NORTHERN TERRITORY GEOLOGICAL SURVEY

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Summary of results. Re–Os molybdenite dating of W–Mo mineralisation in the Barrow Creek pegmatite field, Barrow Creek, Aileron Province

MV McGloin and RA Creaser

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TABLE OF CONTENTS

FIGURES

TABLES

SUMMARY

This record presents the results of new rhenium–osmium (Re–Os) molybdenite geochronology for tungsten–molybdenum (W–Mo) mineralisation from the western group of occurrences in the Barrow Creek pegmatite field. This mineralisation is located within the BARROW CREEK[1] map area of the northern Aileron Province of the Arunta Region. The molybdenite sample was collected from an unnamed, historical, small W–Mo working located 12 km northwest of Barrow Creek. The sample was dated in order to determine a direct age for W–Mo mineralisation associated with the Barrow Creek pegmatite field. By inference, this age likely provides an age for other regional Sn-Ta-W-Mo mineralisation found in the larger pegmatite field.

A Re–Os molybdenite model age of 1794 ± 8 Ma was determined; this result provides the first direct age for W–Mo mineralisation in the Barrow Creek pegmatite field. This age is appreciably younger than previous estimates for this mineralisation, and suggests that previously unrecognised fractionated granite phases of the Bean Tree Granite or another contiguous granite phase are likely responsible for the pegmatite-related mineralisation. Alternatively, an unknown and unexposed granite intrusion may be a potential source for mineralisation at depth in the Barrow Creek area. The Re–Os dating of molybdenite reported in this record demonstrates the potential application of this method to dating ore deposits in future regional geochronology work.

[1] Names of 1:100 000 and 1:250 000 mapsheets are shown in small and large capital letters respectively, ie CRAWFORD, BARROW CREEK.

INTRODUCTION

This record presents new Re–Os molybdenite geochronological results from an unnamed W–Mo occurrence in the Barrow Creek pegmatite field (**Figure 1**). This data was obtained during regional geoscientific investigations, mapping, and mineral systems prospectivity analysis by Northern Territory Geological Survey (NTGS) in June 2015.

Several tin–tantalum–tungsten–molybdenum (Sn–Ta–W–Mo)-bearing pegmatites occur in the Barrow Creek pegmatite field within 30 km radius of Barrow Creek Township (**Figure 2**). The Barrow Creek pegmatite field comprises three geographically distinct zones of pegmatites: the eastern, western and Neutral Junction groups (Frater 2005). The western pegmatite group, of interest in this record, is located 10 km to the west of the eastern pegmatite group, and about 20 km to the northwest of the Neutral Junction group, which is located about 12–20 km northwest of Barrow Creek.

The mineralised pegmatites and associated eluvium deposits of the Barrow Creek pegmatite field are well documented and have been subject to several past exploration and mining endeavours for tantalum, tin, tungsten and mica (see details in Frater 2005). The metal content of these pegmatites is highly variable, and although some pegmatites have previously been worked on small scales, they are considered sub-economic due to low tonnage and grade. Some gravel-hosted eluvial tin and tantalite resources associated with some pegmatites were considered the most economically prospective (Frater 2005).

The mineralised pegmatites are commonly narrow and intrude the predominantly metasedimentary Palaeoproterozoic Bullion Schist (Smith and Milligan 1964, Haines *et al* 1991, Frater 2005). In the vicinity of the western pegmatite group, the Bullion Schist occurs mainly as amphibolite-facies quartz–muscovite schist (Frater 2005). Based on whole-rock geochemistry, mineralisation associated with the western pegmatite group is relatively tin- and niobium-rich rather than tantalum-rich (Frater 2005).

Despite previous study of these pegmatites and associated Sn–Ta–W–Mo mineralisation, direct dating of the pegmatites, associated quartz veins, and related granophile mineralisation has remained enigmatic. The source for mineralised pegmatites in the Barrow Creek pegmatite field has been inferred to be apophyses of fractionated granites of the Barrow Creek Granite Complex that are commonly spatially associated with pegmatite bodies (Frater 2005, Smith 2001, Haines *et al* 1991). However, there appears to be some confusion as to the age of this complex; Frater (2005) suggested crystallisation ages of both 1713 Ma (Budd *et al* 2002, Haines *et al* 1991) and 1803 ± 6 Ma (Smith 2001) for the youngest dated granite phase of this complex. Because of this uncertainty on the age of emplacement of intrusions from the Barrow Creek Granite Complex, and by inference, the age of associated pegmatites and regional Sn–Ta–W–Mo mineralisation, absolute age dating of molybdenite using the Re-Os isotopic system was conducted.

Use of the Re–Os chronometer for dating molybdenite is considered robust and reliable for geochronology purposes (Stein *et al* 2001 and references therein). The Re–Os isotopic system in molybdenite has the ability to endure high-grade metamorphism and deformation, even under granulite-facies conditions, and particularly in terranes that have experienced multiple episodes of hydrothermal, magmatic and metamorphic events (Bingen and Stein 2003). The use of the Re–Os chronometer in molybdenite can be advantageous over other mineral chronometers. For example, unlike the Rb–Sr, K–Ar and ^{40}Ar–^{39}Ar isotopic systems, the molybdenite Re–Os system is not commonly susceptible to chemical and thermal disturbances (Stein *et al* 2001). Additionally, although the Re–Os molybdenite system has relatively lower closure temperatures in some examples (~550°C) compared to traditional U–Pb mineral chronometers (~800–600°C; Schaefer 2016), molybdenite can be a useful chronometer, particularly in polymetamorphosed and deformed terrains, because it is not complicated by overgrowths that are common in minerals like zircon, monazite and xenotime (Stein *et al* 2001). Based on these constraints, the new Re–Os molybdenite age data in this report is considered to represent a robust hydrothermal-magmatic age for mineralisation that has not been affected by subsequent deformation, metamorphism or crustal fluid flow.

This record documents the sampled location, geological context, target mineral description and the relevant analytical data. The sampled location is shown in **Figures 1 and 2**. **Table 1** shows a summary of the results. This record also includes a brief discussion and interpretation of the isotopic data.

ANALYTICAL PROCEDURES

A molybdenite mineral separate of 6.2 mg was made for the sample by metal-free crushing followed by gravity and magnetic concentration methods as described in detail by Selby and Creaser (2004). The ^{187}Re and ^{187}Os concentrations in molybdenite were determined by isotope dilution-thermal ionization mass spectrometry (ID-TIMS) using Carius-tube, solvent extraction, anion chromatography and the thermal ionisation mass spectrometry method. A mixed double spike containing known amounts of isotopically enriched ^{185}Re, ^{190}Os, and ^{188}Os analysis was used (Markey *et al* 2007). Isotopic analysis used a ThermoScientific Triton mass spectrometer by Faraday collector. Total blanks for Re and Os are less than < 3 picograms and 2 picograms respectively, which are insignificant for the Re and Os concentrations in molybdenite. The molybdenite powder HLP-5 (Markey *et al* 1998) was routinely analysed as an internal standard; over a period of one year, an average Re–Os date of 220.66 ± 0.21 Ma (1SD uncertainty, n=5) was obtained. This Re–Os age date is consistent to that reported by Markey *et al* (1998) of 221.0 ± 1.0 Ma. All uncertainties are quoted at 2σ level for all known analytical uncertainty, including uncertainty in the decay constant of ^{187}Re.

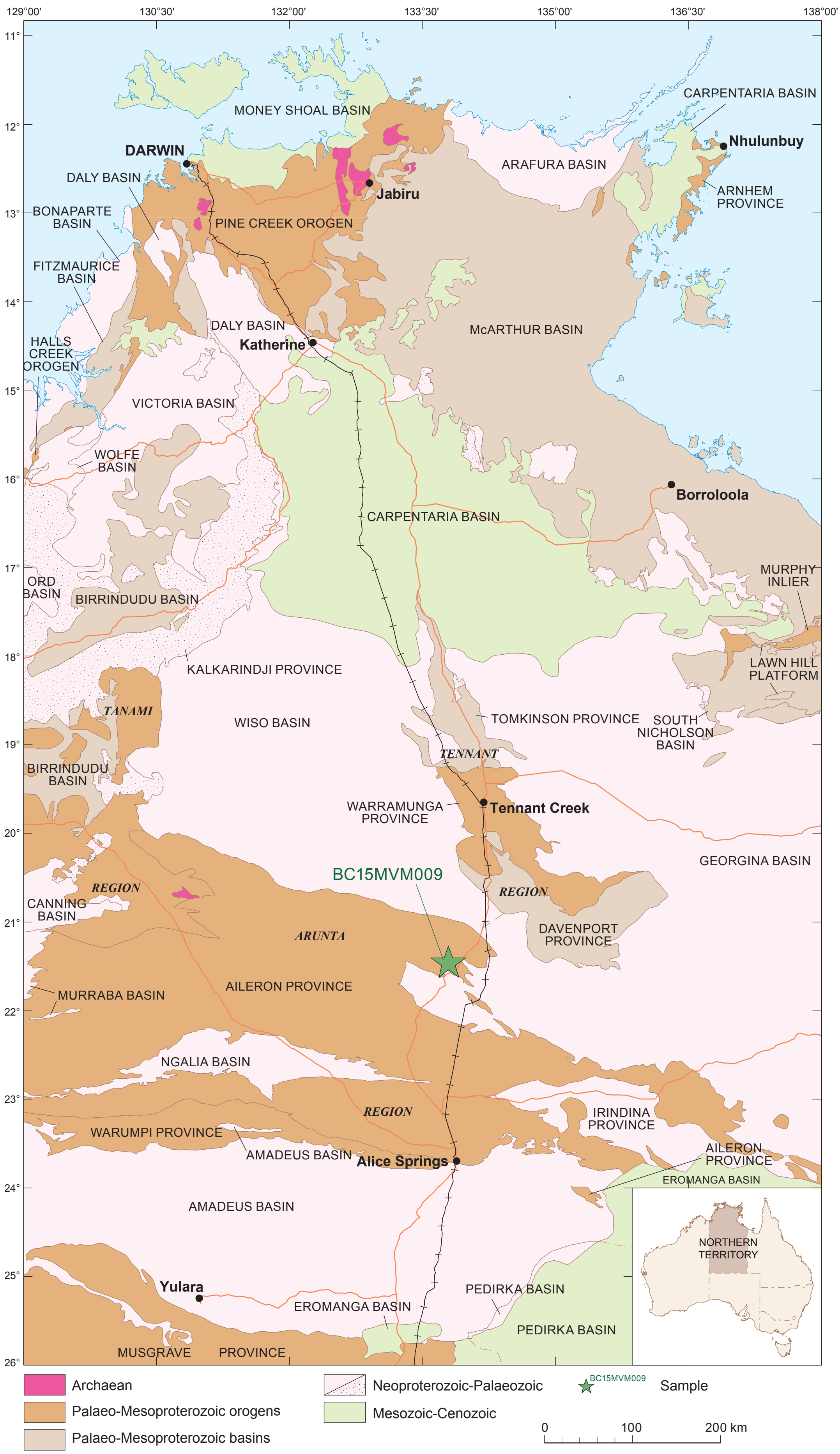

Figure 1. Regional location of the Barrow Creek pegmatite field and W–Mo sample BC15MVM009.

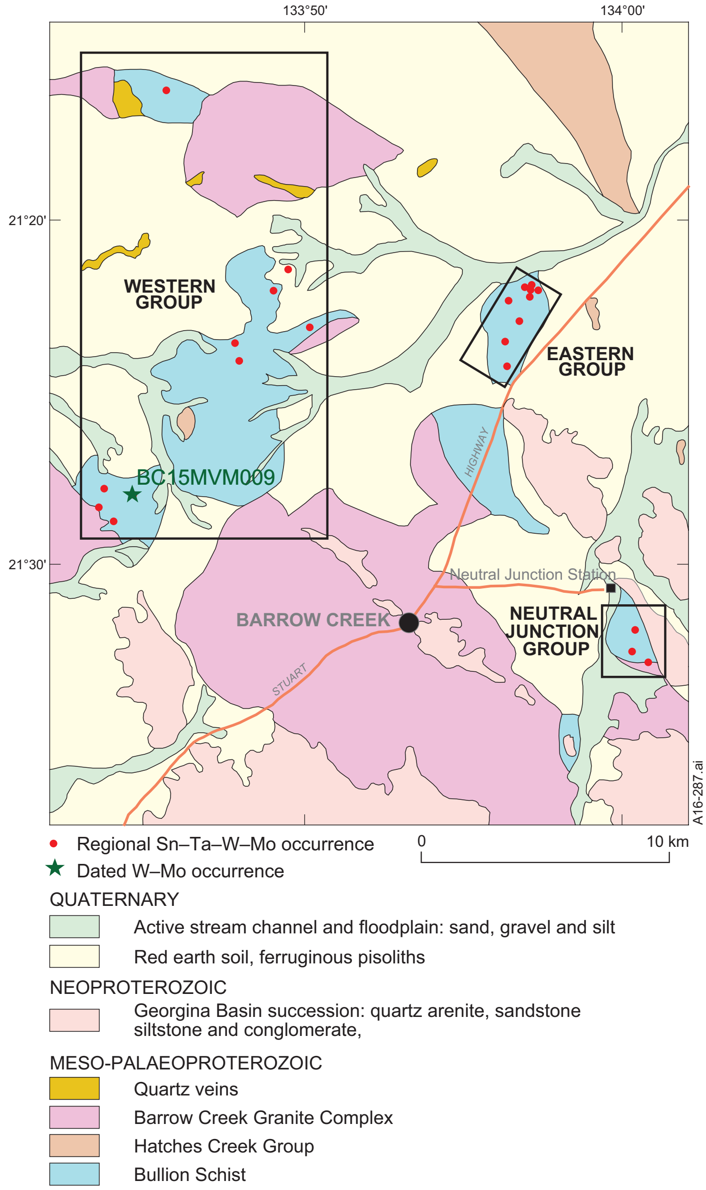

Figure 2. Barrow Creek pegmatite field and sample location. Boxes indicate the three geographical group occurrences of the pegmatite field.

Table 1. Summary of molybdenite dating result for BC15MVM009. All uncertainties are quoted at the 2σ level of precision.

Stratigraphic Unit	Sample No	Target mineral	MGA94 zone	Easting (mE)	Northing (mN)	Interpreted molybdenite model age (Ma)
Unnamed pegmatite-derived quartz vein	BC15MVM009	molybdenite	53K	374990	7626226	1794 ± 8

SAMPLE ANALYSED

Unnamed W–Mo mineral occurrence, western Group, Barrow Creek pegmatite field (BC15MVM009)

Sample information

NTGS Sample ID: BC15MVM009
Collector: MV McGloin
1:250 000 mapsheet: BARROW CREEK (SF53-06)
1:100 000 mapsheet: CRAWFORD (5655)
Region/Province: Aileron Province, Arunta Region
Grid Reference: MGA94 Zone 53, 374990mE 7626226mN
Informal name: Unnamed W–Mo working
Lithology: pegmatite-derived quartz vein
Geochronology target: molybdenite

Interpreted model age summary

Molybdenite mineralisation model age of 1794 ± 8 Ma

Location details, lithological characteristics and regional geologic constraints

Trace molybdenite was sampled from a pegmatitic quartz vein in an unnamed W–Mo working (MODAT site 00881; NTGS 2016). This working is located 5 km east of the QT, Slippery and Krakatoa Sn–Ta pegmatite mineral occurrences within the western pegmatite group of the Barrow Creek pegmatite field, about 12 km northwest of Barrow Creek and the Stuart Highway.

At the sample location, five small working pits are exposed on a small prominent hill. The sampled quartz vein hosts variable amounts of muscovite, tourmaline and hematite, as well as minor traces of black wolframite (**Figure 3**). Such mineralised quartz veins are commonly associated with the margins of pegmatite intrusions; Frater (2005) noted that both veins and pegmatites are mineralised with Sn–Ta–W–Mo regionally. This consistent mineralogy and regional geological relationships are interpreted to suggest that the quartz veins are pegmatite-derived, and although no pegmatite intrusion is visible at surface, it is likely to occur at depth below the working. No other minerals of economic interest (eg tantalite, cassiterite, scheelite) were observed; however, trace sulfides were associated with hematite staining on the eastern side of the hill.

Several of these veins are oriented in a northeast-southwest trend, but orientation is locally variable. Quartz veins intrude both metasedimentary rocks of the Bullion Schist (Bagas and Haines 1991, Frater 2005) and an unnamed orthoamphibolite. The Bullion Schist is overprinted by a northeast-striking, near vertical foliation at the sampled location. A subtle crenulation cleavage is also evident in some of the exposed schist. The quartz veins cross-cut this deformation. On vein margins, the Bullion Schist is commonly intensely tourmalinised and shows evidence for greisenisation and contact metamorphism. On the eastern side of the hill, pervasive quartz-tourmaline alteration is evident. Several large metamorphic minerals (eg andalusite, cordierite) occur in schist on vein margins.

The nearest mapped outcrop of granite is the Bean Tree Granite, a leucocratic biotite-muscovite granite located 2 km east-southeast from the W–Mo occurrence. Several additional granitoid phases outcrop within a 10 km radius of the W–Mo occurrence, including several tourmaline-bearing pegmatites and a large intrusive body of the biotite-adamellite-bearing Ooralingie Granite. The Ooralingie Granite is also part of the Barrow Creek Granite Complex (Bagas and Haines 1991).

The age of pegmatite-related W–Mo mineralisation in the Barrow Creek pegmatite field can be constrained by currently mapped geological relationships and associated geochronology. SHRIMP U–Pb dating of the Bullion Schist yields a maximum depositional age of 1824 ± 10 Ma, making the Bullion Schist an interpreted correlative of the Lander Rock Formation (Claoué-Long *et al* 2008,

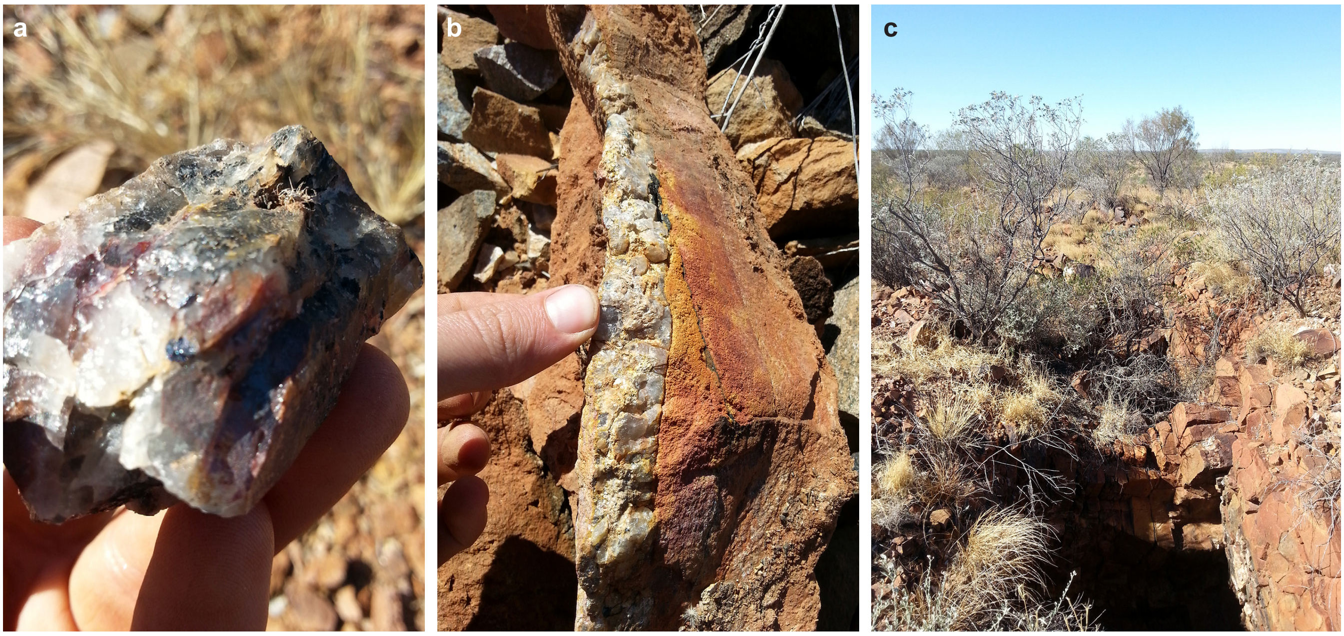

Figure 3. (**a**) Close up of molybdenite associated with hematite on the margin of the quartz vein; (**b**) close up of mineralised pegmatite-derived quartz vein containing tourmaline; (**c**) historical W–Mo working on top of small hill worked for wolframite and molybdenite.

Scrimgeour 2013). A further constraint on the maximum depositional age is given by the Strzeleckie Volcanics that overlie the Bullion Schist regionally (Haines *et al* 1991) and have a magmatic crystallisation age of 1805 ± 6 Ma (Claoué-Long *et al* 2008). The pegmatite intrusions must be younger or near contemporaneous with the overlying Strzeleckie Volcanics. These volcanics may also be contemporaneous with emplacement of the Barrow Creek Complex (Scrimgeour 2013).

No direct dating of pegmatites has been carried out in the Barrow Creek pegmatite field or elsewhere in BARROW CREEK. Furthermore, some details of the timing and distribution of granite phases on BARROW CREEK remain uncertain. This uncertainty also precludes an accurate constraint on the timing of pegmatite-related mineralisation in the Barrow Creek pegmatite field. Frater (2005) suggested that pegmatite and quartz vein-hosted Sn–Ta–W–Mo mineralisation of the Barrow Creek pegmatite field may be related to felsic magmatism at either ca 1803 Ma or ca 1713 Ma.

SHRIMP U–Pb zircon dating of two phases of the Barrow Creek Granite Complex yield magmatic crystallisation ages of ca 1810–1800 Ma. The Ooralingie Granite has a magmatic crystallisation age of 1809 ± 5 Ma, and is intruded by the Bean Tree Granite, which has a similar magmatic crystallisation age of 1803 ± 6 Ma (Smith *et al* 2001). The Ali Curung Granite (Haines *et al* 1991) also outcrops in BARROW CREEK, comprising several mica-bearing phases as well as leucogranite and granodiorite. No absolute geochronology for phases of the Ali Curung Granite exist; however, a minimum emplacement age is constrained by an intrusive relationship with the ca 1820 Ma maximum depositional zircon age for the Hatches Creek Group (Scrimgeour 2013 and references therein). The Ali Curung Granite has been suggested to be a potential correlative of three distinct regional episodes of granite magmatism: (i) the ca 1810–1800 Ma Barrow Creek Complex (Haines *et al* 1991, Frater 2005, Scrimgeour 2013); (ii) regional low-aluminium granite magmatism at ca 1780–1750 Ma (Zhao and McCulloch 1995); and (iii) regional felsic intrusions emplaced at ca 1720–1710 Ma (Haines *et al* 1991, Budd *et al* 2002, Frater 2005). Haines *et al* (1991) suggested a potential correlation with the Elkedra Granite, which yields a magmatic crystallisation U–Pb zircon age of 1720 ± 6 Ma (Page 1995). The speculation emphasises the poorly understood temporal relationship between the Barrow Creek Granite Complex and the Ali Curung Granite in BARROW CREEK. Without such timing constraints, it becomes impossible to confidently confirm the age and source of local pegmatite bodies and related quartz veins that sourced Sn–Ta–W–Mo mineralisation in the Barrow Creek pegmatite field. Thus a molybdenite sample (sample BC15MVM009) from a wolframite and tourmaline-bearing quartz vein was collected to determine the direct age of this W–Mo mineralisation.

Re–Os molybdenite analytical information

Analyst: Robert A Creaser, University of Alberta
Instrument: ThermoScientific Triton mass spectrometer by Faraday collector
Acquisition Date: 16 February 2016
Standards: The molybdenite powder HLP-5 (Markey *et al* 1998)

Isotopic results and interpretation

ID-TIMS analysis of molybdenite from sample BC15MVM009 yielded a model age of 1794 ± 8 Ma (2σ). This new molybdenite age provides the first robust age constraint on the timing of one example of W–Mo mineralisation in the Barrow Creek pegmatite field. By inference, this is the age of associated pegmatites and regional Sn–Ta–W–Mo mineralisation. **Table 2** lists the Re–Os isotopic data and age results.

The age reported here is younger than the timing of deposition of the Bullion Schist (ca 1824 Ma; Claoué-Long *et al* 2008) and indicates that the pegmatite and quartz-vein-related mineralisation, at least at the sample location, is likely related to late-stage felsic magmatism associated with the ca 1810–1800 Ma Barrow Creek Granite Complex. The new age is within uncertainty of the magmatic crystallisation age for the Bean Tree Granite (1803 ± 6 Ma; Smith *et al* 2001). However, it is likely that a slightly younger, more fractionated late-stage granite phase was involved in pegmatite emplacement. The age yielded from the Re–Os molybdenite chronometer is likely to be comparable to the U–Pb zircon chronometer, particularly because pegmatitic melts would likely crystallise rapidly at a similar time as mineralising magmatic-hydrothermal fluids were exsolved from the crystallising melt. An alternative explanation is that the new molybdenite age indicates a link with more regional felsic magmatism related to the Esther Granite. This granite is mainly found at Mount Peake where it is associated with the Anningie Tin Field. The Esther Granite has a U–Pb SHRIMP zircon igneous crystallisation age of 1789 ± 6 Ma (Cross *et al* 2005), which is within the error range of the new molybdenite age. Furthermore, phases of the Esther Granite are thought to extend into both the NAPPERBY and the BARROW CREEK mapsheets.

Finally, the molybdenite age in this record precludes a possible link to regional ca 1720–1710 Ma granites (eg the Elkedra Granite, and speculatively, the undated Ali Curung Granite) as previously suggested by Frater (2005). It is likely that mineralisation related to other pegmatites in the Barrow Creek pegmatite field has a similar ca 1795 Ma age based on generally consistent geological, mineralogical and chemical observations at all these mineralised occurrences, as discussed in Frater (2005).

Table 2. Summary of Re–Os isotopic data and age determinations; ppb = parts per billion, ppm = parts per million. All uncertainties are quoted at the 2σ level of precision.

Sample	Re (ppm)	± 2σ	^{187}Re (ppm)	± 2σ	^{187}Os (ppb)	± 2σ	Model age (Ma)	± 2σ (Ma)
BC15MVM009	8.006	0.025	5.032	0.016	152.6	0.1	1793.5	8.3

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REFERENCES

Bagas L and Haines PW, 1991. *Barrow Creek, Northern Territory (Second Edition). 1:250 000 geological series map, SF53-6*. Northern Territory Geological Survey, Darwin.

Bingen B and Stein S, 2003. Molybdenite Re–Os dating of biotite dehydration melting in the Rogaland high-temperature granulites, S Norway. *Earth and Planetary Science Letters* 208, 181–195.

Claoué-Long JC, Maidment D and Donnellan N, 2008. Stratigraphic timing constraints in the Davenport Province, central Australia: A basis for Palaeoproterozoic correlations. *Precambrian Research* 166(1–4), 204–218.

Cross A, Claoué-Long JC, Scrimgeour IR, Crispe A and Donnellan N, 2005. Summary of results. Joint NTGS–GA geochronology project: northern Arunta and Tanami regions 2000–2003. *Northern Territory Geological Survey, Record* 2005-003.

Frater KM, 2005. Tin–tantalum pegmatite mineralisation of the Northern Territory. *Northern Territory Geological Survey, Report* 16.

Haines PW, Bagas L, Wyche S, Simons B and Morris DG, 1991. *Barrow Creek, Northern Territory (Second Edition). 1:250 000 geological map series explanatory notes, SF53-6*. Northern Territory Geological Survey.

Markey RJ, Stein HJ and Morgan JW, 1998. Highly precise Re–Os dating for molybdenite using alkaline fusion and NTIMS. *Talanta* 45**,** 935–946.

Markey RJ, Stein HJ, Hannah JL, Selby D and Creaser RA, 2007. Standardizing Re–Os geochronology: A new molybdenite reference material (Henderson, USA) and the stoichiometry of Os salts. *Chemical Geology* 244, 74–87.

NTGS, 2016. Mineral Deposit Database (MODAT). *Northern Territory Geological Survey, Digital Information Package* DIP003.

Page RW, 1995, *OZCHRON database, Geoscience Australia, Canberra*. Unpublished SHRIMP I data. http://www.ga.gov.au/oracle/ozchron/ [accessed November 2016].

Selby D and Creaser RA, 2004. Macroscale NTIMS and microscale LA–MC–ICP–MS Re–Os isotopic analysis of molybdenite: Testing spatial restrictions for reliable Re–Os age determinations, and implications for the decoupling of Re and Os within molybdenite. *Geochimica et Cosmochimica Acta* 68, 3897–3908.

Schaefer BF, 2016, *Radiogenic Isotope geochemistry: a guide for industry professionals*. Macquarie University, Sydney, Australia, Cambridge University Press.

Scrimgeour IR, 2013. Chapter 12: Aileron Province: in Ahmad M and Munson TJ (compilers). *'Geology and mineral resources of the Northern Territory'. Northern Territory Geological Survey. Special Publication* 5.

Smith J, 2001. Summary of Results, Joint NTGS–AGSO Age Determination Program 1999–2001. *Northern Territory Geological Survey, Record* 2001-007.

Smith KG and Milligan EN, 1964. *Barrow Creek, Northern Territory (First Edition). 1:250 000 geological map series explanatory notes, SF53-6*. Bureau of Mineral Resources, Australia, Canberra.

Stein HJ, Markey RJ, Morgan JW, Hannah JL and Schersten A, 2001. The remarkable Re–Os chronometer in molybdenite: how and why it works. *Terra Nova* 13, 479–486.

Zhao J and McCulloch MT, 1995. Geochemical and Nd isotopic systematics of granites from the Arunta Inlier, central Australia: implications for Proterozoic crustal evolution. *Precambrian Research* 71(1), 265–299.