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 (H*P*) 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 H*P* recrystallization and deformation at epidote–amphibolite facies. Nevertheless, published estimates for the H*P* 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 H*P* mineral assemblage of hornblende (B-site Na = 0.3-0.4 apfu) + clinozoisite + kyanite ±staurolite + paragonite + rutile ±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/cm^3, 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 H*P*–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.

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