**Supplementary information**

**Fig. 1 Geological setting**

The collision between Greater India and Asian caused the Cretaceous close of Neo-Tethys Ocean and the formation of Yarlung–Zangbo Suture Zone (YZSZ)1-2 on the Tibetan Plateau. YZSZ extends across 2000 km from Dongpo–Purang in the west to Zedang–Luobusa in the east at *c.* 29ºN, separating the Lhasa block to the north from the Indian continent to the south. The well-preserved ophiolite is discontinuously distributed along the YZSZ. The salient features of YZSZ are the highly refractory nature of mantle rocks3 and paucity of crustal compositions4. The Luobusa massif is located at the eastern YZSZ, covering an area of 70 km2. The massif is predominantly composed of refractory mantle harzburgite and less refractory clinopyroxene-bearing harzburgite with poorly preserved crustal rocks, which is underlain by thick-layered transition-zone dunite. It has attracted a lot of interests for the reason of hosting the largest chromite deposit in China.

**Fig. 2 Petrographic observations**

Three groups of mantle peridotites have distinctive petrographic characteristics. First, normal residual peridotites are typical of protogranular texture (Figs. 2a–b). The silicate minerals have nearly equal grain sizes. Chromites are chocolate brown (transmitted light, Fig. 2a) and typically anhedral with vermicular shape and variable sizes (Fig. 2a). Second, SSZ peridotites after hydrous melting are prominently distinguished by strong porphyroclastic texture (Figs. 2c–d). The coarse orthopyroxene or olivine grains (up to 1–2 cm) are commonly rimed by smaller silicate grains. Orthopyroxene porphyroclasts commonly have fine, parallel, needle clinopyroxene exsolution lamellae, which is not developed in the first group of peridotites. Coarse granular clinopyroxene is rare, nearly invisible under microscope. The chromite crystals are completely black and characteristically euhedral (transmitted light, Fig. 2c). Third, metasomatized samples by Cr-rich asthenospheric melt are sub-equigranular to slightly porphyroclastic (Figs. 2e–f). Clinopyroxene occurs as elliptic inclusions within orthopyroxene or narrow strips at the margin of orthopyroxene. EMPA and Laser results did not show any chemically compositional difference between the two occurrences of clinopyroxene. The strong evidence of metasomatism is the presence of hydrous amphiboles, which are located at the margin of clinopyroxene strips (Figs. 2g–h). Overall, we can well distinguish three different types of mantle peridotites from the Luobusa massif by careful petrographic observations.

**Fig. 3 A diversity of structures of chromitite**

**a)** Disseminated chromitite having a sharp boundary with dunite envelope.

**b)** Banded chromitite. Thin chromitite layers and dunite (~2cm wide) are alternating.

**c)** Nodular chromitite. The rounded or ellipsoid nodules (0.5 to 1.5 cm in diameter) are isolated by olivine matrix.

**d)** Massive chromitite. Chromite nodules are densely compacted and contacting with each other to form massive chromitite, which are bounded with a dike of massive chromitite and difficult to be timely identified.

**e)** Anti-nodular chromitite. Chromite grains are distributed around the patches of olivine, making them to be visually anti-nodular.

**f)** Amphibole and clinopyroxene inclusions within chromitite.

**Fig 4 Modelled melt compositions in equilibrium with SSZ peridotites**

**a)** SSZ clinopyroxenes from the Luobusa peridotites have similar REE patterns to clinopyroxene phenocryst from high-Ca boninite5. b) Modelled melt compositions in equilibrium with SSZ clinopyroxene are likely to be boninitic. The grey area represents boninitie compositions6. The partition coefficients of clinopyroxene-melt under hydrous melting follow Mcdade et al.7. The Cl-chondrite-normalized and primitive mantle values follow Sun and McDonough.

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