In the deeper parts of subduction zones, high pressures and temperatures are expected to inhibit brittle behavior. However, earthquakes are known to occur even at depths as great as 670 km. Within a subducting slab, a double seismic zone has been observed at intermediate depths of 50–200 km in several subduction zones, and the lower planes of seismicity are located within the oceanic mantle. Because serpentinite shows dehydration-related instability (Raleigh and Paterson 1965), such earthquakes might be related to the embrittlement triggered by dehydration. This “dehydration embrittlement” is attributed to increasing pore pressure as a result of a positive volume change during the dehydration reaction. However, this mechanism may disappear at depths greater than 60 km because of a negative volume change during the dehydration. Laboratory experiments have tested this phenomenon, but the results are complicated and the implications are still being debated. Another challenge for the dehydration embrittlement hypothesis is whether it can explain how oceanic mantle is hydrated at depths of several tens of kilometers. Outer-rise fault zones near the trench form one possible location at which mantle hydration occurs. Here, seawater may infiltrate along the fault planes and result in the formation of serpentinite in the oceanic mantle.

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METAMORPHISM AND CONTINENTAL GROWTH Part 1
Metamorphism and continental growth: introduction – M. SATISH–KUMAR, Tetsuo KAWAKAMI and Nobuhiko NAKANO

Original Articles
A Matter of time: The importance of the duration of UHT metamorphism – Simon L. HARLEY
Pan-African granulites of Madagascar and southern India: Gondwana assembly and parallels with modern Tibet – Ian C. W. FITZSIMONS
Peak and post-peak development of UHT metamorphism at Mather Peninsula, Rauer Islands: Zircon and monazite U-Th-Pb and REE chemistry constraints – Tomokazu HOKADA, Simon L. HARLEY, Daniel J. DUNKLEY, Nigel M. KELLY and Kazumi YOKOYAMA
U-Pb zircon geochronology in western part of the Rayner Complex, East Antarctica – Kenji HORIE, Tomokazu HOKADA, Yoichi MOTOYOSHI, Kazuyuki SHIRAIHNI, Yoshikuni HIBOI and Mami TAKEHARA
Detrital zircon provenances for metamorphic rocks from southern Ser Rondane Mountains, East Antarctica: A new report of Archean to Mesoproterozoic zircons – Ippei KITANO, Yasuhito OSAKAI, Nobuhiko NAKANO and Tatsuro ADAKI
Possible polynemorphism and brine infiltration recorded in the garnet–sillimanite gneiss, Skallevikshalsen, Lützow–Holm Complex, East Antarctica – Tetsuo KAWAKAMI, Tomokazu HOKADA, Shuhei SAKATA and Takaumi HIRATA

Interplate coupling along the subducting plate interface results in the great earthquakes that occur in subduction zones. However, if serpentinite is present at the subducting plate interface, the markedly low coefficient of friction and frictional recovery of serpentinite leads to a weak plate coupling (e.g. Katayama et al. 2013). Moreover, the weak plastic strength of serpentinite will enhance any ductile deformation and may result in the inhibition of subduction thrust earthquakes (e.g. Hirauchi et al. 2010). This could explain the aseismic behavior of serpentinized forearc mantle in the relatively cold subduction zones of Alaska and Chile, where the down-dip limit of interplate earthquakes coincides with the depth of the Moho. The weak plastic strength of serpentinite also influences the patterns of convection in mantle wedges, where the large contrast in plastic strength between serpentine and olivine results in a strongly decoupled plate interface, and hence a cold and stagnant forearc mantle wedge.

Although the presence of serpentinite along the subducting plate interface tends to inhibit the development of large thrust earthquakes, the occurrence of slow earthquakes, including deep low-frequency tremors and episodic slow slips, can be related to the rheological behavior of serpentinite. Aqueous fluids appear to play a critical role in the generation of slow earthquakes by elevating the pore pressure; however, the slowness of these events, compared to regular earthquakes, points to additional factors. The slow stick–slip behavior exhibited by serpentinite under hydrothermal conditions may explain the long duration and small stress release of slow earthquakes (Okazaki and Katayama 2015). This means that the generation of slow earthquakes requires not only pore-fluid pressure but also the presence and deformation of serpentinite. Such environments may be limited to relatively warm and young subduction zones, such as those of southwest Japan and Cascadia.