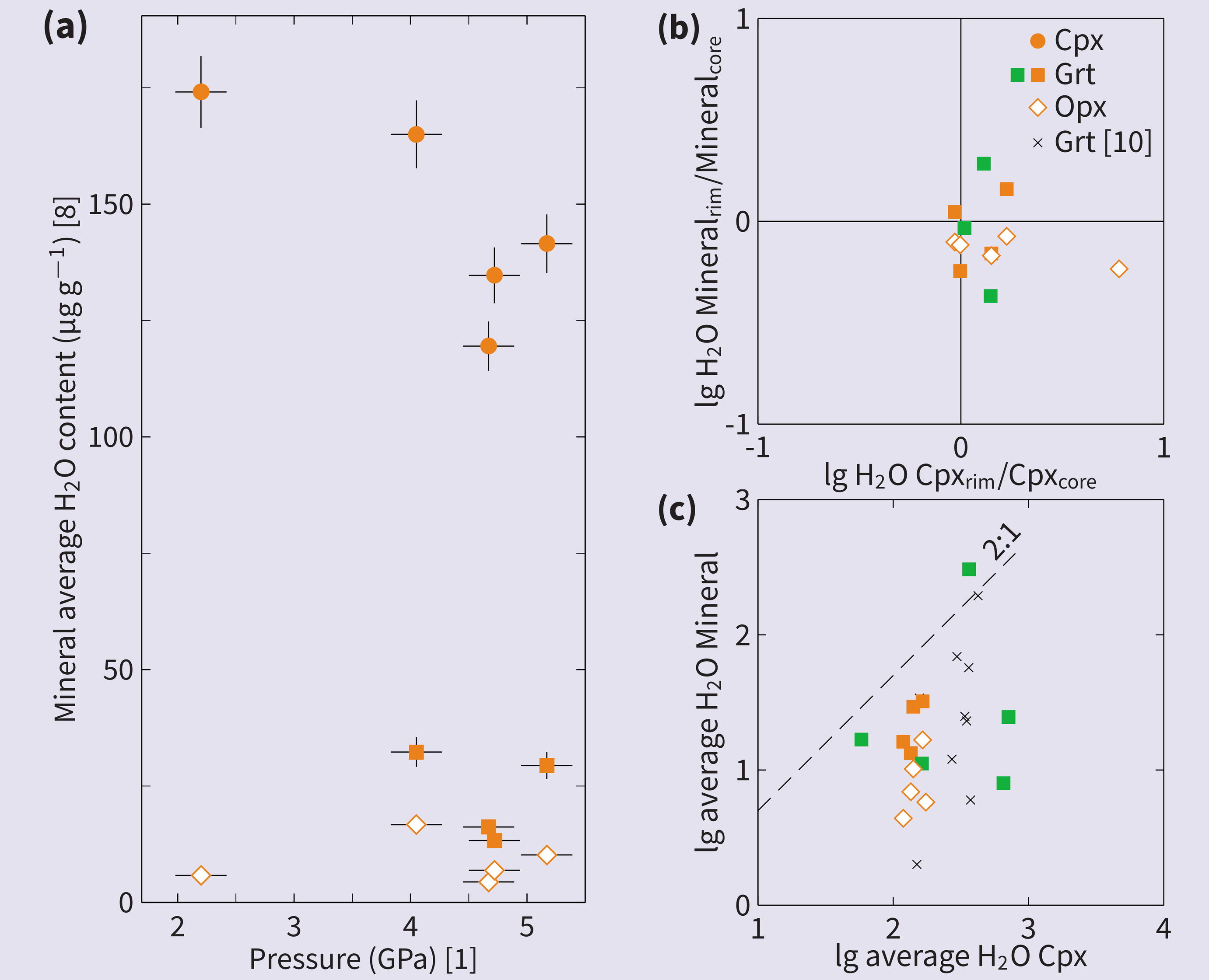

Fig. 6: Bivariate diagrams that show mineral average data for H_2O in NAMs. (a) H_2O content versus metamorphic pressure calculated from the mineral chemistry of orthopyroxene and garnet [1]. Uncertainties refer to 1σ. (b) Ratios calculated from the H_2O content of mineral rims and cores. (c) Mineral H_2O contents. Other information shows typical subsolidus H_2O partitioning between pyroxenes (dashed line, [9]) and with garnet (crosses, [10]).

Conclusion

(1) The H_2O content of clinopyroxene correlates inversely with retrograde metamorphic pressure.
(2) Orthopyroxene records H_2O loss at grain rims.
(3) Precipitation of pargasite lamellae in clinopyroxene from penetrating external H_2O seems unlikely, because cogenetic orthopyroxene lacks chemical equilibrium in the amphibole stability field and shows non-typical H_2O partitioning.

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References

[1] Spengler, D., Włodek, A., Zhong, X., Loges, A. & Cuthbert, S. J. Retrogression of ultrahigh-pressure eclogite, Western Gneiss Region, Norway. *European Journal of Mineralogy* **35**, 1125–1147 (2023).
[2] Smith, D. C. Coesite in clinopyroxene in the Caledonides and its implication for geodynamics. *Nature* **310**, 641–644 (1984).
[3] Katayama, I., Parkinson, C. D., Okamoto, K., Nakajima, Y. & Maruyama, S. Supersilicic clinopyroxene and silica exsolution in UHPM eclogite and pelitic gneiss from the Kokchetav massif, Kazakhstan. *American Mineralogist* **85**, 1368–1374 (2000).
[4] Smith, D. C. *A review of the peculiar mineralogy of the 'Norwegian coesite-eclogite province' with crystal-chemical, petrological, geochemical and geodynamical notes and an extensive bibliography*, 1–206 (Elsevier, 1988).
[5] Spencer, K. J. *et al.* Campaign-style titanite U–Pb dating by laser-ablation ICP: implications for crustal flow, phase transformations and titanite closure. *Chemical Geology* **341**, 84–101 (2013).
[6] Spengler, D., Alifirova, T. A. & van Roermund, H. L. M. Subcratonic and tectonic evolution of pyroxenite and eclogite with lamellar inclusions in garnet, Western Gneiss Region, Norway. *Journal of Petrology* **62**, egab008 (2021).
[7] Koch-Müller, M., Matsyuk, S. S. & Wirth, R. Hydroxyl in omphacites and omphacitic clinopyroxenes of upper mantle to lower crustal origin beneath the Siberian platform. *American Mineralogist* **89**, 921–931 (2004).
[8] Bell, R. D., Ihinger, P. D. & Rossman, G. R. Quantitative analysis of trace OH in garnet and pyroxenes. *American Mineralogist* **80**, 465–474 (1995).
[9] Demouchy, S. & Bolfan-Casanova, N. Distribution and transport of hydrogen in the lithospheric mantle: a review. *Lithos* **240–243**, 402–425 (2016).
[10] Aulbach, S. *et al.* Water in omphacite and garnet from pristine xenolithic eclogite: *T-X-*fO_2 controls, retentivity, and implications for electrical conductivity and deep H_2O recycling. *Geochemistry, Geophysics, Geosystems* **24**, e2023GC011170 (2023).