COBRA – The assessment of petroleum and mineral resource potential of the Amadeus Basin

Susanne Schmid[1,2], Peter Schaubs[1], James Austin[1], Clive Foss[1], David Gray[1], Carsten Laukamp[1], Richard Kempton[1], Julien Bourdet[1], Christine Trefry[1] and Monica leGras[1]

Introduction

The Central Oz Basins Resource Assessment (COBRA) initiative was a collaboration between CSIRO, the Northern Territory Geological Survey, the Geological Survey of Western Australia and industry partners Central Petroleum, Globe Mineral Resources and First Quantum Minerals. The project ran for 3 years from 2012 to 2015. COBRA consisted of geophysical, sedimentological, geochemical, hydrogeochemical, spectral, structural and mineralogical investigations that lead to an integrated 3D model of the Amadeus Basin.

The Amadeus Basin extends over 170 000 km^2 of the NT and WA and is part of the Neoproterozoic–Palaeozoic Centralian Superbasin. The basin contains two sedimentary packages of Neoproterozoic and Cambrian–Carboniferous age, separated by a regional unconformity and unconformably overlain by Cenozoic sedimentary cover.

The COBRA study shows that the Amadeus Basin meets all criteria for hosting base metal deposits. The newly generated 3D basin architecture reveals that the pre-Amadeus rift succession (**Figure 1**), exposed along the SW basin margin (Tjauwata Group), is several kilometres thick between magnetic basement and Amadeus Basin fill. The delineation of this succession identifies an important potential source for base metals. The interpretation also highlights numerous new anticlines and synclines within the basin (**Figure 2**) that are fundamental for trapping

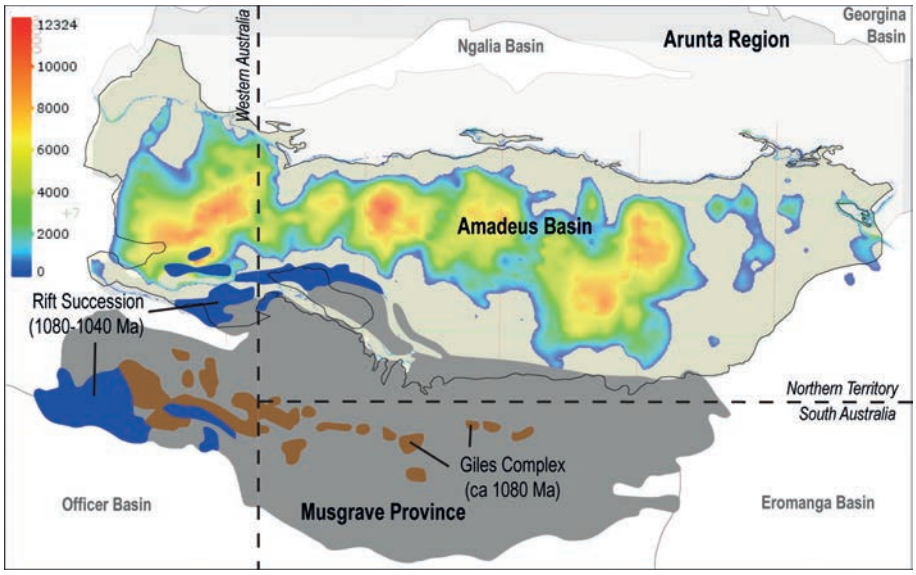

Figure 1. Distribution of pre-Amadeus Basin rift phase successions (solid blue) throughout the Musgrave Province including the new interpreted Amadeus Basin extent (modified after Close *et al* 2003, Camacho *et al* 2015) and newly interpreted rift succession between metamorphic basement and Amadeus Basin succession (base Heavitree Quartzite) modelled from gravity and magnetic data. Scale is thickness in metres.

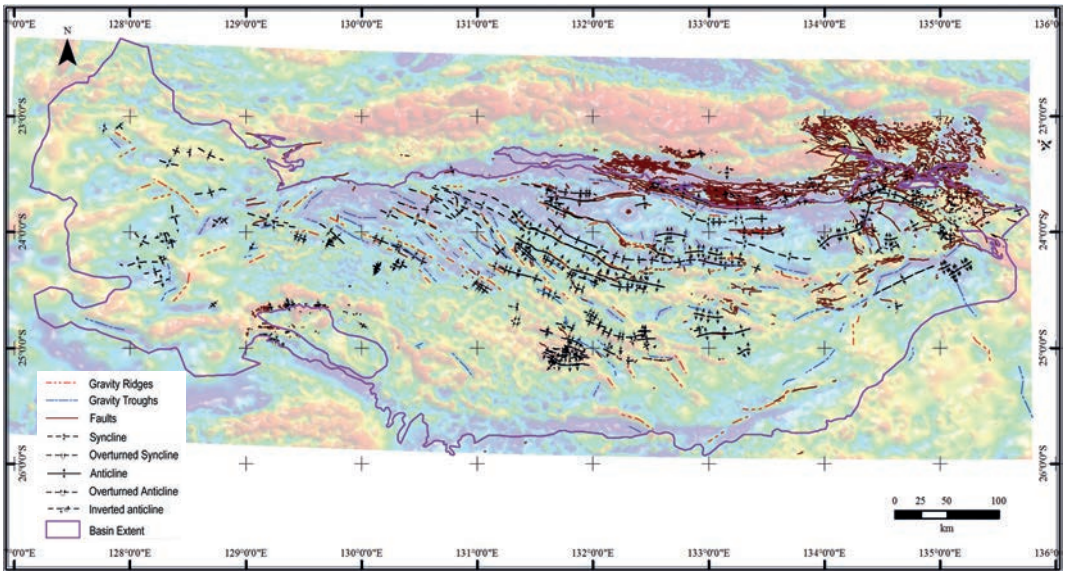

Figure 2. Amadeus Basin map showing structures interpreted from a combination of magnetic and gravity data. Background image is first vertical derivative gravity image.

[1] CSIRO Mineral Resources Flagship, 26 Dick Perry Avenue, Kensington WA 6151, Australia
[2] Email: susanne.schmid@csiro.au

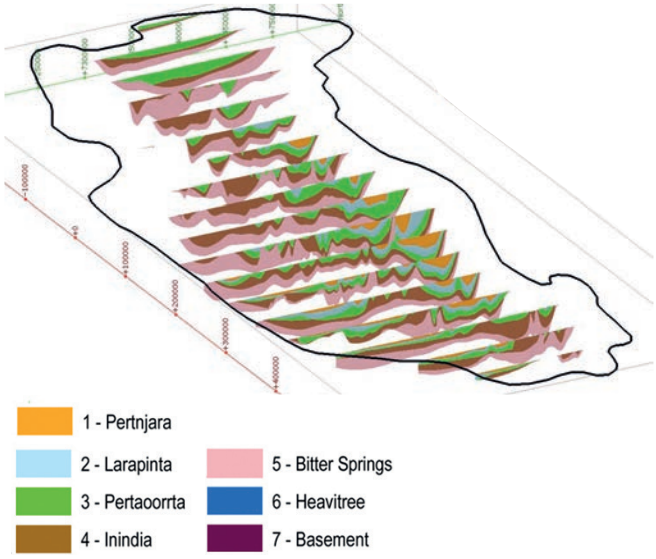

Figure 3. 3D model view towards NW showing modelled package between Bitter Springs and Pertnjara packages (5x vertical exaggeration).

hydrocarbons or metal-bearing fluids. 3D modelling (**Figures 3**, **4**) of the sedimentary succession shows that the southern part of the basin was uplifted, whereas the northern part deepened during the Alice Springs Orogeny, creating a major structural divide that is expressed as the 'Central Ridge'. The reactivation of structures and associated movement of thick salt intervals within the Neoproterozoic Gillen Formation (and middle Cambrian Chandler Formation) led to the basin-wide circulation of highly saline brines, as reflected in groundwater data (**Figure 5**). Such saline brines are efficient carriers of base metals. The high salinity in combination with diagenetic temperatures of ca 100°C in younger units and up to 170°C in older units gives an ideal temperature range for potential base metal mineralisation and hydrocarbon maturation. Hydrothermal fracturing occurred at temperatures up to 270°C along the basin margin further increasing the potential for mineralisation.

The redox potential of the sedimentary succession is favourable for hosting Mississippi Valley-type (MVT), sedimentary exhalative-type (SEDEX), redbed Cu-type (Kupferschiefer) or sedimentary base metals deposits (summarised in **Table 1**). The depositional environment and geochemical composition of the Arumbera Sandstone and Johnnys Creek Formation favours these units as the most likely to be a source of redbed Cu-style metals (**Figure 4**). The most likely stratigraphic units for hosting MVT deposits are dolostone-dominated intervals in the Cambrian succession. There is also potential for MVT mineralisation related to hydrocarbon accumulation. Reduced marine shales that may host SEDEX deposits are rare, with the most likely host being the Pertatataka Formation. The Arumbera Sandstone, Cambrian dolostones and Pertatataka Formation can be explored by using a combination of shallow magnetics and ASTER data.

Overall, the Amadeus Basin is regarded as highly prospective for hosting potential economic base metal deposits, as well as hydrocarbon accumulations.

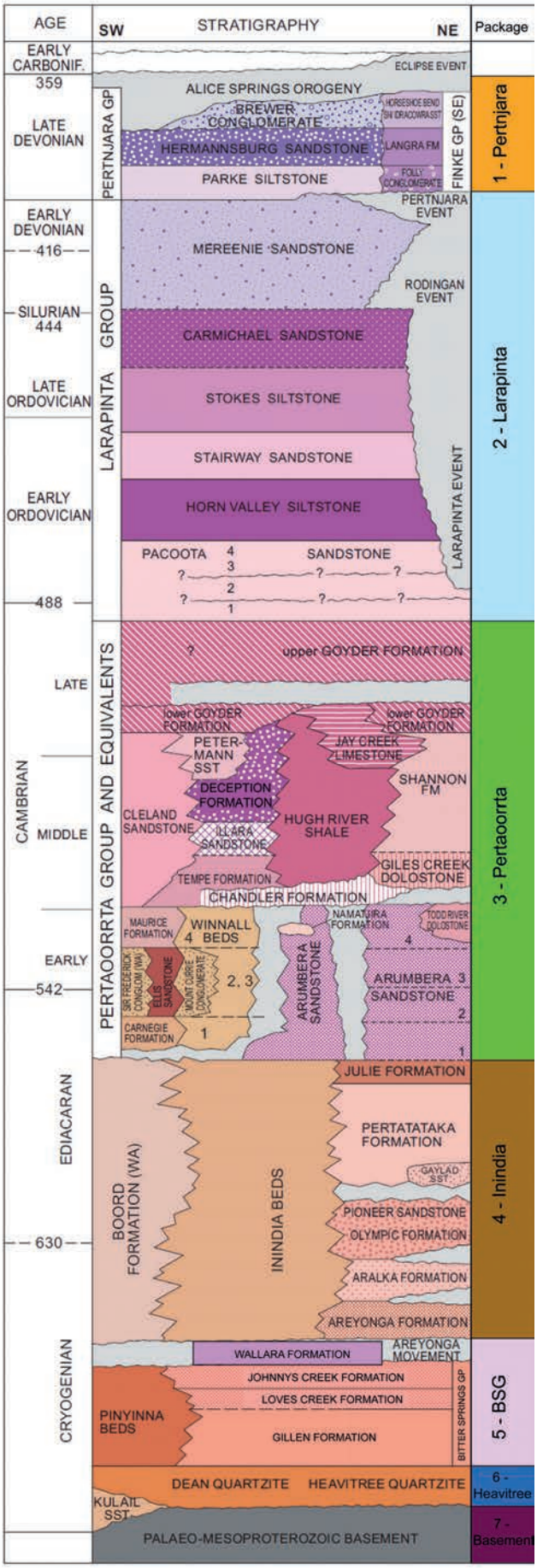

Figure 4. Stratigraphic column for Amadeus Basin based on Edgoose (2013), updated to include revised Bitter Springs Group nomenclature by Normington *et al* (2015) and packages used in this study.

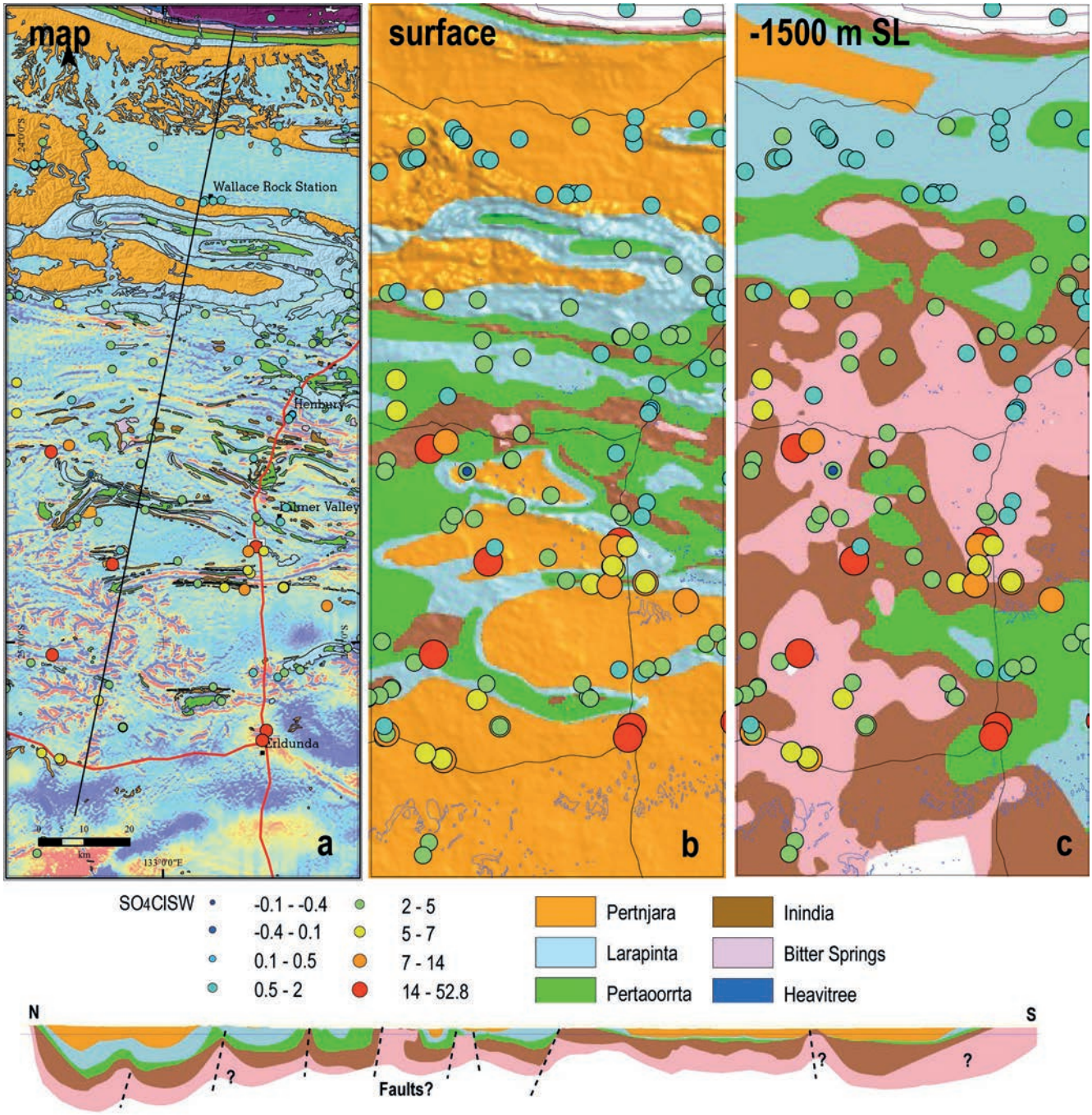

Figure 5. Map and cross-section showing elevated SO_4 over Cl (gypsum indicator) in groundwater and spatial link to underlying salt units potentially carried into shallow aquifers along structures. (**a**) current outcrop map, (**b**) interpreted simplified geological map without Cenozoic sediments, and (**c**) interpreted simplified map at 1500 m below sea level, showing shallow groundwater enriched in gypsum hydrologically linked to underlying salt units.

Table 1. Amadeus Basin stratigraphic units with potential for sourcing or hosting base metal mineralisation.

Stratigraphic Unit	Package name	Current Redox State	Red-bed Cu	SEDEX	MVT	Sedi-mentary
Horseshoe Bend Shale	Pertnjara	oxidised	x			x
Brewer Conglomerate	Pertnjara	oxidised	x			
Stokes Siltstone	Larapinta	oxidised & reduced				x
Horn Valley Siltstone	Larapinta	reduced		x		x
Pacoota Sandstone	Larapinta	reduced & oxidised				x
Goyder Formation	Pertaoorrta	reduced			x	x
Jay Creek Limestone	Pertaoorrta	reduced			x	
Shannon Formation	Pertaoorrta	reduced & oxidised			x	
Hugh River Shale	Pertaoorrta	oxidised	x			x
Deception Formation	Pertaoorrta	oxidised	(x)			
Giles Creek Dolostone	Pertaoorrta	oxidised & reduced			x	
Illara Sandstone	Pertaoorrta	oxidised	(x)			
Tempe Formation	Pertaoorrta	oxidised & reduced	x			x
Chandler Formation	Pertaoorrta	oxidised	x			x
Todd River Dolostone	Pertaoorrta	oxidised			x	
Arumbera Sandstone	Pertaoorrta	oxidised	x			
Julie Formation	Inindia	reduced			x	x
Pertatataka Formation	Inindia	reduced		x		x
Olympic Formation	Inindia	reduced & oxidised	(x)			x
Aralka Formation	Inindia	reduced		x		x
Wallara Formation	Bitter Springs	reduced		x	x	
Johnnys Creek Formation	Bitter Springs	oxidised	x		x	x
Loves Creek Formation	Bitter Springs	reduced & oxidised			x	
Gillen Formation	Bitter Springs	oxidised			x	

References

Camacho A, Armstrong R, Davis DW and Bekker A, 2015. Early history of the Amadeus Basin: Implications for the existence and geometry of the Centralia Superbasin. *Precambrian Research* 259, 232–242.

Close DF, Edgoose CJ and Scrimgeour IR, 2003. *Hull and Bloods Range Special, Northern Territory. 1:100 000 geological map series explanatory notes.* Northern Territory Geological Survey, Darwin.

Edgoose C, 2013. Chapter 23: Amadeus Basin: in Ahmad M and Munson TJ (compilers). *'Geology and mineral resources of the Northern Territory'. Northern Territory Geological Survey Special Publication* 5.

Normington VJ, Donnellan N and Edgoose C, 2015. Neoproterozoic evolution of the Amadeus Basin: evidence from sediment provenance and mafic magmatism: in *'Annual Geoscience Exploration Seminar (AGES) 2015. Record of abstracts'. Northern Territory Geological Survey, Record* 2015-002, 73–78.