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Eocene to Oligocene retrogression and recrystallization of the Stak eclogite in northwest Himalaya

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ABSTRACT

Highly retrogressed eclogite is present in the Stak massif located on the northern edge of the Indian continental margin in northern Pakistan. Garnet in foliated samples contains omphacite inclusions (X_{jd} = 0.33–0.40) and quartz inclusions and latter retain Raman spectroscopic evidence for high residual pressures up to 0.52 GPa. These garnet grains do not show apparent compositional zoning. By contrast, one sample contains euhedral grains of garnet with quartz inclusions that show residual pressures as low as 0.25 GPa. These garnet grains do not contain omphacite inclusions, and show different compositional zoning compared to the omphacite-bearing garnet. The metamorphic condition of this sample was estimated to be 1.0–1.4 GPa/650–710 °C using residual pressure values of quartz inclusions in garnets and the garnet–clinopyroxene geothermometer. The U–Pb ages of zircon grains range from 158 to 28 Ma with a cluster between at ca. 32 Ma, which is younger than that of the peak ultrahigh-pressure metamorphic ages of eclogitic massifs in the northwestern Himalaya, e.g. Kaghan and Tso Morari. We suggest that the retrogressed eclogitic rocks in the Stak massif were heated by nearby Nanga Parbat Haramosh massif at ca. 32 Ma, subsequent to peak eclogite facies conditions. During this heating, part of the eclogite was largely recrystallized to form euhedral garnet grains. These results suggest that the Stak massif resided at a lower crustal depth while other ultrahigh-pressure massifs were exhumed in western Himalaya.

1. Introduction

High-pressure (HP) and ultrahigh-pressure (UHP) eclogites have been reported along the northern edge of the western Himalaya. These rocks elucidate the tectono-metamorphic evolution of the Himalayan orogen. Eclogites from the Himalaya were first reported by Chaudhry and Ghazanfar (1987) in the Kaghan Valley, northern Pakistan, where coesite inclusions were reported by O'Brien et al. (2001). Coesite was also reported from the Tso Morari eclogite, northwest India (e.g., Mukherjee and Sachan, 2001; Sachan et al., 2004). Western Himalayan eclogites preserve the Indian plate margin subduction and the knowledge of pressure (P)–temperature (T)–time (t) evolution of these eclogite is crucial to reveal the early evolution of the India–Asia collision (e.g. de Sigoyer et al., 2000; Leech et al., 2005). The oldest Himalayan eclogites are dated between 55 and 51 Ma in the Tso Morari massif in Ladakh, India (de Sigoyer et al., 2000; Leech et al., 2005; St-Onge et al., 2013), whereas the Kaghan eclogites, in Pakistan, were dated at ~47–44 Ma (Tonarini et al., 1993; Kaneko et al., 2003; Parrish et al., 2006). Guillot et al. (2007) proposed that the age difference between the Tso Morari and Kaghan eclogites reflected the initial geometry of the Indian margin, prior to the initial India–Asia collision. The age of the eclogites, initially interpreted as the age of continental subduction of the northern Indian margin beneath the south Asian margin, has more recently been re-interpreted as reflecting the age of subduction of the northern Indian margin beneath the oceanic arc (soft collision), prior to the final India–Asia collision (hard collision) (Hébert et al., 2012; Guillot and Replumaz, 2013).

In the Stak area, northern Pakistan, a retrogressed eclogitic massif, located between the Kaghan and Tso Morari massifs (Fig. 1a), was first reported by Le Fort et al. (1997), who suggested peak metamorphic conditions of >1.3 GPa and >610 °C. Lanari et al. (2013) carried out X-ray mapping of a single thin section and calculated a P–T path, with peak conditions at 2.5 GPa at 750 °C. However the metamorphic history of the massif is still not well understood. This paper presents Raman spectroscopic analysis, compositional analysis of minerals, and in-situ SHRIMP U–Pb dating of zircon from the samples of the Stak massif, to better define the metamorphic evolution of this area.

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