Carbon and nitrogen isotopes and mineral inclusions in diamonds from chromitites of the Mirdita ophiolite (Albania) demonstrate recycling of oceanic crust into the mantle

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ABSTRACT

Geophysical investigations and laboratory experiments provide strong evidence for subduction of ancient oceanic crust, and geological and mineralogical observations suggest that subducted oceanic crust is recycled into the upper mantle. This model is supported by some direct petrologic and mineralogical evidence, principally the recovery of super-deep diamonds from kimberlites and the presence of crustal materials in ophiolitic chromitites and peridotites, but many details are still unclear. Here we report the discovery of ophiolite-hosted diamonds in the podiform chromitites of the Skenderbeu massif of the Mirdita ophiolite in the western part of Neo-Tethys. The diamonds are characterized by exceedingly light C isotopes (Δ13C$_{pom} = -25\%$), which we interpret as evidence for subduction of organic carbon from Earth’s surface. They are also characterized by an exceptionally large range in δ15N$_{air}$ (−12.9‰ to +25.5‰), accompanied by a low N aggregation state. Materials sparsely included in diamonds include amorphous material, Ni-Mn-Co alloy, nanocrystals (20 × 20 nm) of calcium silicate with an orthorhombic perovskite structure (Ca-Pv), and fluids. The fluids coexisting with the alloy and Ca-Pv provide clear evidence that the diamonds are natural rather than synthetic. We suggest that the Skenderbeu diamonds nucleated and grew from a C-saturated, NiMnCo-rich melt derived from a subducted slab of ocean crust and lithosphere in the deep mantle, at least in the diamond stability field, perhaps near the top of the mantle transition zone. The subsequent rapid upward transport in channeled networks related to slab rollback during subduction initiation may explain the formation and preservation of Skenderbeu diamonds. The discovery of diamonds from the Mirdita ophiolite not only provides new evidence of diamonds in these settings but also provides a valuable opportunity to understand deep cycling of subducted oceanic crust and mantle composition.

Keywords: Mirdita ophiolite, diamond, NiMnCo alloy, calcium silicate perovskite, carbon and nitrogen isotopes, subduction, West Albania

INTRODUCTION

It has become apparent over the last decade that there are a variety of diamond-forming processes in the mantle that can be linked to major geologic events. For many years it was assumed that diamonds occur in only three geological setting: (1) in cratonic mantle (carried to Earth’s surface by kimberlite, lamproite, and lamprophyre); (2) in ultrahigh-pressure (UHP) metamorphic rocks such as gneiss and eclogite exhumed by slab rollback in continent-continent collision zones; and (3) in meteorite impact craters (Sobolev and Shatsky 1990; Xu et al. 1992; Koebert et al. 1995; Goresy et al. 2001; Shirey et al. 2013). Studies of mineral inclusions in kimberlite diamonds (e.g., Stachel and Harris 2008; Shirey et al. 2013; Stachel and Luth 2015) have shown that such diamonds are derived mostly from the subcontinental lithospheric mantle at depths below about 150–200 km along both continental and oceanic geothermal gradients, and from convecting mantle beneath the lithospheric-asthenosphere boundary (Stachel et al. 2005). Some diamonds may have originated at even greater depths (>700 km) in the sublithospheric mantle/asthenosphere mantle. However, the actual abundance of diamonds formed below the lithosphere is not known and may be much larger than what has been erupted in kimberlites and other diamond-hosting rocks (Shirey et al. 2013). Thus, the estimated volume of diamonds in Earth may reflect the availability of transport mechanisms that can bring diamonds to the surface without their being graphitized or oxidized.

In recent years several other diamond-hosting rocks have been identified including: (1) volcanic rocks, such as picrites (Golovko and Kaminsky 2010), meimechites (Kaminsky 2007; Kaminsky et al. 2016), and basalt (Kaminsky et al. 2016); (2) plutonic rocks, such as peridotites and chromitites (Pearson et al. 1989; Bai et al. 1993) and pyroxenites (Kaminsky 2007). Diamonds were first reported in ophiolitic chromitites and peridotites by Bai et al. (1993), but these discoveries were largely ignored or simply attributed to natural or anthropogenic contamination. Since that time numerous ultrahigh-pressure and highly reduced phases, accompanied by a wide range of other exotic minerals, have been reported from peridotites and chromitites in...