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In-situ Moissanite in Dunite of the Luobusa Ophiolite, Tibet: Implications for Deep Mantle Origin

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We report the discovery of an in-situ natural moissanite in Cr-spinel hosted by dunite of the Luobusa ophiolite, Tibet. The dunite envelopes a podiform chromitite, separating it from the harzburgite in which the chromitite occurs (Fig. 1). The moissanite occurs as a twinned grain, about 15 by 20 μm, formed by two interpenetrating tabular crystals (Fig. 2a, b). The moissanite is green in color (Fig. 2c), and has parallel extinction. Its Raman spectrum has shifts at 967−971 cm−1, 787−788 cm−1, and 766 cm−1 (Fig. 2d). The absorption peaks in the infra-red spectra are at 696 cm−1, 767 cm−1, 1450 cm−1, and 1551 cm−1 (Fig. 2e), which are distinctly different from the peaks for synthetic silicon carbide (Fig. 2f, broad peak aroud 926 cm−1 and peak at 1529 cm−1). The analysis method and

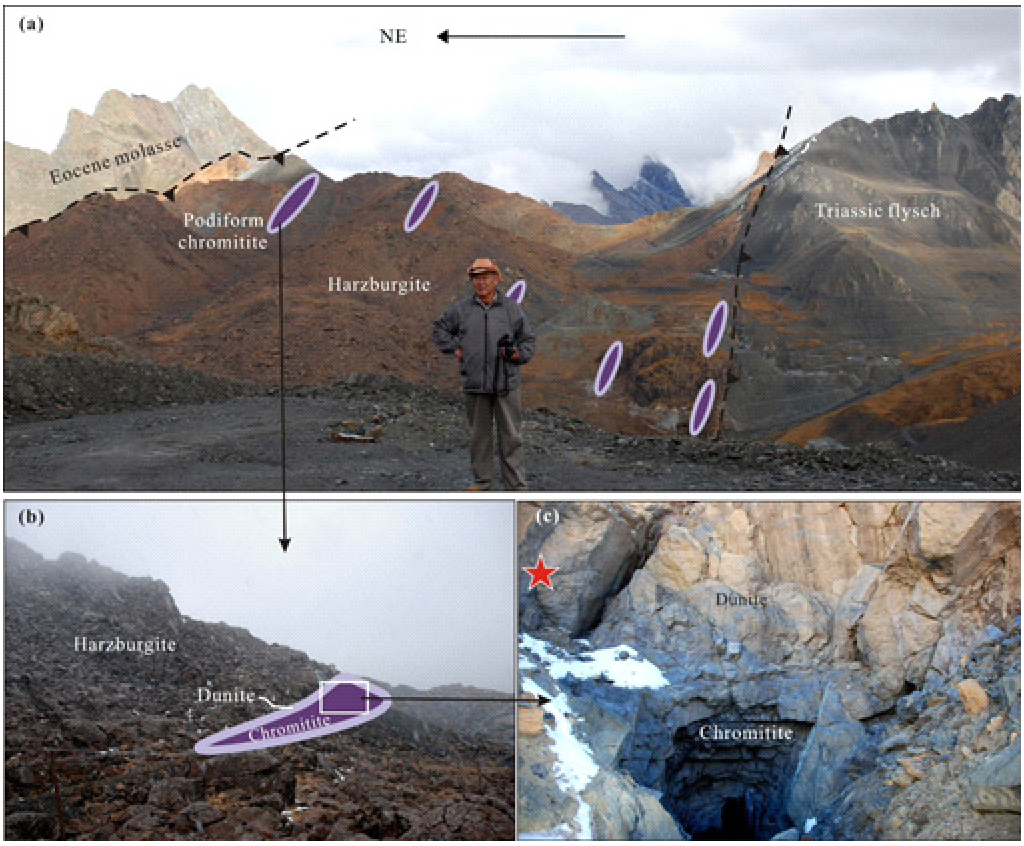

Fig. 1 Field photographs showing the occurrence of moissanite-bearing dunite in the Luobusa mantle peridotite
(a) The relationship among podiform chromitites, mantle peridotite and country rocks in the Kangjinla mining area, Luobusa; (b) A dunite envelope surrounding the chromitite body in the enclosing harzburgite; (c) The sampling location marked as a red star

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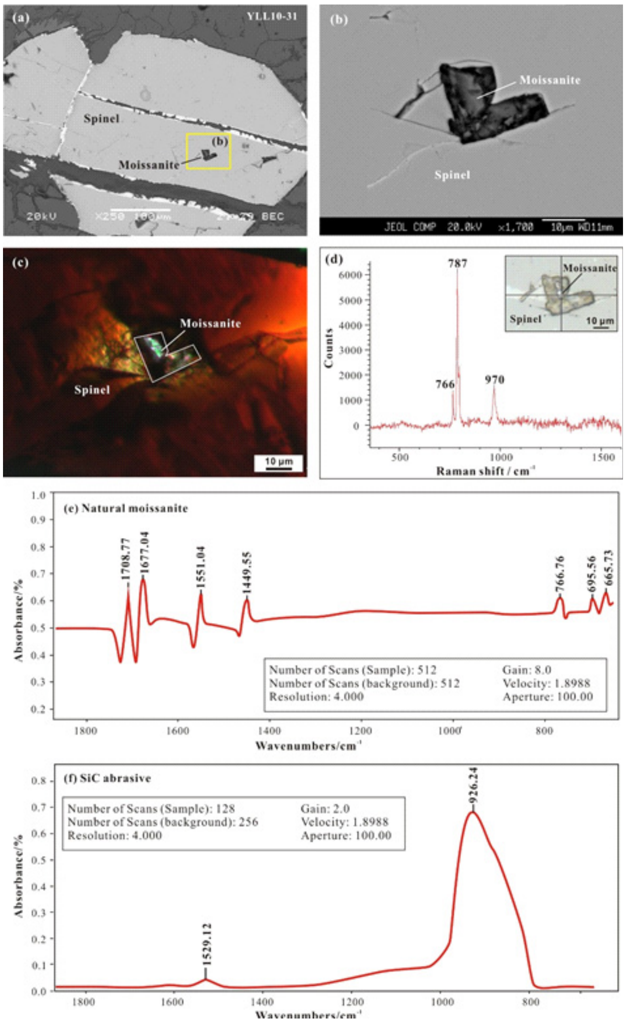

Fig. 2 In-situ occurrence of natural moissanite in Cr-spinel from a dunite envelope (sample YLL10-31) surrounding a chromitite ore body in the Luobusa ophiolite

(a) Moissanite inclusion in a grain of Cr-spinel; (b) Back-scattered electronic image showing the morphology of the moissanite inclusion; (c) Photomicrograph under plane-polarized light showing the green color of moissanite; (d) Raman spectrum of natural moissanite; (e) Infra-red spectrum of natural moissanite; (f) Infra-red spectrum of artificial SiC abrasive

more detailed characters of moissanite were described in Liang et al. (2014).

Moissanite is one of the deepest mantle minerals known to reach the surface (Hazen et al., 2013). Thermodynamic analysis and experiments (Essene and Fisher, 1986; Mathez et al., 1995; Ulmer et al., 1998) showed that moissanite formation requires oxygen fugacities several orders of magnitude below that of the iron-wüstite buffer (Trumbull et al., 2009), a typical upper mantle environment suitable for forming diamonds (Jacob et al., 2004). All moissanite grains analysed thus far, from whatever source, have very depleted carbon isotope compositions ($\delta^{13}C$ from −18‰ to −35‰) (Trumbull et al., 2009), much lighter than the main carbon reservoir in the upper mantle ($\delta^{13}C$ near −5‰) (Deines, 2002; Cartigny, 2005). Trumbull et al. (2009) suggested that moissanite formed in the lower mantle since the ^{13}C-depleted carbon is supported by extraterrestrial carbon, and there have been no other explanations until now. Combing with other ultra-high pressure and highly reduced minerals found by previously research (Bai et al., 2002; Yang et al., 2007, 2010, 2012; Xu et al., 2009; Yamamoto et al., 2009; Dobrzhinetskaya et al., 2009), the in-situ natural moissanite reporting here indicates a lower mantle origin of some materials in the Luobusa mantle peridotite. Then, we have to consider how and where the host dunite formed?

Dunite always envelops podiform chromitite with a zonal pattern that grades outward into harzburgite. In dunite, the chemical composition of olivine and spinel is always intermediate between those of harzburgite and chromitite. Combing with trace element characteristics, the dunite in which the moissanite occurs is thought to have formed by melt-rock reaction between MORB-type peridotite and boninitic magma at shallow depths in a supra-subduction zone (SSZ) environment (e.g., Zhou et al., 1996). If this model is correct, some small part of the deep mantle must have been incorporated into the Luobusa ophiolite. These materials have been transfer upward into the mid-ocean ridge of the Neo-Tethys Ocean. Then, what is the transfer channel?

Deep mantle material presumably could rise either by mantle upwelling beneath a spreading ridge or by a plume, or perhaps by some combination of the two. Helium isotope of volcanic rocks along the Yarlung Zangbo suture zone suggest that mantle plumes were active during the evolution of Neo-Tethys (Wu et al., 2004; Ye et al., 2007), and possible Late Jurassic and Early Cretaceous hospots have been described along the suture (Zhu et al., 2008). So, a mantle plume channel might be a reasonable pathway to bring some lower mantle materials up. On the other hand, an existing spreading ridge could attract the crown of a mantle plume close to it and made materials exchanged between the mantle plume and mid-ocean ridge (Niu and Hékinian, 2004; Kokfelt, 2005).

Therefore, one possible scenario is that a mantle plume interacted with a Neo-Tethyan spreading ridge (MOR) in such a way that the plume head contributed material to the lithospheric mantle from a much greater depth. At a later stage, during closure of Neo-Tethys, the ophiolitic peridotites containing deep mantle materials were modified by fluids and/or melts in a (SSZ) environment, and eventually emplaced on land. This model provides an explanation for the co-existence in the Yarlung Zangbo suture of rocks formed in MOR, SSZ, and plume-like environments.

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