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Genesis of jadeite–quartz rocks in the Yorii area of the Kanto Mountains, Japan

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ABSTRACT

This paper reports the results of U–Pb dating and REE (rare earth element) analysis of zircons separated from jadeite–quartz rocks within serpentinite mélanges in the Yorii area of the Kanto Mountains, Japan. These rocks contain jadeite, albite, and quartz, with minor aegirine–augite, zircon, monazite, thorite, allanite, and titanite. Mineral textures provide evidence of a jadeite + quartz = albite reaction during formation of these jadeite–quartz rocks. Zircon crystals separated from the jadeite–quartz rocks can be split into two distinct types, here named Types I and II, based on their morphology and REE concentrations. Type I zircons are prismatic and have fluid, jadeite, quartz, and albite inclusions. Those show positive Ce and negative Eu anomalies and HREE (heavy rare earth element) enriched chondrite normalized REE patterns and have higher REE concentrations than those generally found in magmatic zircons. Type I zircons would have precipitated from a fluid. Mineralogical observation provides that Type I zircon crystallized at the same timing of the formation of the jadeite–quartz rocks. Type II zircons are porous and have REE patterns indicative of a hydrothermal zircon. Both types of zircons are fluid-related. Type I zircons yield U–Pb ages of 162.2 ± 0.6 Ma, with an MSWD (mean square weighted deviation) of 1.4. At this time, Japan was still a part of the eastern margin of the Asian continent, with the subduction of the oceanic paleo-Pacific Plate leading to the formation of the Jurassic Mino–Tanba–Chichibu accretionary complex in Japan. The age data indicate that the jadeite–quartz rocks formed in a deep subduction zone environment at the same time as the formation of the Jurassic accretionary complex in a shallower near-trench subduction zone environment. The jadeite–quartz rocks contain high concentrations of Zr and Nb, with low LILE (large ion lithophile elements) concentrations, suggesting that the HFSE (high field strength elements) can be concentrated into jadeite–quartz rocks prior to a fluid moving up into the mantle wedge. Typical arc volcanic rocks are depleted in the HFSE, suggesting that the high HFSE concentrations within jadeite–quartz rocks are consistent with fluids being stripped of their HFSE prior to interaction with mantle material during the formation of arc magmas. Although these jadeite-bearing rocks are rare occurrences on the surface exposure, they could be abundant in or above subducted slabs.

1. Introduction

Jadeite occurrences have been reported from several differing lithological units within the Kanto Mountains of Japan: in the Sanbagawa metamorphic rocks (Seki, 1960), in albitite (Seki, 1961), in Cretaceous sandstone (Seki, 1965), and in tectonic blocks of metabasalt (Arai et al., 2011; Tanabe et al., 1982) and ultramafic rocks (Hirajima, 1983). The processes whereby jadeite-bearing rocks, especially jadeitites, are formed have recently been the subject of debate. The presence of jadeite, especially when coexisting with quartz, is thought to indicate a high-pressure environment, with the currently accepted jadeitite formation mechanisms being metasomatic replacement of a protolith (Bleeck, 1908; Chhibber, 1934; Coleman, 1961; Compagnoni et al., 2007; Dobretsov and Ponomareva, 1965; Okay, 1997; Shigeno et al., 2005) or direct precipitation from aqueous fluids (García-Casco et al., 2009; Harlow, 1994; Harlow and Sorensen, 2005; Morishita et al., 2007; Shi et al., 2005; Sorensen et al., 2006). Both mechanisms require extensive fluid infiltration and fluid–mineral reactions; however, these two models differ significantly in that one requires a protolith, whereas the other does not. Yui et al. (2010) concluded that a 'metasomatic replacement model' and a 'precipitation model' are the two end-member mechanisms of jadeitite genesis.

Jadeites are rocks with modal proportions of jadeite of >90%, and often contain minor albite, quartz, sodic amphibole, mica, omphacite, kosmochlor, zoisite, titanite, rutile, allanite, apatite, zircon, chromite, pyrite, and graphite (Harlow and Sorensen, 2005;

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Harlow et al., 2007). These rocks have chemical compositions that are characterized by elevated concentrations of Al and Na, often with high Zr and Hf (Morishita et al., 2007; Shi et al., 2008; Yui et al., 2010). Jadeitites typically occur as tectonic blocks within serpentinites, and are often associated with high-pressure rocks, such as blueschists, eclogites, and/or garnet amphibolites, that form in plate subduction/collision zones (e.g., Coleman, 1961; Harlow and Sorensen, 2005; Harlow et al., 2007). Recent in situ single-grain isotope and trace element analysis of zircon has enabled significant progress in the determination of the genetic processes that form jadeitite. For example, Tsujimori et al. (2005) undertook ion microprobe U–Pb analysis of zircons that contained rutile and jadeite inclusions found within jadeitite from Osayama, Japan. This research indicated that these zircons were of hydrothermal origin, supporting the model whereby jadeitite directly precipitates from aqueous fluids. Similar genetic models have also been suggested for jadeitite in Syros, Greece (Bröcker and Keasling, 2006), Myanmar (Qui et al., 2008; Shi et al., 2008), and in an area north of the Motagua Fault in Guatemala (Yui et al., 2010). Yui et al. (2010) also determined the trace element compositions of zircons to assess the composition of fluids that these jadeitites precipitated from. In addition, Fu et al. (2009) determined the oxygen isotope and trace element compositions of zircons in jadeitites from Osayama, Syros, and south of the Motagua Fault in Guatemala. Although some hydrothermal zircons were found in the Osayama jadeitites, the majority of the analyzed zircons were of relict igneous origin. These indicate that jadeitite may form by a metasomatic replacement of a protolith, and/or by a direct precipitation from aqueous fluid.

Twelve areas of jadeites occurrences are currently known in Japan (Fig. 1A). U–Pb ages of zircons within these some jadeitites and jadeite-bearing rocks have been previously evaluated (Mori et al., 2011; Tsujimori et al., 2005; Tsutsumi et al., 2010; Yui et al., 2012). In this study, we focus on jadeite–quartz rocks from the Yorii area of the Kanto Mountains in Japan. Zircons from this jadeite–quartz rock have previously been analyzed, with six points of SHRIMP U–Pb analysis yielding an age of 159 ± 5 Ma (Tsutsumi et al., 2010). However, the authors did not indicate the crystallization process of zircons and host jadeite–quartz rocks. Thus, the meaning of the age is unclear whether it is the timing of the crystallization of jadeite–quartz rocks or the timing of the crystallization of the protolith of jadeite–quartz rocks. The authors suggested that further study is necessary to understand the origin of these jadeite–quartz rocks.

In this paper, we present and discuss new SHRIMP U–Pb ages and trace element compositions of zircons in a jadeite–quartz rock from the Yorii area, Saitama Prefecture, Japan. We also report the petrological and geochemical characteristics of the jadeite–quartz rock and compare it with previous studies. This study provides essential information that furthers our understanding of the processes of jadeite formation and the relationship between jadeite formation and crustal evolution.

2. Geological setting

Jadeite–quartz rocks in serpentinite mélanges have previously been reported from the Yorii area of the Kanto Mountains, Saitama, Japan (Hirajima, 1983; Fig. 1B). Eight geological units are present in

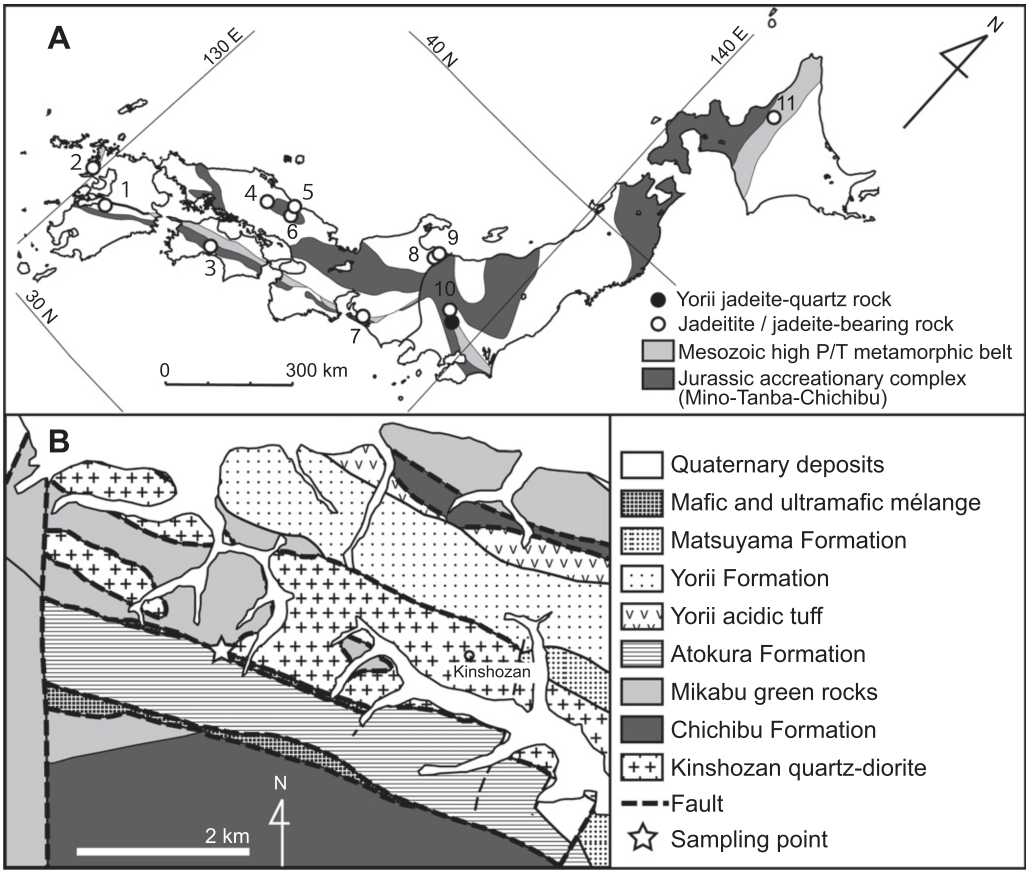

Fig. 1. (A) Locations of jadeite occurrences in Japan. 1: Saito and Miyazaki (2006); 2: Shigeno et al. (2005); 3: Maruyama et al. (1978); 4: Kobayashi et al. (1987); 5 and 6: Masutomi (1966); 7: Seki (1960); 8: Chihara (1958); 9: Kawano (1939); 10: Tanabe et al. (1982); 11: Imaizumi and Kanehira (1980). (B) Geological map of the study area (modified after Makimoto and Takeuchi (1992)).