

related with the defect cluster distribution (Inset in Fig. 3.3-16). TEM observations confirmed the existence of APBs in magnetite which we suspect may be a key feature of unseen mixed valent iron oxides.

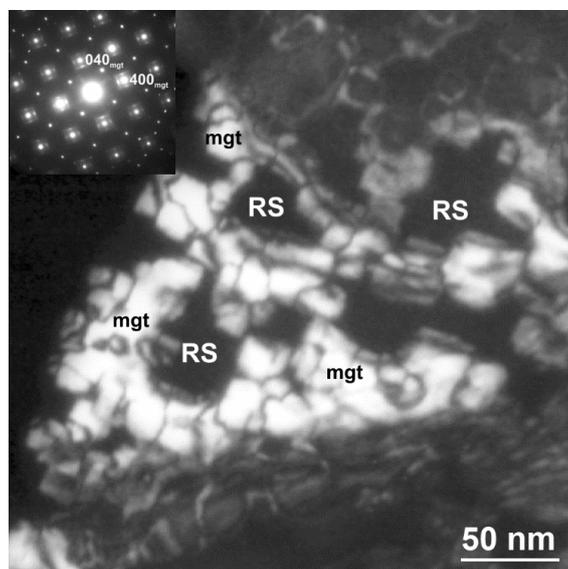


Fig. 3.3-16: Dark-field TEM image of an intergrowth of magnetite (mgt) and rock-salt phase (RS) in the decomposition from a mixed valence iron-magnesium oxide.

m. *Reappraisal of natural omphacite: To see a world in a nanoscale domain (T. Tsujimori and R. Fukushima/Sendai, N. Miyajima)*

Omphacitic pyroxene, with compositions close to $\text{Ca}_{0.5}\text{Na}_{0.5}(\text{Mg},\text{Fe}^{2+})_{0.5}\text{Al}_{0.5}\text{Si}_2\text{O}_6$, is ubiquitous in a variety of high-pressure (HP) and ultrahigh-pressure (UHP) metamorphic rocks of basaltic protoliths. Its parageneses and major-element compositions have been commonly used to characterize subducted oceanic crusts in the HP–UHP metamorphic belts. In our project, we explore the potential of nanoscale properties of omphacite to understand the kinetics of metamorphic processes in exhumed HP–UHP rocks.

Omphacite at high temperature has disordered $C2/c$ symmetry. At temperature recorded in blueschist and most orogenic eclogites, however, the difference in space-group symmetry between ordered ($P2/n$) omphacite and disordered ($C2/c$) diopsidic pyroxene allows the miscibility regions between jadeitic pyroxene ($C2/c$)–omphacite ($P2/n$) and augitic pyroxene ($C2/c$)–omphacite ($P2/n$). The solvus between the ordered $P2/n$ omphacite and other $C2/c$ pyroxenes becomes wider with decreasing temperature. Consequently, the two solvus as a function of temperature have been considered for numerous thermodynamic modelling/analyses of metamorphic phase equilibria for blueschist and eclogites.

The cation ordering in omphacite has been investigated in numerous transmission electron microscopic studies. As shown in Fig. 3.3-17, natural omphacite shows nanoscale antiphase

domain (APD) boundaries, which is the planar crystallographic defects in the lattice structure. It forms via the phase transition from $C2/c$ omphacite to $P2/n$ omphacite. Previous work suggests that the APDs coarsen with increasing time at a given temperature: $\delta^8 = 4.8 \times 10^{36} \exp(-75,000/RT)t$, where δ is the mean APD size and t the time. Evidence includes numerous observations of APD in different temperature range of blueschist and eclogites in different localities; note that the observed APD in some low-temperature $P2/n$ omphacites might have formed from metastable $C2/c$ omphacite. However, the systematics are not as simple as they have been simplified in the above equation. For example, a process like deformation (or multiple deformations) leads to recrystallization easily.

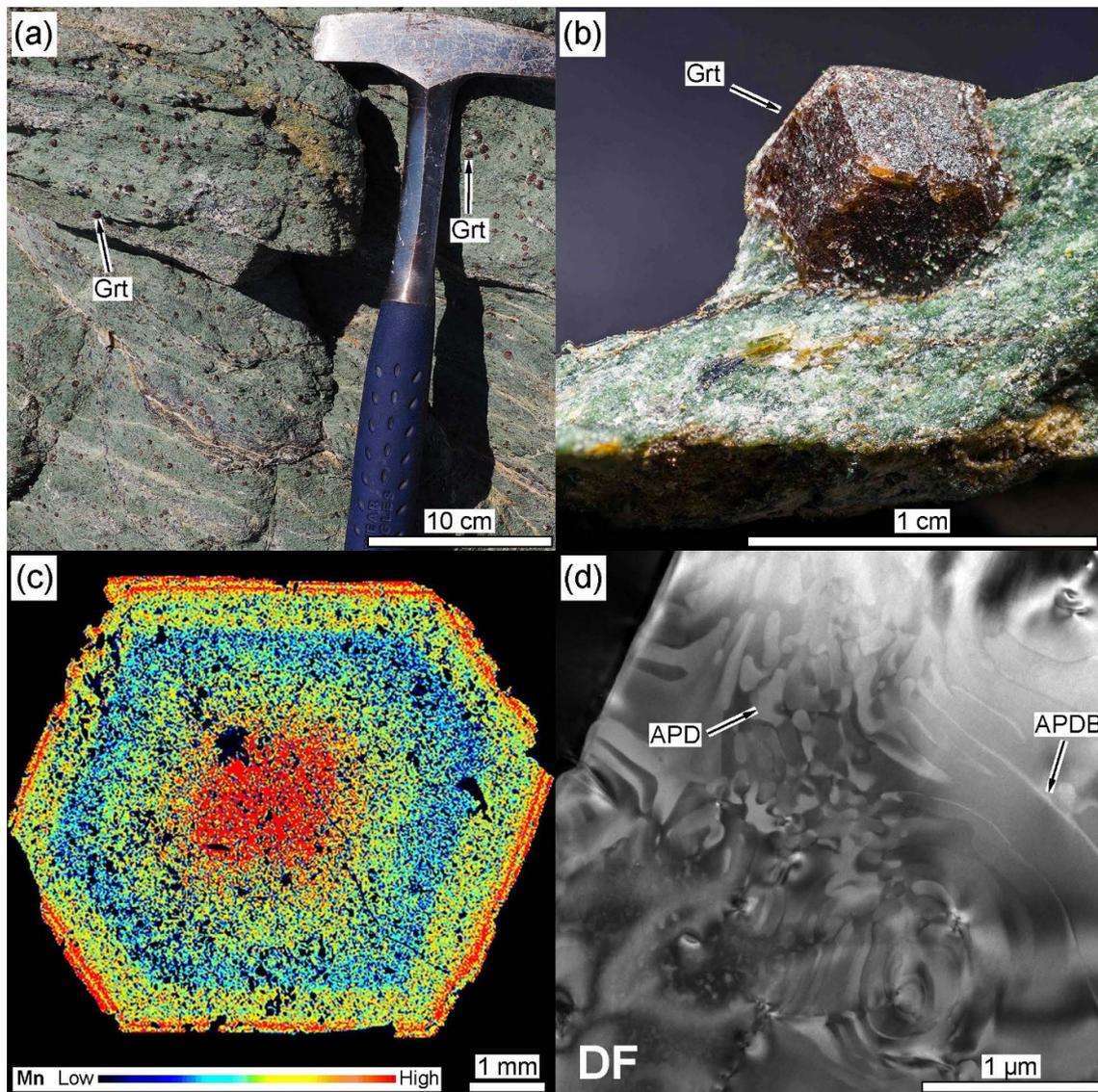


Fig. 3.3-17: (a) Low-temperature eclogite on the island of Syros showing abundant garnet porphyroblasts in a foliated matrix. (b) The investigated euhedral garnet with rhombic dodecahedron shape. (c) Electron microprobe X-ray mapping of a center-cut euhedral garnet extracted from a sample shown in (b). Raw intensity data was processed using R version 3.5.3. (d) Dark field TEM image of omphacite within garnet in (c) showing antiphase domain (APD) and antiphase domain boundary (APDB).