Alteration and age of the Browns Range heavy rare earth element deposits

by

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Threats and opportunities

Rare earth elements (REE) are in high demand for use in advanced technologies, and supplies of both light (LREE) and heavy REE (HREE) to the global market are dominated and tightly controlled by China. The supply of higher value HREE is particularly critical, since these are currently produced from just one region in China, and manufacturers are seeking reliable alternative REE sources. The East Kimberley – West Tanami region of northern Western Australia is emerging as a potentially significant REE province, containing deposits of both LREE and HREE in a variety of mineralization styles (Fig. 1a).

The Browns Range project — owned and operated by Northern Minerals Limited — is presently the most advanced HREE project outside China. REE mineralization occurs as xenotime ([Y,HREE]PO_4) and subordinate florencite ([Ce,LREE]$Al_3(PO_4)_2(OH)_6$) in several hydrothermal quartz vein and breccia deposits that cut local basement rocks (Cook et al., 2013).

The genesis, regional prospectivity and exploration-relevant characteristics of this newly recognized style of REE mineralization are poorly understood. A collaborative project was therefore undertaken to investigate the mineralogy and distribution of primary host rocks and any hydrothermal alteration associated with REE using thin-section petrography, geological and hyperspectral logging, and multi-element geochemistry. It was also necessary to determine the age of REE mineralization using SHRIMP U–Pb dating of xenotime from six representative drillcores from deposits at Wolverine (four holes), Gambit (one hole) and Area 5 (one hole; Fig. 1b).

Location and geological setting

The Browns Range project collectively comprises several HREE deposits and prospects cropping out in basement rocks towards the western end of the Browns Range Dome, in the northwest part of the Granites–Tanami Orogen (Fig. 1). The stratigraphy in the Granites–Tanami Orogen comprises an older 'basement' of deformed and metamorphosed Paleoproterozoic to Mesoproterozoic clastic sedimentary rocks and volcanic rocks, intruded by several suites of syntectonic granitic rocks, all overlain unconformably to non-conformably by younger, non-metamorphosed, Mesoproterozoic siliciclastic and carbonate cover rocks (Ahmad et al., 2013). At Browns Range, deformed Paleoproterozoic, metasedimentary rocks of the Browns Range Metamorphics are intruded by granite plutons assigned to the c. 1820 to 1790 Ma Frederick and Grimwade suites (Cook et al., 2013; Ahmad et al., 2013), and the entirety is overlain unconformably and non-conformably by the siliciclastic Gardiner Sandstone (Birrindudu Group), having a poorly constrained age somewhere in the range 1735–1640 Ma (Dunster and Ahmad, 2013; Fig. 1b).

Mineralogy of host rocks, mineralization and hydrothermal alteration

The principal defined resource is in the Wolverine deposit (4.97 Mt at 0.86% total rare earth oxides, Northern Minerals, 2015), occurring predominantly in an east-trending, steeply north-dipping and west-plunging siliceous breccia band up to 20 m thick, along a slightly dilational jog in a fracture or fault cutting the metasedimentary host. Significant resources have also been estimated for the Gambit, Gambit West, Area 5, Cyclops and Banshee deposits, though mineralization in these is distributed in more diffuse quartz-vein arrays.

Host rocks are metamorphosed, broadly compositionally and texturally monotonous, massive to crudely graded, thick bedded, variably lithic and feldspathic arenites and local pebbly conglomerates. REE mineralization occurs as xenotime and subordinate florencite, predominantly in quartz veins and vein-quartz breccias that range in size from relatively small crackle vein arrays, to massive, chaotic vein breccias exceeding 5 m in width. REE-bearing phosphates form irregular aggregates of euhedral to anhedral, variably fractured grains up to several millimetres in diameter, as interstitial infill (cement)

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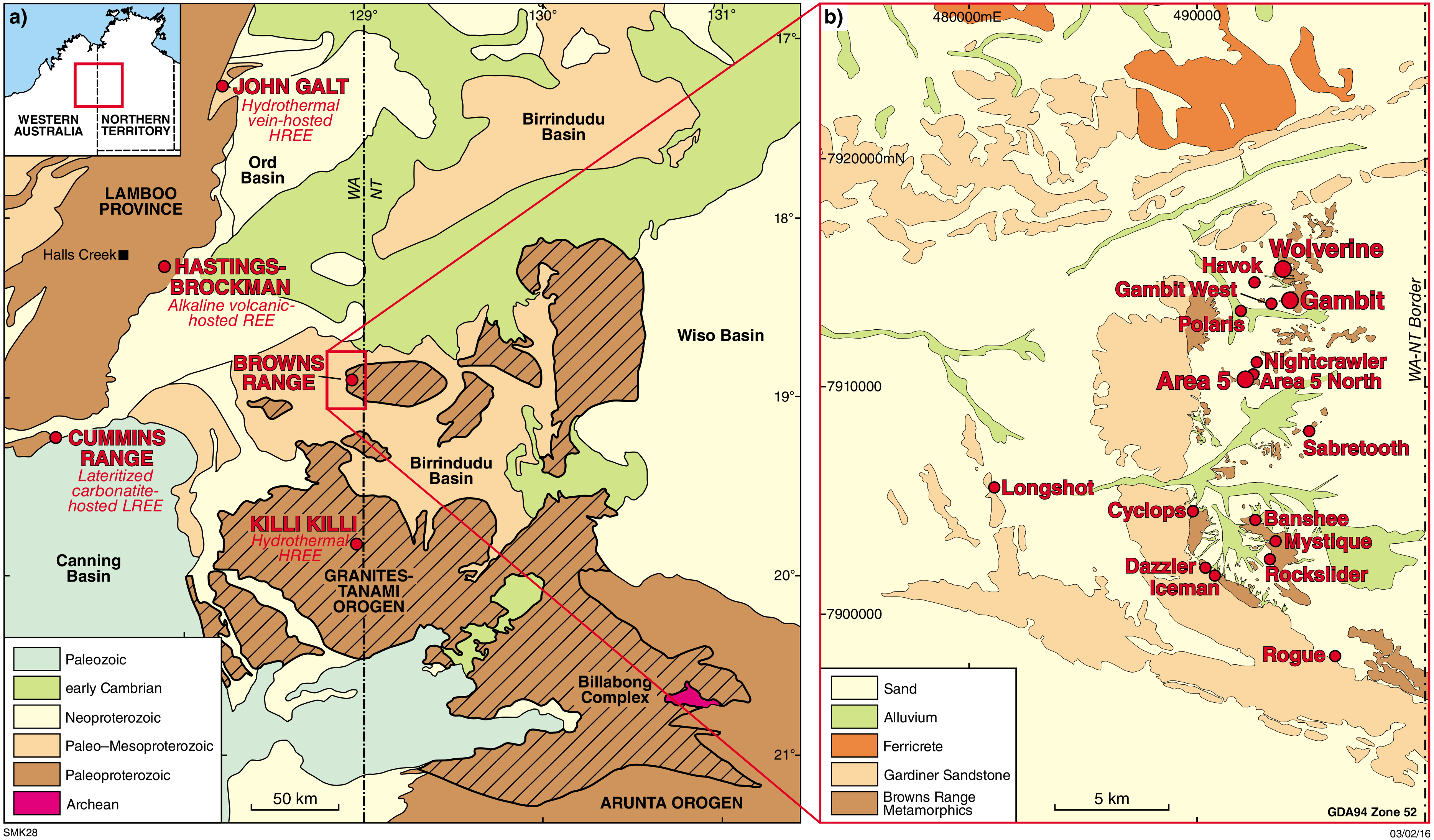

Figure 1. Locations and geological setting of: a) significant REE deposits in northern Australia (modified from Fig. 11.1, Ahmad et al., 2013); b) individual deposits and prospects in the Browns Range Dome. Emphasized deposits in b) are those examined in this research project.

and matrix replacement that has experienced some reworking during evolution of the vein/breccia systems. Xenotime commonly has a pinkish tinge due to dusting with fine-grained hematite, which also occurs sporadically as an independent phase (see also Cook et al., 2013).

The distribution of HREE is determined from hyperspectral data using the algorithm developed by Morin-Ka (2013), and is independently confirmed by drillhole assays (Fig. 2). Intense silicification (significant addition of SiO_2) is only obvious where vein-quartz breccias are strongly developed, and REE grades are greatest. Silicification is less apparent in domains of distributed quartz vein arrays, due perhaps to the generally silica-rich nature of the original host rocks.

Country rocks immediately adjacent to the siliceous, REE-mineralized zones are texturally identical to rocks well away from the REE deposits, but the non-quartz components (feldspars and lithic fragments) are replaced by clay-rich alteration. Hyperspectral data identify the ‘clays’ as smectites/illites, and also show a corresponding complete absence of K-feldspar (due to the replacive nature of the alteration). Whole-rock assays reveal a marked decrease in potassium abundance passing from unaltered to altered rock (Fig. 2). Smectite–illite alteration at Wolverine commonly extends several tens of metres away from both sides of main REE mineralization, presenting a much larger footprint than the REE mineralization itself — though drillholes into this deposit did not extend far enough into the footwall to unequivocally demonstrate alteration symmetry around the central, REE-mineralized structure. Hydrothermal alteration grades outwards into unaltered (feldspar-bearing) country rock that also contains detrital, phengitic (relatively low-Al) muscovite.

Age of REE mineralization

SHRIMP U–Pb dating of xenotime from the Wolverine deposit returned a single, well-constrained age of 1646 ± 5 Ma, regardless of the textural type of xenotime (Fig. 3).

Implications and speculations

The nature and distribution of alteration associated with REE mineralization suggest permeation of initially hot, relatively acid, oxidized fluids from structural conduits into the surrounding country rock, where they were progressively cooled and neutralized. The c. 1820 to 1790 Ma granites emplaced into basement rocks in the Browns Range Dome are much older than the REE mineralization, hence cannot have been sources of the hydrothermal fluids, nor direct drivers of mineralizing processes. The composition and source of the hydrothermal fluids are as yet undetermined.

The Gardiner Sandstone is also probably older than REE mineralization, implying that juvenile or ‘spent’ hydrothermal fluids could have passed through these cover rocks, potentially leaving (yet to be defined) mineralogical pathfinders to buried REE mineralization that are detectable using regional hyperspectral mapping or other remote sensing technology (e.g. radiometrics).

There are two other known hydrothermal HREE prospects in the Granites–Tanami Orogen and eastern Lamboo Province — Killi Killi (West Tanami) and John Galt, about 100 km south and 200 km northwest of Browns Range, respectively (Fig. 1a). The ages of HREE mineralization at these prospects are broadly similar to that at Browns Range (Table 1), and also comparable to the age of unconformity-related uranium mineralization in the Pine Creek Orogen in the Northern Territory (Vallini et al., 2007). This suggests a widespread hydrothermal event about 1650–1620 Ma, confirming the prospectivity of the entire region for (H)REE (and U) deposits.

Table 1. SHRIMP U–Pb ages of hydrothermal HREE mineralization in northern Western Australia

Deposit	*Xenotime U–Pb Age*	*Citation*
Browns Range	1646 ± 5 Ma	GSWA, in prep.
John Galt	1619 ± 9 Ma	GSWA, in prep.
Killi Killi/West Tanami	1632 ± 3 Ma	Vallini et al., 2007

There are no known local contemporaneous magmatic or tectonic events that might have driven hydrothermal fluid evolution and circulation. More distant influences could have been responsible — perhaps, for example, the accretion of the Warumpi Province to the southern margin of the Arunta Orogen during the c. 1640 Ma Liebig Event (Scrimgeour et al., 2005; Hollis et al., 2013).

Conclusions

HREE mineralization at Wolverine (and other deposits) in the Browns Range Dome occurs predominantly as xenotime infill in hydrothermal siliceous breccias and vein arrays. Associated quartz–clay alteration has a footprint considerably larger than the mineralization itself. REE mineralization and alteration can be directly detected in outcrop and drillcore using hyperspectral logging. They are also younger than Birrindudu Group cover rocks. Therefore, it may be possible to explore for REE mineralization beneath (or within?) these cover rocks by detecting the overlying alteration signature of ‘spent’ hydrothermal fluids, using regional hyperspectral and other (e.g. radiometric) survey technologies.

Superficially different HREE deposits at Browns Range, John Galt and Killi Killi (West Tanami) have similar ages. This suggests a widespread REE mineralizing ‘event’ in the North Australian Craton, which therefore remains prospective for the discovery of other (H)REE deposits.

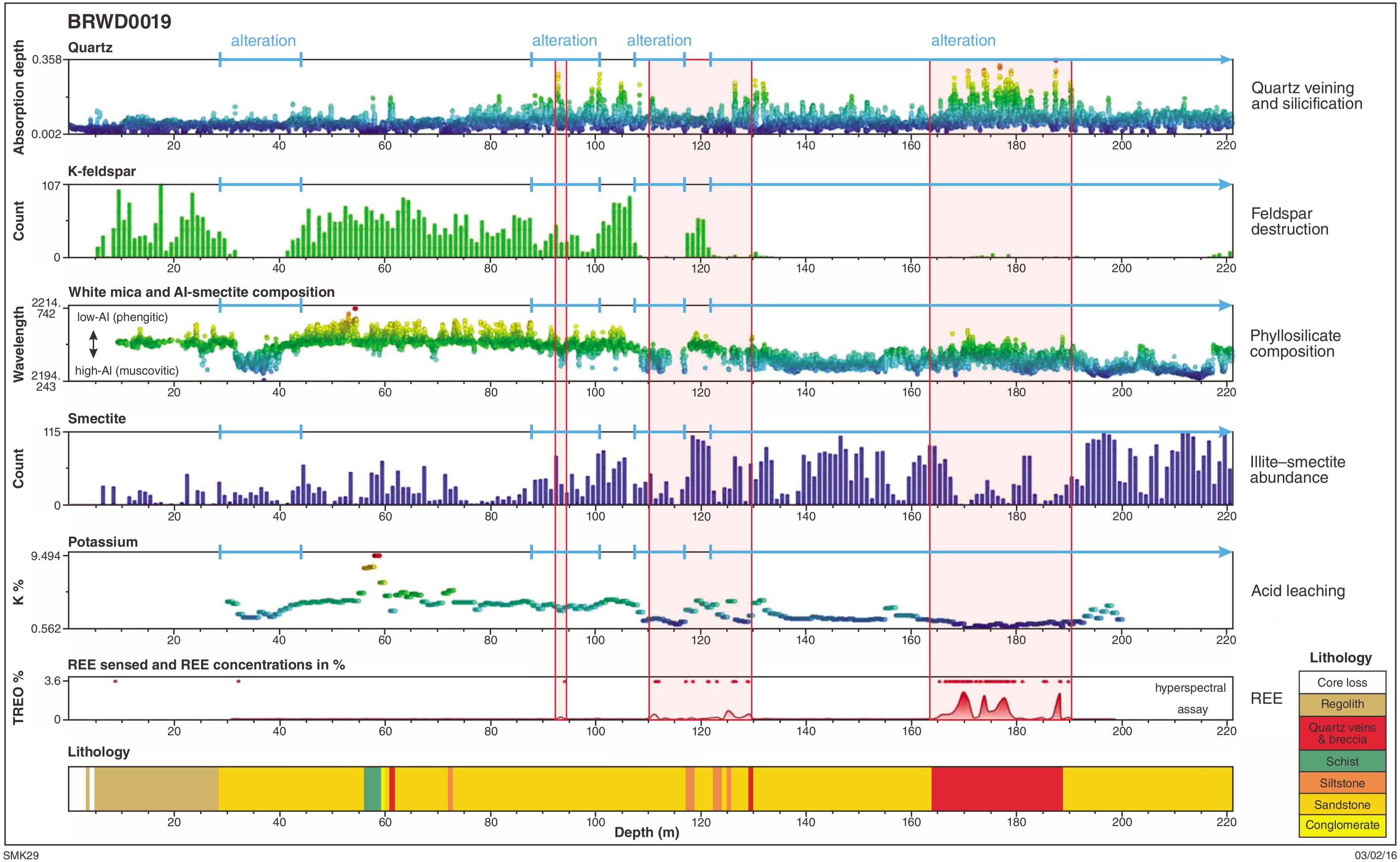

Figure 2. Selected mineralogical and geochemical data for core from drillhole BRWD0019 which passed through the middle of the main breccia zone at the Wolverine deposit. The data illustrate some significant alteration and REE mineralization trends that are also evident in other analysed core from Wolverine, and from the Gambit and Area 5 deposits.

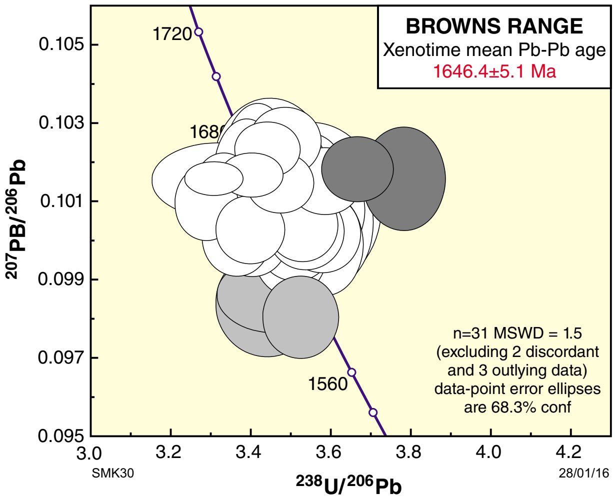

Figure 3. Concordia plot of SHRIMP U–Pb ages for xenotime from the Wolverine HREE deposits, Browns Range Dome

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