The Arnhem Province: New findings on the Palaeoproterozoic basement in east Arnhem Land

S. Kraus, J.A. Whelan, B.L. Reno, N. Kositcin
New NTGS mapping program in east Arnhem Land
• Arnhem Province unconformably overlain by the Palaeo- to Mesoproterozoic McArthur Basin and the Cretaceous Carpentaria Basin.

• Arnhem Province and polymetallic Pine Creek Orogen form central-northern part of the basement of the NAC.

• Connection between Arnhem Province and Pine Creek Orogen?
Project objectives

- New 1:100 000 geological mapping project under the CORE initiative.
- Focused on geology and review of the resource potential of the Palaeoproterozoic Arnhem Province.
- Enhance the knowledge on the stratigraphy of the Arnhem Province.
- Subdivide the recognised units reliably into subunits.
Discontinuous belts and patches of outcrop.

Re-definition of outcrop extension through on-the-ground mapping.

Subdivision into five main lithological units.

Bradshaw Complex likely to be discarded.

**New mapping: Preliminary results**

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- Re-definition of outcrop extension through on-the-ground mapping.
- Subdivision into five main lithological units.
- Bradshaw Complex likely to be discarded.
Grindall Formation

- Only exposed in the Blue Mud Bay area.
- Previously interpreted as stratigraphically lowest and thus oldest unit of Arnhem Province (Haines et al., 1999).
- Steeply dipping interlayered, metre- to decimetre-thick beds of fine grained sand-, silt- and mudstones.
- Total thickness thought to be in excess of 1000 m (Haines et al., 1999).
- Turbidite sequence deposited in a broad, at times deep marine basin.

![Grindall Fm.](image)
Grindall Formation on Morgan Island

- Key relationships between Grindall Fm. and intruding fa-bt-granite, possibly Bukudal Granite (Giddy Suite).
- Minimum depositional age constrained by ca 1835 Ma age of intruding fa-bt-granite.
- New SHRIMP U-Pb zircon maximum depositional age (1934 ± 47 Ma).
- Locally contact metamorphosed (Coast Range, Haines et al., 1999), but on Morgan Island unmetamorphosed.
- Upright, ENE-plunging open folds in SE Morgan Island.
- Quartz-veining is common, usually cm-thick but locally up to dm-thick.
- Regular geochemical analysis: 1 sample 43 ppb gold, several others ca 10 ppb.
Metamorphics & migmatites

- Granulite-facies metasedimentary and metaigneous migmatitic rocks (formerly part of the Bradshaw Complex).
- Elongate, NE-striking belt in northern Arnhem Province (Wonga Creek area).
- Scattered outcrops across Gove Peninsula.
- High-grade equivalents to the largely unmetamorphosed Grindall Formation?
- Two subgroups:
  (A) orthogneiss and migmatite in Wonga Creek area as far east as Cape Arnhem:
  - bt-Kfsp-pl-qtz±grt orthogneiss
  - igneous crystallisation zircon age of 1879 ± 5 Ma (protolith)
    >> oldest known intrusive of Arnhem P.
  - Main gneissic foliation overprinted by parasitic tight folds > 2 discrete events?
Metamorphics & migmatites

- Two subgroups: **(B) metasedimentary migmatite** (Melville Bay Metamorphics).

- Interlayered migmatite, quartzite, metagreywacke and metasiltstone.

- Evidence for high-T, low-P granulite-facies metamorphism (840 °C, 0.83 GPa).

- **grt-bt-pl-qtz±crd** assemblage.

- Migmatite with extensive crd-grt-bearing leucosome (e.g. Wargarpunda Point).

- Leucosome forms network of former melt veins; evidence for transport from sites of partial melting to zones of melt accumulation, up to m-scale channels.

- Compositional layering reflects original sedimentary bedding, overprinted by grain shape foliation.

- Garnet and cordierite observed as peritectic phases formed during partial melting.
Cordierite-garnet-bearing S-type granites

- A suite of garnet- and/or cordierite-bearing, locally foliated S-type leucogranites.
- Includes the Drimmie Head Granite, Bawaka granite (informal), and some unnamed intrusions, all previously mapped as undivided Bradshaw Complex (Pietsch et al., 1997).
- S-type mineralogy, ubiquitous metasedimentary xenoliths/restites similar to rocks from the Grindall Formation and the Melville Bay Metamorphics.
- Formation by \textit{in situ} partial melting of a proximal (meta-) sedimentary protolith during peak metamorphism.
  - Migmatites associated to the Melville Bay Metamorphics are at least partial source of S-type granites (field evidence e.g. at Yirrkala).
  - grt-crd-bt-Kfsp-plag-qtz assemblage.
Cordierite-garnet-bearing S-type granites

- Drimmie Head Granite crystallisation age (1862 ± 4 Ma) is consistent with metamorphic zircon growth in quartzite and migmatite of Melville Bay Metamorphics.
- Broadly granitoid composition, SiO₂ 68.6 – 75.0 wt%, alkaline and subalkaline.
- Weakly to strongly peraluminous.

- Locally preserved grain shape foliation (fsp-bt), orientation reflects only one major deformational event.
- Locally developed flow banding defined by aligned K-feldspar.
Fayalite-biotite-bearing A-type granites (Giddy Suite)

- Youngest unit of the Arnhem Province.
- Comprises the Giddy, Garrthalala, Bukudal and Dhalinybuy granites (Rawlings et al., 1997; Haines et al., 1999).
- Exposed over most of the Arnhem Province.
- Absence of xenoliths, crd and grt.
- Generally unmetamorphosed and undeformed.
- Giddy Granite has locally spaced cleavage >> upper crustal brittle deformation during exhumation?
- Fayalite is ubiquitous, diagnostic for the Giddy Suite.
Fayalite-biotite-bearing A-type granites (Giddy Suite)

• Bukudal Granite:
  - cm-sized reddish spots consisting of Fe-stained fsp usually with a fa-crystal or small mafic xenolith at the centre.
  - Also red Fe-staining along joints.

>> post-magmatic mobilisation of Fe, liberated from breakdown of fa and/or mafic xenoliths.

• Miarolitic cavities in Bukudal Granite
  - subvolcanic textures
  - megacrystic, resorbed K-fsp

>> high-level emplacement of Giddy Suite.
Fayalite-biotite-bearing A-type granites (Giddy Suite)

Subalkaline granites to transitional alkali granites, weakly to strongly peraluminous (67.3 wt% - 78.8 wt% SiO₂).

New SHRIMP U-Pb zircon dating:
- Bukudal Granite 1824 ± 5 Ma (magmatic cryst.),
- Giddy Granite 1829 ± 5 Ma (magmatic cryst.).

>> within error or only slightly younger than previously reported ages (Rawlings et al., 1997).

>> all subunits of the Giddy Suite coeval in age?
Change in metamorphic grade across Arnhem Province

- Metamorphic grade lowest in the south: unmetamorphosed Grindall Formation.
- Highest in the north: granulite-facies metasedimentary-migmatitic rocks of the Melville Bay Metamorphics.

Is Grindall Fm. unmetamorphosed equivalent of the Melville Bay Metamorphics? Two possible scenarios:
(A) higher metamorphic grade in the N result of greater burial depth and/or an elevated geotherm at 1870-1860 Ma,
(B) so far unrecognised regional-scale structure (e.g. strike-slip fault?) juxtaposes granulite-facies rocks in the N against unmetamorphosed rocks in the S.

>> apatite fission track studies along a S-N profile, p-T calculations on garnet.

- Grindall Formation may represent a potential protolith, BUT: New U-Pb detrital zircon age data show differences in provenance between Grindall Fm. and Melville Bay Metamorphics.

>> possibility of lateral variations in available detrital sources, further isotopic information required, also on xenoliths from S-type granites.
Arnhem Province: potential correlatives

1. (Meta-)sedimentary units of the Pine Creek Orogen.

2. Cosmo Supergroup?
   - maximum depositional ages younger than Arnhem Prov.,
   - has 1860 Ma detrital zircon peak, at which time Melville Bay Metamorphics underwent metamorphism.

Results of new work:

1. Nimbuwah Domain:
   Cahill Formation shares dominant age peaks with the Grindall Formation (ca 2300, 2150, 2090, 2050).

2. Cahill Formation shares ca 1910 Ma detrital zircons peak with the Melville Bay Metamorphics.
The ca 1871–1857 Ma Nimbuawah Event is characterised by:

- Felsic and intermediate magmatism, emplacement of the Nimbuawah Complex.
- High-P, moderate-T metamorphism at $\geq 9.2$ kbar and 650 °C.
- Crustal thickening associated with collisional tectonism.

(Hollis & Glass, 2012)
What we know: comparison at 1870-1860 Ma

- Different tectonic setting:
  - Arnhem extensional,
  - Nimbuwah compressional.

- Different thermal gradients:
  - Arnhem high-T, low-P
  - Nimbuwah moderate-T, high-P

>> direct juxtaposition of Arnhem Province and Nimbuwah Domain at 1870 – 1860 Ma unlikely.

- Detrital zircon patterns indicate:
  Grindall Fm., Melville Bay Metamorphics, Cahill Fm. and Nourlangie Schist share partly the same sources, but in very different proportions.

>> coeval lateral equivalents, deposited in different parts of a large sedimentary basin?
References


Thank you for your attention!