

Basement studies in basin analysis: new insights into the evolution of the Lawn Hill Platform

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Why are basement studies important to a basin analysis? How can an understanding of the basement template assist stratigraphic analysis? How do we define basement?

We address these questions through an example of an integrated basement analysis that provides a new interpretation of the basement template underlying the northern Lawn Hill Platform (NLHP)

between the outcropping basement Murphy Inlier and the world-class Century Zn deposit. The interpretation requires a revision of traditional correlations of igneous units from the

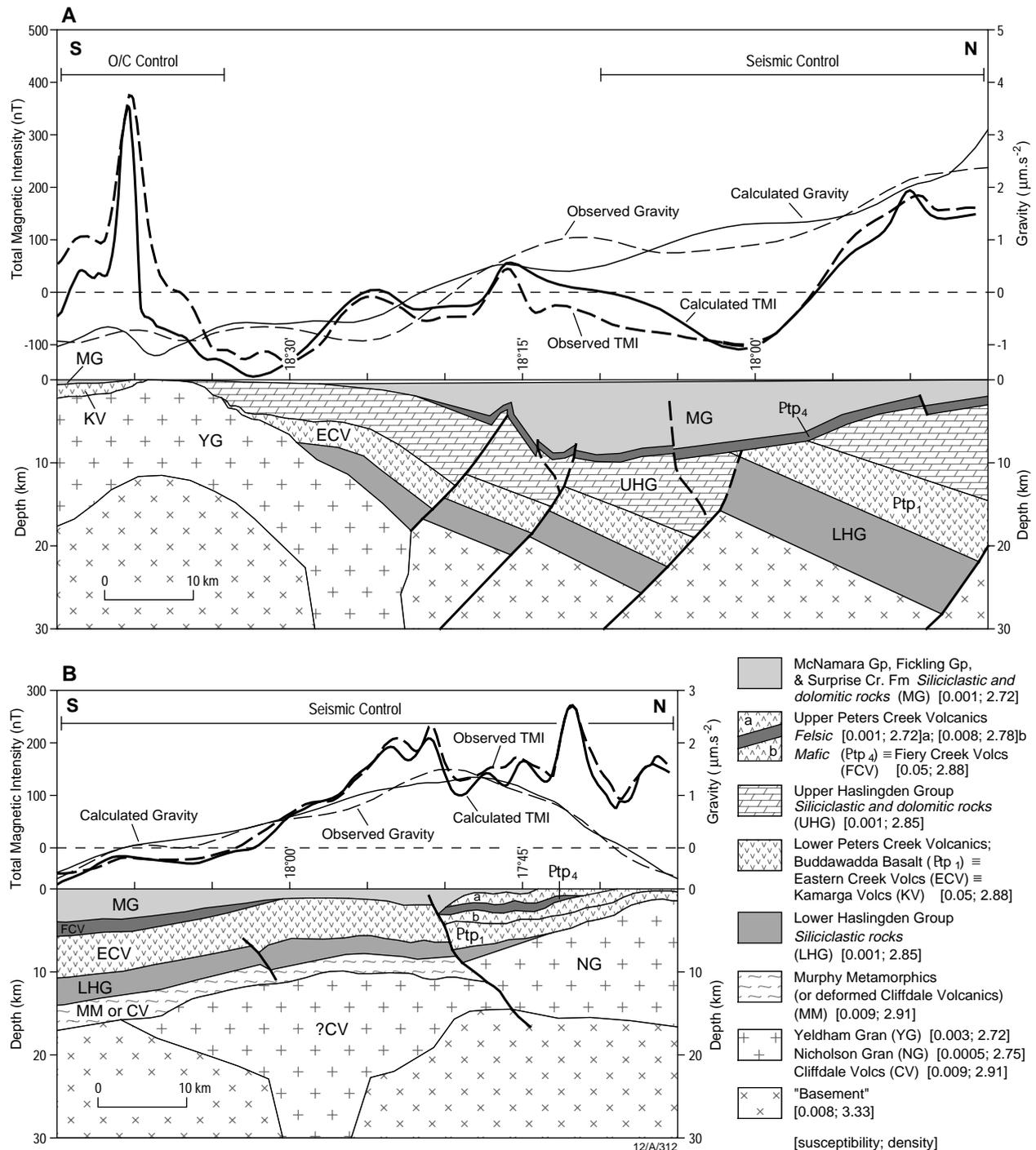


Fig. 29. Geological models derived from both seismic data and outcrop geology are forward-modelled and compared with observed magnetic and gravity profile data. The upper (eastern) profile extends from latitude 17°45'–18°45' along longitude 139°00'. The lower (western) profile extends from latitude 17°35'–18°15' along longitude 138°30'. Note the distinctly discordant relationship between the older and younger igneous units in the eastern profile and the broadly conformable relationship between them in the western profile. Correlation of the various igneous units as shown is consistent with geochronological, geochemical, palaeomagnetic, and recently obtained outcrop relationship data.

period ~1760–1710 Ma. It also provides new insights into the evolution of the overlying Palaeoproterozoic basin phases and models of mineralisation within them.

Sedimentary basins are rarely underlain by homogeneous crystalline igneous basement. Instead, basement rocks are commonly heterogeneous and a product of a series of geological processes, including previous basin formation. The two geological models in Figure 29 suggest that basement underlying the NLHP is no exception. A rare opportunity to constrain basement interpretations exists in the NLHP because all the primary datasets normally used in basement analysis are available: outcrop geological, geopotential, geochronological, geochemical, and palaeomagnetic data. Additionally, and importantly, limited reflection seismic data from petroleum exploration which directly image subsurface structures are also available for the southern flank of the Murphy Inlier (Fig. 31). The basement interpretation draws on regional datasets in AGSO's national databases combined with additional data collected during the 'North Australian basins resource evaluation' (NABRE) project.

Identifying basement

Immediately south of the Murphy Inlier, the seismic data image a southward-thickening sedimentary megawedge (MG; Fig. 29) above a sharp acoustic basement. The megawedge is divided into nine supersequences (not shown in Fig. 29) on the basis of internal characteristics representing distinct basin phases (Scott & Bradshaw 1997: abstract in AGSO Record 1997/12). The packages within the megawedge are correlated with the McNamara Group and the Surprise Creek Formation in the south and with the Fickling Group in the north (Bradshaw et al. 1996: abstract in Baker et al. (Editors), MIC '96: New developments in metallogenic research, the McArthur–Mt Isa–Cloncurry minerals province, Townsville, April 22–23, 20–23; Bradshaw & Scott 1997: abstract in AGSO Record 1997/12). This interpretation differs substantially from the previous correlation of the lower third of the megawedge with the Peters Creek Volcanics (PCV; McConachie et al. 1993: APEA Journal, 33, 237–257). The

acoustic basement reflection is attributed to the top of the Fiery Creek Volcanics (FCV), which underlie the McNamara Group and Surprise Creek Formation in the south. However, outcrop ties require the reflectivity be attributed to the PCV at the northern limits of most western seismic lines. Correlation of these two igneous assemblages is enigmatic, as the isotopic ages of their felsic portions differ by 15 m.y. (Fig. 30). A reconciliation is proposed in the geological models in Figure 29.

What is the basement under the megawedge? How does the igneous record in the north correlate with that in the south? What is the structural template of the basement? Did the basement template influence subsequent basin evolution?

Depth contours on the base of the megawedge calculated from the seismic data follow contours of the magnetic image, but do not deepen sufficiently to account for the large magnetic low that extends southeast from latitude 18°00'S, longitude 139°00'E (Fig. 31). Thus, the assumption of a magnetic layer at the depths of the southward-deepening acoustic basement does not successfully reproduce the observed geopotential data.

A series of magnetic and gravity profile data were extracted from the gridded and reprocessed image data across and extending south of the Murphy Inlier (e.g., Leven et al. 1997: abstract in AGSO Record 1997/12; Scott et al. 1997: abstract in AGSO Record 1997/12). Various models were constructed to investigate the relationship between igneous units and associated basin rocks away from the Murphy Inlier. Two meridional profiles illustrate the most significant results of this study (Fig. 29). The geometries (i.e., depth and dip) of the geological models are constrained by interpretations of relevant seismic data (Scott & Bradshaw 1997: op. cit.). The observed data along the profiles require different magnetic body geometry below a volcanic unit at acoustic basement depths.

Local coherent reflections below the interpreted base of the megawedge provide some evidence of the geometry of heterogeneities within the basement. Geological models derived from Scott & Bradshaw's (1997: op. cit.) interpretation

of the seismic data are forward-modelled to reproduce observed gravity and magnetic data (Fig. 29). The best-fit geological models suggest that there were two igneous events separated by a major extensional event. The extension produced a marked angular unconformity between the two igneous packages in the east, while maintaining a broadly conformable relationship in the west.

The modelling suggests that acoustic basement in the east is the top of the thinner, younger mafic igneous unit, and that the older unit is discordant. However, in the west, the units are broadly concordant, and acoustic basement may alternate between them along the profile. The profile models require a polarity switch in the extensional basement system (Fig. 31). The extension is interpreted to have been accommodated by west-northwesterly to northwesterly normal faults and north-northeasterly to northeasterly transverse faults.

Basement igneous correlations

The seven members of the PCV (Ptp₁₋₇; Fig. 30) traditionally have been assumed to be a broadly coeval, sequential bimodal system, including minor sedimentary packages, but recent fieldwork has revised their outcrop relationships. A major unconformity was identified and traced laterally along the southern flank of the Murphy Inlier between the basal mafic unit (Ptp₁) and the rest of the bimodal pile. The pile above the unconformity contains both intrusive and extrusive bimodal igneous rocks and thin sedimentary units that are not necessarily sequential in age (e.g., Ptp₂ is intrusive and younger than Ptp₃; Fig. 30). Ptp₁ is intensely altered and is distinct from fresher dolerite (Ptp_{ii}) that intrudes it. Palaeomagnetic and geochemical data are reconciled by this new outcrop information (e.g., the pole from Ptp_{ii} is younger than the pole determined for the Lochness Formation, and the geochemical affinity of Ptp_{ii} is with igneous units younger than Ptp₁). Definitive stratigraphic correlation of Ptp₃ with the lower Wollogorang Formation to the north has been made on the basis of a distinctive suite of sedimentary facies including stromatolites. The lower Wollogorang Formation has been dated

at ca 1730 Ma (Page 1997: abstract in AGSO Record 1997/12).

In the southern Mount Isa Inlier (Blake 1987: BMR/AGSO Bulletin 225; Stewart & Blake 1992: AGSO Bulletin 243), the Haslingden Group contains the Eastern Creek Volcanics (ECV) and several kilometres of overlying siliciclastic and minor carbonate sedimentary rocks. The ECV constitute a 6–8-km package of continental flood basalts without any known associated felsic rocks (Bain et al. 1992: in Stewart & Blake op. cit.). Overlying the top of the Haslingden Group (the Lochness Formation), the Quilalar Formation is a quartzite and carbonate unit with thin mafic units in both upper and lower stratigraphic positions.

The type section of the FCV is stratigraphically above both the ECV and Quilalar Formation locally. At some locations, the FCV and the underlying siliciclastic Bigie Formation directly overlie the Lochness Formation with a pronounced angular unconformity. The mapped FCV is generally poorly developed in areas where the Quilalar Formation is preserved. However, in those areas that were visited during the fieldwork a thin mafic unit in the upper part of the mapped Quilalar Formation is frequently underlain by a conglomeratic lithic sandstone that is sedimentologically similar to the Bigie Formation.

Recent field investigations and the combined data summarised in Figure 30 suggest that the PCV pile contains representatives of both regionally recognised mafic igneous events that were initiated at ~1750 Ma (Ptp₁ = ECV) and ~1730 Ma (Ptp_{1i}, Ptp₄, Ptp₆ = FCV ± Quilalar Formation mafic rocks). Intrusive (and extrusive) felsic igneous activity associated with the younger event continued sporadically for at least 20 m.y. (ca 1729–1709 Ma), apparently ceasing earlier in the north than in the south. The thick basin sediments of the upper Haslingden Group that separate the two igneous events in southern outcrops were probably not deposited in the northwest, or were subsequently eroded.

Basement influences on basin development

Regional extension at ca 1730 Ma produced opposing-polarity half-graben in the basement of the NLHP. The resulting basement template had an enduring influence on subsequent basin evolution. Scott & Bradshaw (1997: op. cit.) have interpreted three major tectonic events which affected depositional geometries of the basin phases within the megawedge:

- local, structurally controlled deeps of the extensional to transtensional ca 1640-Ma event developed adjacent to north-northeasterly trending ca 1730-Ma transverse structures;
- likewise, bends in ca 1595-Ma west-northwesterly trending wrench structures localised over older structures produced both negative and positive flower structures; and
- finally, late-stage (<1580 Ma) conjugate joints, probably associated with the initial stages of the Isan Orogeny, are focused and more densely spaced over the earlier structures.

These late stage joints have been postulated to be the primary conduits for mineralising fluids responsible for the Century Zn deposit (Broadbent 1996: abstract in Baker et al. (Editors) op. cit.).

NORTHERN Megawedge		Extrusive	Intrusive	Felsic	Mafic	Sediment	Geochem	Paleomag	Geochron (Ma)	SOUTHERN Megawedge
Peters Creek Volcanics (PCV)		X	X	X			G3		1709±3	FCV
	Ptp ₇	X		X			G3	P2b	1724±2	FCV
	Ptp ₆	X	X		X	X	G2	P2b		
		X	X		X	X	G2	P2c		FCV
	Ptp ₅		X	X			G3	P2b		
	Ptp ₄	X			X					Quilalar Fm
		?X	?X		X	X				
	Ptp ₃					X			~1730±4	Lochness Fm
	Ptp ₂		X	X			G3		1726±2 1729±4	
	Ptp _{1i}		X		X		G2	P2a		ECV
uncon					X		P1			
Ptp ₁	X			X		G1	P(op)		ECV	
	X			X		G1				

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Fig. 30. Comparison of historical and recent NABRE geochronological, geochemical, palaeomagnetic, and geological data for the igneous associations from the north and south outcrop belts. The basement interpretation of the NLHP requires a revision of traditional correlations between the two belts. Geochemical data are grouped (G1–G3) by compositional affinities (D.E. Mackenzie, AGSO, unpublished report). Paleomagnetic poles are labelled with a relative age (1>2, a>b>c) as determined by their positions on the apparent polar-wander path (Idnurm et al. 1995: Precambrian Research, 72, 1–41; Idnurm 1997: abstract in AGSO Record 1997/12; M. Idnurm, AGSO, unpublished data); P(op) = overprint, no primary pole is available; the P2c pole of the FCV appears to be younger than the Ptp₅₋₇ P2b pole; the sample was obtained from a section where no Quilalar Formation or felsic FCV are preserved. Geochronological data are obtained from U–Pb SHRIMP analysis of samples from the indicated units, except for Ptp₃, which is estimated from ages obtained from correlatives (see text); ages are from Page (1988: Precambrian Research, 40/41, 1–19), Page (1997: abstract in AGSO Record 1997/12), Page & Sweet (in press: Australian Journal of Earth Sciences), and R.W. Page (AGSO, unpublished data); the 1709-Ma date for the FCV was obtained from a unit whose map relationships suggest it is a very late-stage intrusion. uncon = unconformity established by recent fieldwork. X = major component or mode of emplacement; x = minor component or mode of emplacement.

Conclusion

Understanding the basement template has significant impact on how we model subsequent basin evolution and fluid flow histories. Importantly, geometries that produce perfect fits to geopotential data are not adequate to help constrain models because they can produce implausible geological cross-sections. A multidisciplinary integration of all data to produce realistic geological models of the basement is required. Radically different fluid flow

patterns, aquifer geometries, and burial histories of potential metalliferous source rocks are predicted by the opposing-polarity half-graben in the basement of the NLHP. Similarly, the structural interconnectivity of any plumbing system and tapping of deep fluids cannot be fully modelled without an understanding of the basement template.

Basement under the NLHP is not homogeneous. It is a complex assemblage of a variety of rock types of different ages and structural heterogeneities. Understanding the nature of the influence of the underlying basement template in the NLHP has contributed to the identification of a major base-metal prospect in Century host-rock equivalents (Bradshaw et al. 1998: AGSO Record 1998/4).

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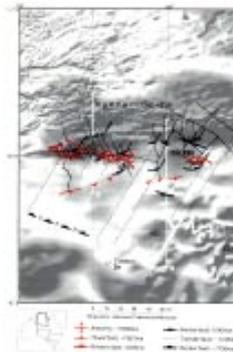


Fig. 31. Simplified fault map of the northern Lawn Hill Platform (NLHP) underlain by greyscale TMI (total magnetic intensity, reduced to the pole) data, and showing a plan view of the spatial relationships of various deformation events. A broad north-northeasterly trending zone in the basement system (~1730 Ma) extends across the NLHP and appears to transfer extension from southward-dipping bounding faults in the northeast to northward-dipping bounding faults in the southeast. The world-class Century Zn deposit is positioned at the southern extent of the polarity-reversing structure. The basement system appears to influence the geometry and distribution of later deformation events (at 1640 and 1595 Ma). A and B are the locations of geological models presented in Figure 29. The locations of seismic profiles on the southern flank of the Murphy Inlier are shown as solid black lines. The broad ~east-west long-wavelength magnetic anomaly of the Murphy Inlier extends across the entire study area, beyond the limited outcrop belt at the northwest limit of the seismic grid. The high-frequency magnetic signature in the southeast corresponds to outcropping Eastern Creek Volcanics (ECV). The Kamarga Dome (KD) is cored by the ancient Yeldham Granite (see profile A, Fig. 29). The small inset shows the locations of the NABRE project area and NLHP.