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Review

New aspects and perspectives on tsavorite deposits

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ABSTRACT

Tsavorite, the vanadian variety of green grossular, is a high value economic gemstone. It is hosted exclusively in the metasedimentary formations from the Neoproterozoic Metamorphic Mozambique Belt. The deposits are mined in Kenya, Tanzania and Madagascar and other occurrences are located in Pakistan and East Antarctica. They are located within metasomatized graphitic rocks such as graphitic gneiss and calc-silicates, intercalated with meta-evaporites. Tsavorite is found as primary deposits either in nodule (type I) or in quartz vein (type II), and in placers (type III). The primary mineralizations (types I and II) are controlled by lithostratigraphy and/or structure. For the African occurrences, the protoliths of the host-rocks were deposited at the beginning of the Neoproterozoic within a marine coastal sabkha environment, located at the margin of the Congo–Kalahari cratons in the Mozambique Ocean. During the East African–Antarctican Orogeny, the rocks underwent high amphibolite to granulite facies metamorphism and the formation of tsavorite deposits occurred between 650 and 550 Ma. The nodules of tsavorite were formed during prograde metamorphism, calcium coming from sulphates and carbonates, whereas alumina, silicates, vanadium and chromium probably came from clays and chlorite. The veins were formed during the deformation of the metasedimentary platform units which experienced shearing, leading to the formation of fault-filled veins. Metasomatism developed during retrograde metamorphism. The metasedimentary sequences are characterized by the presence of evaporitic minerals such as gypsum and anhydrite, and scapolite. Evaporites are essential as they provide calcium and permit the mobilization of all the chemical elements for tsavorite formation. The H_2S–S_8 metamorphic fluids characterized in primary fluid inclusions of tsavorites and the $\delta^{11}B$ values of coeval dravite confirm the evaporitic origin of the fluids. The V_2O_3 and Cr_2O_3 contents of tsavorite range respectively from 0.05 to 7.5 wt.%, while their $\delta^{18}O$ values are in the range of 9.5–21.1‰. The genetic model proposed for tsavorite is metamorphic, based on chemical reactions developed between an initial assemblage composed of gypsum and anhydrite, carbonates and organic matter deposited in a sabkha-like sedimentary basin.

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Contents

1. Introduction

Tsavorite is the gemmological trade name for the vanadian grossular discovered by the Scottish geologist C. Bridges in north-eastern Tanzania in 1967 (Bridges, 1974), about 10–15 km east of Komolo village, today the Lemshuku mining area (Feneyrol et al., 2010a, 2010b). Switzer (1974) showed that the green colour of grossular is due to substitution of aluminium by vanadium (and some chromium) in the octahedral site following the formula $Ca_3(Al, V, Cr)_2(SiO_4)_3$, indicating that tsavorite is a solid solution between dominant grossular and minor goldmanite. Bridges discovered the first economic deposit of tsavorite in 1970 near the Tsavo National Park in south-eastern Kenya and took possession of the first claims in 1971. New finds in the area allowed a regular production in Kenya and the American jewellery company Tiffany & Co. decided to promote the gemstone in the U.S. Its president H.B. Platt together with C. Bridges gave to the green grossular the name tsavorite in reference to the Tsavo National Park. Germans named the gemstone tsavolite and finally the CIBJO (Confédération Internationale de la Bijouterie, Joaillerie et Orfèvrerie) adopted the name tsavorite although it is not accepted by the International Mineralogical Association (IMA).

Today, tsavorite is a high value economic coloured gemstone used in jewellery. The gemstone is (i) durable with a hardness between 7 and 7.5 on the Mohs scale, lacks cleavage and is chemically resistant; (ii) aesthetic with its green colour that is considered to be more vivid than emerald (Pardieu, 2005), due to its high dispersion (0.028), refractive index (1.740), saturation, brilliance and transparency (Pardieu and Hughes, 2008); (iii) and rare as there are only few economic deposits worldwide, mostly confined to the Neoproterozoic Metamorphic Mozambique Belt (NMMB). The garnets of gem quality are often small pieces. The largest recorded tsavorite crystal was about 925 carats (185 g) and found in 2007 in Merelani, north-eastern Tanzania (Wilson et al., 2009). There is no stock exchange for the control of prices but a carat (0.2 g) for commercial tsavorite generally costs between 100 and 300 US$ (www.tanzanite-gemstone.com). Top-quality grade tsavorite can cost between 1000 and 2000 US$ per carat but for larger crystals it can reach a few (tens of) thousands US$. The giant crystal of tsavorite from Merelani was valued at more than 2 million US$.

Gemmological studies predominate over geological investigations on the tsavorite deposits and models for their formation are scarce. The aim of the present paper is to review geological and recent metallogenetic studies to propose a typology of the deposits and to discuss their genetic model which seems to be unique. This paper is largely based on the PhD thesis of Feneyrol (2012) and field work developed by the Institute of Research and Development (IRD) with the academics in Tanzania, Madagascar and Kenya. This paper reviews the different gem tsavorites from the NMMB and uneconomic tsavorite occurrences worldwide synthesizing the geology, mineralogy and chemistry of the deposits, ages of formation, and oxygen isotope and chemical composition of tsavorite. The review will propose a typology of tsavorite deposits in the NMMB and a discussion on the different possible genetic models for their formation in the light of recent metallogenetic studies.

2. The Neoproterozoic Metamorphic Mozambique Belt

The NMMB also known as the Mozambique Belt (Holmes, 1951), is a north–south trending orogenic belt formed during the Neoproterozoic and Cambrian periods by the closure of the Mozambican Ocean (Dalziel, 1997; Hoffman, 1991; Shackleton, 1996; Stern, 1994). It resulted from an oblique Himalayan-type collision between crustal fragments from East Gondwana and West Gondwana's African cratons of