Exploring for the future: new U-Pb geochronology for the South Nicholson region and implications for stratigraphic correlations

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SUMMARY

Zircon and xenotime U-Pb SHRIMP geochronology was conducted on samples from the South Nicholson Basin, and western Mount Isa Orogen. These samples were collected from outcrop and core from the Northern Territory and Queensland. The age data indicate the South Nicholson Basin was deposited after ca. 1483 Ma but deposition most likely had ceased by ca. 1266 Ma; the latter age likely represents post-diagenetic fluid flow in the area, based on U-Pb xenotime data. Geochronology presented here provides the first direct age data confirming the South Nicholson Group is broadly contemporaneous with the Roper Group of the McArthur Basin, which has identified facies with high hydrocarbon prospectivity. In addition, geochronology on the Paleoproterozoic McNamara Group provides new age constraints that have implications for the regional stratigraphy. The data obtained in this geochronological study allow for a comprehensive revision of the existing stratigraphic framework, new correlations and enhances commodity prospectivity in central northern Australia.

Key words: South Nicholson Basin, Mount Isa, geochronology, Proterozoic basin, EFTF

INTRODUCTION

Geoscience Australia, as part of the Exploring for the Future (EFTF) program is tasked with obtaining new pre-competitive data to better understand the potential of mineral, energy and water resources undercover. A key component of the programme is the acquisition of the South Nicholson Basin deep crustal seismic reflection data, which was completed in August 2017 in collaboration with the Northern Territory Geological Survey, the Geological Survey of Queensland and AuScope (Henson et al., 2018). A geochronological investigation has been undertaken to better understand the internal stratigraphy of the area to compliment other components of EFTF including the South Nicholson Basin seismic survey (Carr et al., in press) and a regional geochemical study (Jarrett et al., 2019).

The Paleo- to Mesoproterozoic rocks of the South Nicholson Basin and western Mount Isa Orogen are of particular interest as they may correlate temporally to the Paleo- to Mesoproterozoic McArthur Basin to the northwest, and the Paleoproterozoic rocks of the Mount Isa Orogen farther east, both of which host base-metal mineralisation and rocks with hydrocarbon prospectivity. The basin evolution and stratigraphy of the South Nicholson region remains comparatively poorly understood, largely due to the undercover nature of many of the rocks and paucity of existing data.

The South Nicholson Group has been correlated with the Roper Group of the McArthur Basin (Plumb et al., 1980), which contains organic-rich facies with significant hydrocarbon potential (e.g. Revie, 2017). The timing of deposition of the South Nicholson Group has been inferred to be ca. 1500–1320 Ma, based on the age of the Roper Group of the McArthur Basin (Jackson et al., 1999; Rawlings et al., 2008; Ahmad and Munson, 2013b; Yang et al., 2018). However, this correlation remains to be confirmed, as published U-Pb age constraints from the South Nicholson Group only comprise zircon detrital dates older than ca. 1569 Ma (Jackson et al., 1999; Page et al., 2000; Carson et al., 2011; Magee et al., 2013). A substantial amount of age data exists for the older Paleoproterozoic basin units (e.g. McNamara Group) of the Mount Isa Orogen in Queensland; however, the stratigraphic relationships of these units west into the Northern Territory remain uncertain. This study uses U-Pb zircon and xenotime geochronology to better understand the stratigraphy in time and space, and assess stratigraphic correlations.

METHOD AND RESULTS

U-Pb isotopic analyses were undertaken using the SHRIMP IIe at Geoscience Australia (GA), Canberra. Prior to analysis, samples were imaged via Scanning Electron Microscope (SEM) using cathodoluminescence imagery (CL) for zircon and backscatter electron imagery (BSE) for xenotime. Analytical procedures for zircon follow those published by Compston et al., (1984), Claoué-Long et al., (1995), Nelson (1997), and Williams (1998). Xenotime was analysed in situ following analytical procedures of Cross and Williams (2018). The preferred means of determining depositional ages in sedimentary sequences are dating of interbedded tuffaceous horizons (particularly useful in Proterozoic sequences where paleontological control is absent, rare or ambiguous). Tuffs are however absent in the vast majority of the targeted units within the South Nicholson region. We have thus conducted a comprehensive program of SHRIMP detrital zircon analysis to improve the basin chronostratigraphy. Factors relevant to the interpretation of detrital zircon data are outlined in Carson (2013).

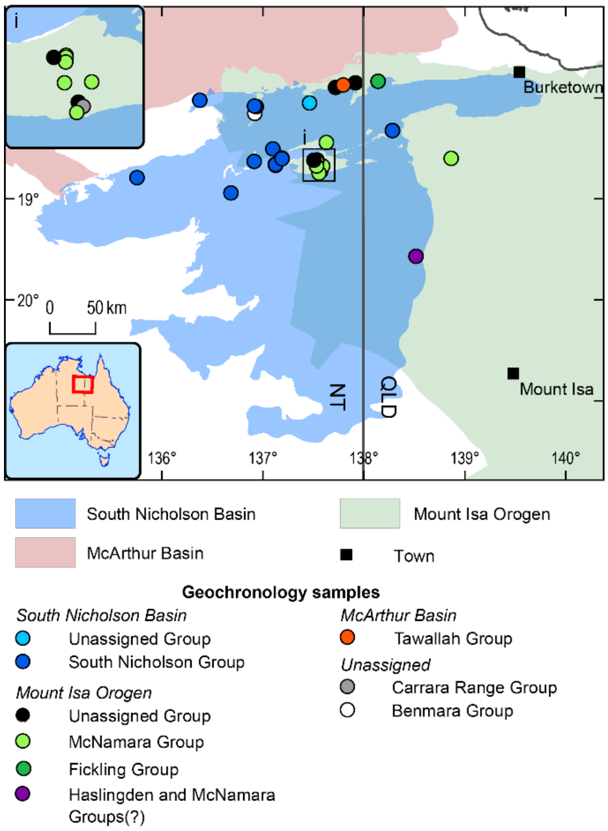

Figure 1. Regional map of the South Nicholson region, showing selected province boundaries (Raymond et al., 2018) and distribution of geochronology samples; i denotes inset diagram.

Over 40 geochronology samples across the South Nicholson region (Figure 1) have been analysed, incorporating the South Nicholson Group and underlying McNamara, Fickling, Benmara, Tawallah and Carrara Range groups (Figure 2) as well as several units whose stratigraphic affinities are unclear. Zircon U-Pb age data from units ascribed to the South Nicholson Group were obtained from the east to west South Nicholson Basin. The results yield maximum depositional ages (MDA) ranging from ca. 1660–1470 Ma. The youngest MDA at ca. 1470 Ma obtained from the Constance Sandstone of the Accident Subgroup is also the youngest MDA obtained for the broader South Nicholson Basin and is consistent with a MDA of ca. 1483 Ma from the underlying Crow Formation (Wild Cow Subgroup). Notably, zircons comprising the ca. 1483 Ma population in the Crow Formation exhibit a pristine euhedral morphology, suggesting a volcanoclastic origin. The MDA of the Crow Formation thus may closely approximate the true stratigraphic age. Xenotime U-Pb age data (overgrowths on detrital zircon) were also obtained from the Constance Sandstone, yielding a weighted mean age of ca. 1266 Ma, which is interpreted as the timing of a fluid flow event. Together, we interpret these zircon and xenotime data to bracket the deposition of the South Nicholson Basin to between ca. 1483–1470 Ma and ca. 1266 Ma, establishing a robust broad correlation with the Roper Group in the McArthur Basin.

Detrital spectra from South Nicholson Group samples typically feature dominant age peaks between ca. 1870–1760 Ma, with minor age peaks between ca. 1660–1545 Ma and ca. 2560–2470 Ma, consistent with derivation from multiple sources from across the North Australian Craton (NAC). The source of the ca. 1483 Ma magmatic zircons in the Crow Formation is less apparent, as known igneous rocks around this age are rare in Australia, but include the Yellow Waterhole Granite, Queensland (ca 1493 Ma; Page and Sun, 1998), tuffaceous components in the Mainoru Formation, Northern Territory (ca 1493 Ma; Jackson et al., 1999), Paterson Orogen, Western Australia (ca 1476, 1453 Ma; Bagas, 2004; Kirkland et al., 2013) and the Coompana Province, southern Australia (ca. 1505–1478 Ma; e.g. Wingate et al., 2015). This age is also consistent with igneous sources in Laurentia, within the Yavapai, Penokean, Grenville and Granite-Rhyolite provinces (e.g. Goodge and Vervoort, 2006; Bickford et al., 2015).

The relationship of the McNamara Group from Queensland west into the Northern Territory remains somewhat uncertain, due to stratigraphic differences and no absolute age data for the McNamara Group in the Northern Territory. New detrital geochronology on the McNamara Group in the Northern Territory have MDA that range from ca. 1790 Ma for the basal Drummond Formation to ca. 1606 Ma for the uppermost Widdallion Sandstone Member. Notably, the Drummond Formation lacks any zircons younger than ca. 1700 Ma. In contrast, the overlying Brumby Formation, Shady Bore Quartzite and Plain Creek Formation are dominated by younger ca. 1650–1635 Ma populations, more characteristic of populations commonly found in the McNamara Group in Queensland, the McArthur Group in the McArthur Basin and reflecting the widespread prevalence of ashfall tuffs of this age (e.g. Page et al., 2000). The marked provenance shift between the Drummond and Brumby formations may suggest a previously unrecognised unconformity within the McNamara Group in the South Nicholson region, changes in paleo-environment or source terrane uplift, or a combination of the above. The Drummond Formation age spectra bears remarkable resemblance with that of the underlying Gator Sandstone (Carrara Range Group) and Surprise Creek Formation (unassigned, and whose stratigraphic affinity with the type locality of the Surprise Creek Formation in Queensland remains to be demonstrated). We suggest that the Drummond Formation forms the uppermost part of the older Carrara Range Group. The Carrara Range Group together forms part of an interbedded package of siliciclastics (including the 'Surprise Creek Formation') and ca. 1725 Ma felsic volcanics (e.g. Top Rocky Rhyolite).

A number of units, previously assigned to the South Nicholson Group, or of unclear stratigraphic affinity, may be equivalent to the McNamara Group. Firstly, from the north-western South Nicholson region (Figure 1), a clastic sequence unconformably overlies the Benmara Group, comprising (in relative age order from oldest to youngest) the Bowgan Sandstone, Crow Formation (type section, Rawlings et al., 2008) and the Mittiebah Sandstone(?), as well as the unassigned Caulfield beds. The zircon detrital spectra from these units display remarkable similarity and are dominated by two major zircon populations; a ca. 1660–1640 Ma population, a typical signature of the McNamara Group, and a ca. 1870–1860 Ma peak, characteristic of NAC basement (e.g. Ahmad and Munson, 2013a). Notably, these units bear little similarity with other available South Nicholson Group detrital age spectra. We conclude these sedimentary rocks more likely represent McNamara Group, and not South Nicholson Group. We further speculate that, given their texturally immature, proximal facies (Rawlings et al., 2008), these units were derived largely from the nearby Murphy Metamorphic basement, possibly during an episode of ca. 1640 Ma uplift, equivalent to the Riversleigh

Inversion in the Mount Isa region. Underlying the above sequence, the Buddycurrawa Volcanics of the Benmara Group comprises mostly vesicular trachytic alkaline lava flows. The igneous crystallisation age of the Buddycurrawa Volcanics is unknown. It has however been previously correlated with other regional volcanic units of ca. 1725 Ma age (e.g. Top Rocky Rhyolite, Peters Creek Volcanics) or with nearby trachyte alkaline volcanics in the Coanjula diamond field, for which a single K–Ar age of ca. 1665 Ma has been obtained (Lee et al., 1991). The geochronology results, while not yielding a conclusive extrusion age, provide a *maximum* age constraint of ca. 1662 Ma, thereby eliminating any correlation with ca. 1725 Ma volcanic units.

Together, the results and interpretations presented in this study, albeit tentative at this point, necessitate a careful revision of the stratigraphy of the South Nicholson region.

CONCLUSIONS

Key conclusions from U-Pb zircon and xenotime geochronology on the South Nicholson Basin and Mount Isa Orogen are outlined below:

1. The Wild Cow and Accident subgroups of the South Nicholson Group are confirmed to be temporally equivalent to the Roper Group, McArthur Basin, with a depositional bracket of ca. 1480–1266 Ma;
2. An episode of fluid-flow through the South Nicholson Group occurred at ca. 1266 Ma;
3. Better stratigraphic control and revision of existing stratigraphic relationships within the South Nicholson region, which enable improved stratigraphic correlations with other, more overtly prospective adjacent basins, such as the McArthur Basin and the Lawn Hill Platform (QLD);
4. The renaming of some maps units will likely be required, based on the geochronological data.

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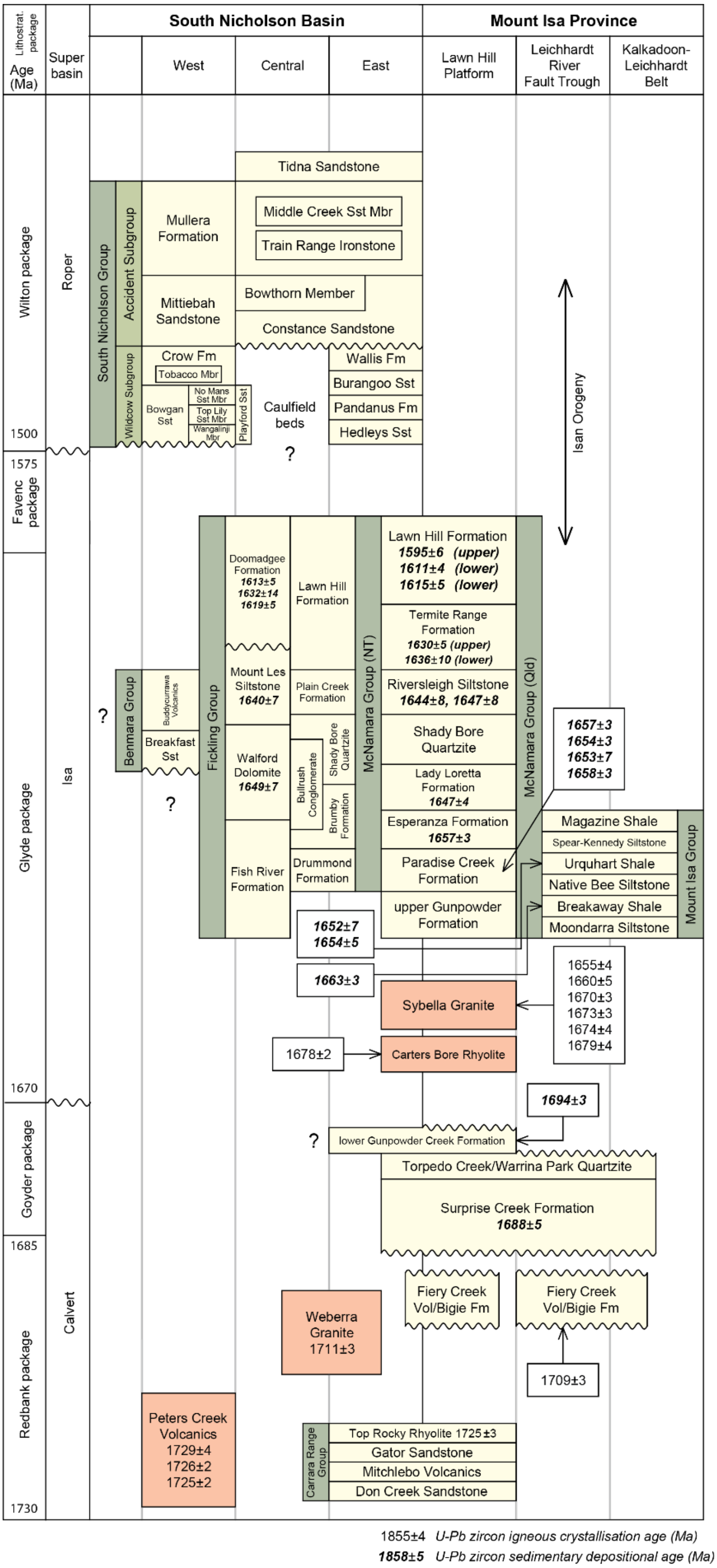

Figure 2. Existing stratigraphy of the South Nicholson Basin and western Mount Isa Orogen (after Carr et al., in press and references therein). Note this chart only includes U-Pb ages considered to be the timing of sedimentary deposition or igneous crystallisation (i.e. does not include maximum depositional ages from sedimentary units).