

Reassessing Japan's earliest subduction-metamorphic record: New constraints on peak P - T conditions for the Fuko Pass metacumulate, Oeyama belt

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Until recently, the oldest geological evidence for subduction-related metamorphism in the Japanese Islands was considered to include the Kitomyo Schist (Kurosegawa Belt) and the Fuko Pass metacumulate unit (FPM; Oeyama Belt), excluding Early Paleozoic jadeitite formation (Tsujimori, 2017). However, the discovery of ~360 Ma metamorphic zircons in pelitic rocks from the Kitomyo Schist (Matsunaga, Tsujimori et al., 2021) has ruled out the previously proposed ~480 Ma high-pressure (HP) event, leaving the FPM as the only plausible record of Early Paleozoic subduction metamorphism in Japan. The FPM is unusual in that its protolith was a troctolitic-anorthositic cumulate complex, and its metamorphic evolution has been interpreted as a middle-pressure granulite-facies stage (as indicated by spinel + Al-rich clinopyroxene) followed by HP recrystallization and deformation at epidote-amphibolite facies. Nevertheless, published estimates for the HP peak remain broad (P = ~1.1–1.9 GPa; T = ~550–800 °C; Tsujimori and Liou, 2004). Here, we re-evaluate peak phase relations using the whole-rock composition of the foliated epidote amphibolite (FEA) reported by Tsujimori and Liou (2004).

The FEA and associated leucogabbroic metagabbros in the FPM preserve an unusual HP mineral assemblage of hornblende (B-site Na = 0.3–0.4 apfu) + clinozoisite + kyanite $\pm$ staurolite + paragonite + rutile $\pm$ corundum. Phase-equilibrium modeling in the NCKFMASHTO (Na_2O - CaO - K_2O - FeO - MgO - Al_2O_3 - SiO_2 - TiO_2 - H_2O - O_2) system, assuming H_2O -saturated conditions with corundum and kyanite in excess, reproduces the observed assemblage and the elevated amphibole B-site Na within a narrower P - T window of ~680–760 °C and 1.7–2.1 GPa than previously proposed. These conditions fall near the amphibolite-eclogite facies transition and overlap the high-pressure end of earlier estimates. At peak conditions, the calculated density of the FEA reaches ~3.4 g/cm³, comparable to unaltered upper-mantle peridotite but substantially higher than serpentinized peridotite. Parametric whole-rock composition tests further show that the paragonite stability field contracts with decreasing bulk-rock K but expands with increasing Na, whereas staurolite stability diminishes as Na increases.

These new P - T estimates imply an apparent geothermal gradient of ~12–13 °C/km, which is higher than classic cold slab-interface geotherms but is more appropriately described as HP-intermediate rather than exceptionally warm. The inferred thermal state may therefore reflect a transient thermal regime shortly after subduction initiation and/or metamorphism within (or adjacent to) the mantle wedge, rather than equilibration along a persistently cold slab interface. Although the FPM has been interpreted as a tectonic slice with a metamorphic history distinct from the surrounding serpentinized lherzolite of the Oeyama body, our results may also be compatible with fluid-present (H_2O -rich) metamorphism within, or closely linked to, the same structural unit. Importantly, the narrow P - T window robustly tests competing tectonic interpretations of the FPM. Regardless of the detailed tectonic scenario, the FPM provides a key tectonic constraint on reconstructions of the Japanese margin's passive-to-active transition, and demonstrates how phase-equilibrium modeling can extract robust peak P - T constraints from low-variance amphibolite assemblages.

References

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