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Marble-hosted ruby deposits from Central and Southeast Asia: Towards a new genetic model

Virginie Garnier [a], Gaston Giuliani [a,b,*], Daniel Ohnenstetter [a], Anthony E. Fallick [c], Jean Dubessy [d], David Banks [e], Hoàng Quang Vinh [f], Thérèse Lhomme [d], Henri Maluski [g], Arnaud Pêcher [h], Kausar Allah Bakhsh [i], Pham Van Long [j], Phan Trong Trinh [f], Dietmar Schwarz [k]

[a] CRPG/CNRS, BP 20, 15 rue Notre-Dame des Pauvres, 54501 Vandœuvre-lès-Nancy cedex, France
[b] IRD, UR154 LMTG, 14 avenue Edouard Belin, 34100 Toulouse, France
[c] Scottish Universities Environmental Research Centre, East Kilbride, Rankine Avenue, Glasgow G75 0QF, Scotland, United Kingdom
[d] UMR 7566 G2R/CNRS, Université Henri-Poincaré, BP 239, 54506 Vandœuvre, France
[e] School of Earth Sciences, University of Leeds, Leeds LS2 9JT, United Kingdom
[f] Institute of Geological Sciences, CNST, Nghia Dô, Câu Giây, Hanoi, Vietnam
[g] Laboratoire de Géochronologie, Université de Montpellier 2, Place Eugène Bataillon, 34095 Montpellier, France
[h] Maison des Géosciences, Laboratoire de géodynamique des Chaînes alpines, 181 rue de la piscine, 38400 — St Martin d'Hères, France
[i] GSP, Geoscience Laboratory, P.O. Box 1461, Shahzad Town, Islamabad, Pakistan
[j] Vietnam National Gem and Gold Corporation, 91 Dinh Tien Hoang street, Hanoi, Vietnam
[k] Gübelin Gemmological Laboratory, Maihofstrasse, 102, CH-6000 Lucerne 9, Switzerland

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ABSTRACT

Marble-hosted ruby deposits represent the most important source of colored gemstones from Central and South East Asia. These deposits are located in the Himalayan mountain belt which developed during Tertiary collision of the Indian plate northward into the Eurasian plate. They are spatially related to granitoid intrusions and are contained in platform carbonates series that underwent high-grade metamorphism. All occurrences are located close to major tectonic features formed during Himalayan orogenesis, directly in suture zones in the Himalayas, or in shear zones that guided extrusion of the Indochina block after the collision in South East Asia. Ar–Ar dating of micas syngenetic with ruby and U–Pb dating of zircon included in ruby gives evidence that these deposits formed during Himalayan orogenesis, and the ages document the extensional tectonics that were active, from Afghanistan to Vietnam, between the Oligocene and the Pliocene.

The petrography shows that ruby-bearing marbles formed in the amphibolite facies (T=610 to 790 °C and P~6 kbar). A fluid inclusion study defines the conditions of gem ruby formation during the retrograde metamorphic path (620<T<670 °C and 2.6<P<3.3 kbar) for the deposits of Jegdalek, Hunza and northern Vietnam.

Whole rock analyses of non-ruby-bearing marbles indicate that they contain enough aluminum and chromiferous elements to produce all the ruby crystals that they contain. In addition, (C, O)-isotopic analyses of carbonates from the marbles lead to the conclusion that the marbles acted as a metamorphic closed fluid system that were not infiltrated by externally-derived fluids. The carbon isotopic composition of graphite in marbles reveals that it is of organic origin and that it exchanged C-isotopes with the carbonates during metamorphism. Moreover, the O-isotopic composition of ruby was buffered by metamorphic CO_2 released during devolatilisation of marble and the H-isotopic composition of mica is consistent with a metamorphic origin for water in equilibrium with the micas. The (C, O, H)-isotopic compositions of minerals associated with marble-hosted ruby are all in agreement with the hypothesis, drawn from the unusual chemistry of CO_2–H_2S–COS–S_8–AlO(OH)-bearing fluids contained in fluid inclusions, that gem ruby formed at P~3 kbar and 620<T<670 °C, during thermal reduction of evaporite by organic matter, at high temperature-medium pressure metamorphism of platform carbonates during the Tertiary India–Asia collision. The carbonates were enriched in Al- and chromiferous-bearing detrital minerals, such as clay minerals that were deposited on the platform with the carbonates, and in organic matter. Ruby formed during the retrograde metamorphic path, mainly by destabilization of muscovite or spinel. The metamorphic fluid system was rich in CO_2 released from devolatilisation of carbonates, and in fluorine, chlorine and boron released by molten salts (NaCl, KCl,

* Corresponding author. Present address: CRPG/CNRS, BP 20, 15 rue Notre-Dame des Pauvres, 54501 Vandœuvre-lès-Nancy cedex, France.
E-mail address: giuliani@crpg.cnrs-nancy.fr (G. Giuliani).

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