The origin of tourmaline nodules in granites; preliminary findings from the Paleoproterozoic Scrubber Granite

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Abstract

Tourmaline nodules, also termed clots, clusters, and orbicules, are found in numerous granites worldwide. Nodules are typically spherical, 2 to 50 cm in diameter, and comprise tourmaline and quartz(–feldspar) cores surrounded by leucocratic haloes. Tourmaline nodules in the Paleoproterozoic Scrubber Granite of the southern Gascoyne Complex exhibit a greater diversity of morphologies and textures relative to other nodule localities, and some nodule morphologies, including starburst and rosette textures, are unique to the study area. Tourmaline nodules in the Scrubber Granite probably crystallized from pockets of volatile-rich fluid exsolved from the host granitic magma.

KEYWORDS: granite, tourmaline, orbicular, Paleoproterozoic, Western Australia, Gascoyne Complex, Capricorn Orogen, Moorarie Supersuite

Introduction

Although tourmaline nodules have been documented since the early 1800s, the physical and chemical parameters that govern their formation have yet to be resolved. Distinctive in appearance, nodules consist of tourmaline and quartz(–feldspar) clots surrounded by a halo of leucocratic granite. There are two main hypotheses for the origin of the nodules. The first suggests that nodules result from post-magmatic metasomatic–hydrothermal replacement of previously crystallized granite by externally derived, boron-rich fluids (e.g. Rozendaal and Bruwer, 1995). The other asserts that nodules are magmatic–hydrothermal features related to the separation and entrapment of immiscible B-rich fluids from coexisting granitic magma (e.g. Sinclair and Richardson, 1992).

Tourmaline nodules are a distinctive feature of the Paleoproterozoic Scrubber Granite of the Gascoyne Complex, Western Australia. Nodules are morphologically diverse and are randomly distributed throughout massive to tectonically foliated regions of the host granite. Although sparse groundmass tourmaline occurs in discrete regions of the Scrubber Granite, tourmaline crystals are typically restricted to nodule cores within the study area. In contrast, biotite is present throughout the host granite, and locally within halo material, but is absent in nodule cores.

Tourmaline nodules in the Scrubber Granite were investigated as part of a Master of Science project at the University of Saskatchewan. This paper focuses on detailed field-based nodule descriptions that were completed during the 2003 field season. Complementary petrography, whole rock and tourmaline crystal chemistry, tourmaline fluid inclusion microthermometry, as well as stable and radiogenic isotope studies were completed on representative nodules from the Scrubber Granite (Shewfelt, 2005). Although some tourmaline nodules are spatially associated with Sn–W mineralization (e.g. Rozendaal and Bruwer, 1995), no such association is recognized in the Scrubber Granite.

Geological setting

The 1800 Ma Scrubber Granite is part of the Moorarie Supersuite, a group of granites intruded into the southern Gascoyne Complex during the Capricorn Orogeny (Occhipinti and Sheppard, 2001; Occhipinti et al., 2001). The granite intrudes the Archean to Paleoproterozoic Halfway Gneiss and the Paleoproterozoic Dumbie Granodiorite. A 3.5 km elongate exposure of the Scrubber Granite, centred approximately 5 km west-southwest of Mooloo Downs Homestead, was chosen for this study as it contains abundant nodules of diverse morphologies combined with excellent exposures. This intrusion is

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superficially divided into three lobes by colluvium and alluvium (Fig. 1).

Field observations

Tourmaline nodules in the Scrubber Granite range from 2 to 30 cm in diameter and are randomly distributed throughout the study area (Fig. 1a). There is no direct relationship between nodule abundance and location within the intrusion; regions containing abundant nodules are in close proximity to regions devoid of nodules (Fig. 1b).

The host granite typically contains 50% quartz, 20% plagioclase, 15% alkali feldspar, 10% biotite, and 5% muscovite. Biotite forms elongate clots 1 to 2 mm in length that define a weak to moderate foliation. The leucocratic halo material surrounding nodules typically comprises 60% quartz, 20% plagioclase, 12% alkali feldspar, and 3% muscovite (±5% biotite). Although core zone mineralogy varies between and within nodule types, it typically comprises 60% tourmaline, 30% quartz, and 8% plagioclase (±2% alkali feldspar).

The Scrubber Granite contains a myriad of nodule morphologies (Fig. 2). Approximately 60% of nodules observed in the field are spherical (Fig. 2a). Nodules in foliated regions of the host granite are typically elongate parallel to the foliation and locally exhibit aspect ratios up to 1:5. These observations indicate that nodules pre-date the dominant episode of deformation affecting the Scrubber Granite.

'Tourmaline rosette nodules' contain dense rosettes comprising thin, prismatic tourmaline crystals that locally extend up to 1 cm in length. Rosette are surrounded by tourmaline-rich cores that are texturally similar to spherical nodules (Fig. 2b). The rosettes are randomly located within the tourmaline-rich cores, and there is no direct relationship between the size of the nodule and the size of the rosette.

Nodules containing prismatic tourmaline crystals up to 1 cm in length that radiate outward into the

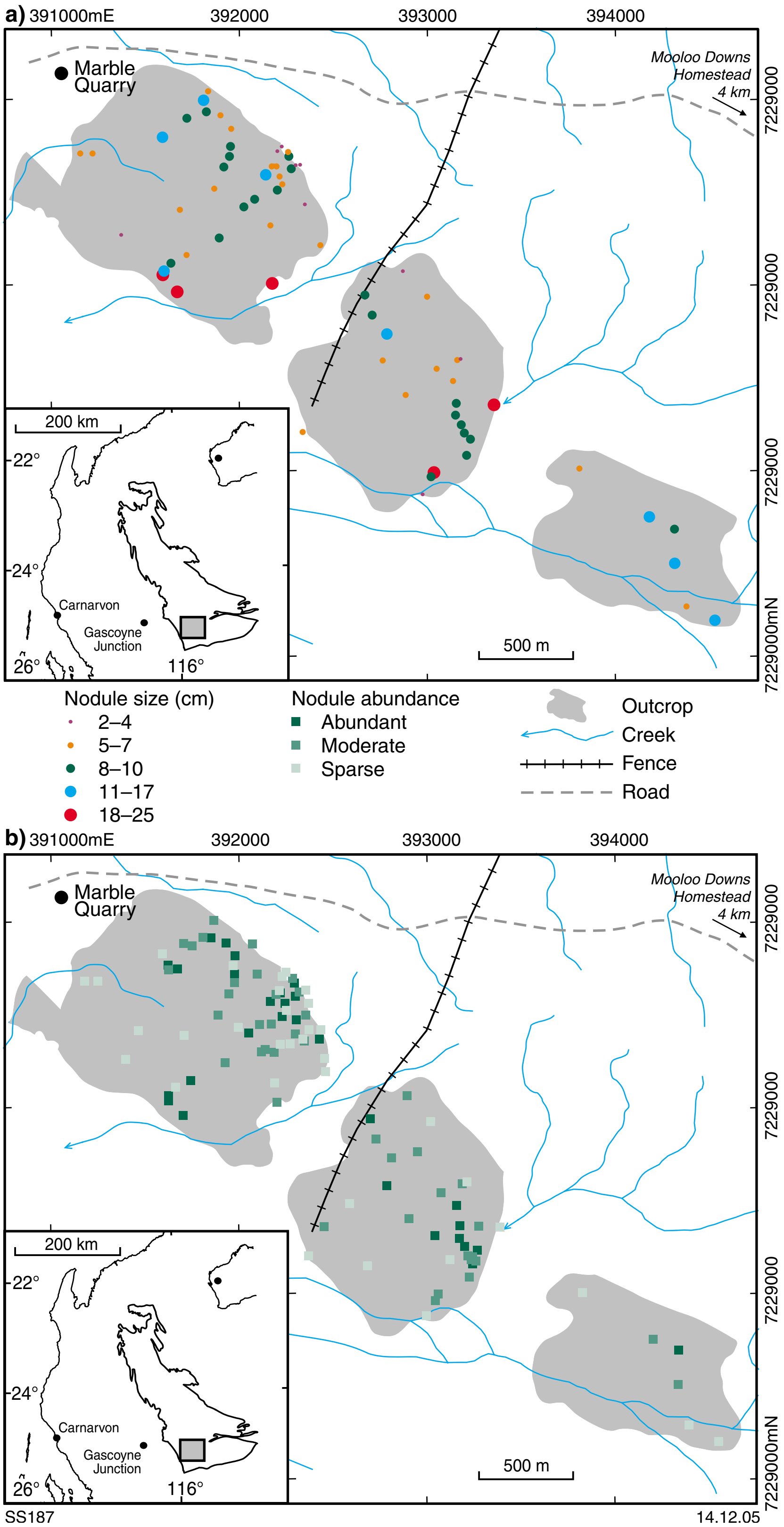

***Figure 1.** Outline of the three lobes of the Scrubber Granite and field locations where the following data were collected: a) nodule size variations across the three lobes; b) variation in nodule abundance across the three lobes (abundant = >8 nodules/m^2; moderate = >4 nodules/m^2; and sparse = <4 nodules/m^2).*

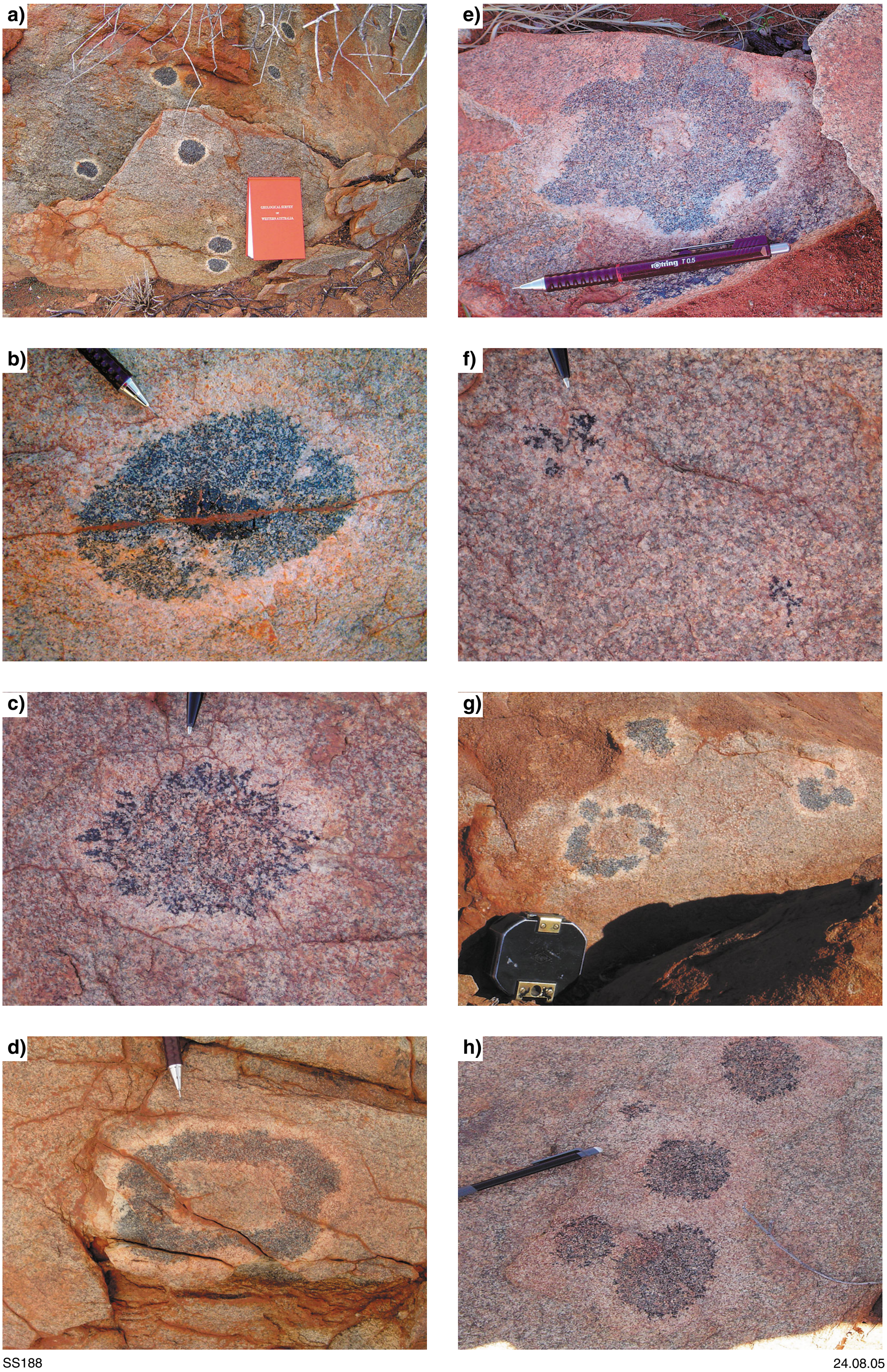

Figure 2. Various tourmaline nodule morphologies in the Scrubber Granite: a) spherical nodules; b) tourmaline rosette nodule (fracture is a later feature); c) starburst nodule; d) ring-shaped nodule; e) flower nodule; f) proto-nodule; g) telephone dial nodules; and h) swarm of five starburst nodules contained within merged haloes

halo material are termed 'starburst nodules' (Fig. 2c). These nodules are typically coarser grained relative to other nodule types.

'Ring-shaped ' nodules completely enclose an inner granitic zone and are characterized by the presence of an additional halo zone that separates the tourmaline-rich core from the inner host granite (Fig. 2d). Related to this morphologic type are nodules that resemble stylized flowers and also enclose an inner granitic zone ('flower nodules'; Fig. 2e). 'C-shaped nodules' (not illustrated) are similar to ring and flower nodules, but do not completely enclose the inner host granite.

Nodules typically less than 2 cm in diameter are termed 'proto-nodules' (Fig. 2f), due to their small size and general absence of surrounding halo material. These nodules are perhaps small precursors to larger, more developed nodules.

Aggregates of four or more nodules were observed throughout the Scrubber Granite. Small nodules arranged in a circular pattern are termed 'telephone dial nodules' (Fig. 2g). Randomly arranged nodule swarms locally display merged haloes (Fig. 2h).

Nodules of various shapes and sizes lacking a specific morphologic character were termed 'irregular nodules'. These nodules typically comprise splays and blebs of tourmaline(–quartz–feldspar) surrounded by leucocratic haloes.

Other features observed in the Scrubber Granite include nodule tubes, tourmaline veins, quartz–tourmaline patches, small pegmatite pods, and sparse xenoliths. 'Nodule tubes' are sparsely distributed throughout the host granite, typically adjacent to spherical nodules. Locally extending up to 4 m in length, nodule tubes are characterized by rounded terminations and leucocratic haloes. Tourmaline veins of varying widths are similar in mineralogy and texture to nodules, and locally crosscut nodules of all morphologic types. In a discrete region of the central lobe of the Scrubber Granite, coarse white quartz and prismatic black tourmaline crystals form quartz–tourmaline patches. Devoid of the leucocratic haloes that surround adjacent spherical nodules, these patches are physically different from nodules and from discrete pegmatite pods that are sparsely dispersed throughout the Scrubber Granite.

Xenoliths within the host granite include a 10 cm-long gneissic inclusion and a 5 cm-long muscovite-rich pelitic inclusion. Although some proponents of the replacement theory suggest that nodules may represent xenoliths that have been replaced by tourmaline-rich fluids (e.g. LeFort, 1991), the sparse xenoliths observed in the Scrubber Granite do not exhibit evidence of alteration to tourmaline, and are not spatially associated with nodules. Additionally, nodules throughout the study area lack evidence of such replacement. A key observation relevant to this discussion is the lack of replacement textures in proto-nodules, as these nodules may represent the early stages of nodule development.

Discussion

Nodules of the Scrubber Granite are strikingly similar to tourmaline nodules in other localities, particularly those documented in South Africa. Nodules observed in the Cnydas Granite (Jankowitz, 1987) and the Cape Granite Suite (Rozendaal and Bruwer, 1995; Rozendaal et al., 1995) are typically spherical in shape, but also form ring-shaped and tube-like morphologies. These authors proposed that nodules are post-magmatic replacement features, and that the nodules are genetically related to tourmaline veins which acted as 'feeders' for nodule development. Although this 'vein-based' replacement theory may explain the spatial association of nodules and Sn–W mineralization in the region, it does not explain the various nodule morphologies observed in these areas. It remains difficult to envision how spherical and ring-shaped textures could be generated from planar or linear fluid injections. Rozendaal and Bruwer (1995) stated that '…the mechanism responsible for their spherical shape is not fully understood, but could relate to point nucleation at the end of dendritically arranged micro-fractures'.

Sinclair and Richardson (1992) focused on explaining nodule morphology and texture when considering the origin of tourmaline nodules of the Seagull Batholith in the Northwest Territories of Canada. Several features of this batholith argue for a magmatic–hydrothermal origin: nodules are typically spherical in shape; nodules are concentrated in the roof zone of this batholith and decrease in abundance with depth; miarolitic cavities, features typically associated with late-stage volatile fluid exsolution, are present in some roof zone nodules and are locally lined with tourmaline and quartz(–topaz); and there is a lack of planar structural features (i.e. veins) related to nodule development. Based on these features, Sinclair and Richardson (1992) proposed that a 'pocket-based' fluid exsolution theory best explained the formation of nodule morphologies and textures observed in the Seagull Batholith.

Likewise, several features of the Scrubber Granite tourmaline nodules argue for a synmagmatic crystallization origin, and are not consistent with post-crystallization replacement theories: nodules are typically spherical to globular, which is the preferred shape for pockets of immiscible fluid to decrease surface tensions; nodule formation pre-dated, and appears to be unrelated to, deformation in the Scrubber Granite; there is no evidence that nodule formation involved the replacement of the host granite or sparse xenoliths, even in the proto-nodules; and there is a general lack of structural features related to nodule development. Tourmaline veins are sparse, and typically overprint nodules. Additionally, good three-dimensional exposures show that nodules are not spatially associated with tourmaline veins or fracture fill.

Based on the field observations summarized above, it is proposed that tourmaline nodules of the Scrubber Granite represent the solid product of immiscible B-rich fluid pockets that separated from the crystallizing granitic magma. Pre-solid state fluid exsolution better explains the formation of the multitude of nodule morphologies and textures observed in the Scrubber Granite (and other nodule localities discussed here), as opposed to post-crystallization replacement. Leucocratic haloes may represent the difference between the initial size of the volatile-rich fluid pocket and its resulting size upon cooling and contraction. Ferromagnesian components in this region may have contributed to the formation of tourmaline that became concentrated in the core.

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Debbie Shewfelt, co-author

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Debbie Shewfelt completed this study to fulfill part of the requirements for a Master of Science degree in Geology. She is currently employed as a Research Geologist at the Saskatchewan Research Council in Saskatoon, Saskatchewan. She is involved in the petrography of Archean and Proterozoic basement rocks, mostly in conjunction with uranium and gold mineralization.

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