A comparison of Ordovician and Devonian magmatism in the eastern Lachlan Fold Belt: re-evaluating exploration targets

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The importance of the role of Ordovician mafic to intermediate magmatism in the metallogenesis of the eastern Lachlan Fold Belt (LFB) has been increasingly recognised in the past decade. Ordovician igneous rocks host large gold and copper deposits of porphyry–epithermal style (e.g., North Parkes, Cadia, Peak Hill) and structurally controlled vein style (e.g., Sofala area), and are probable sources of metals in many younger deposits.

A commonly strong magnetic signature, 'shoshonitic' geochemistry, high platinum group element (PGE) concentrations, and strongly positive εNd isotopic signature have all been used in the past to characterise Ordovician magmatism (e.g., Wyborn 1988: BMR Research Newsletter, 8, 13–14; Wyborn 1992: Tectonophysics, 214, 177–192; Wyborn & Sun 1993: AGSO Research Newsletter, 19, 13–14). Recent sampling in the Dubbo and Forbes 1:250 000 Sheet areas (by AGSO and the NSW Department of Mineral Resources in association for the National Geoscience Mapping Accord, NGMA) has emphasised that characteristics of some Devonian volcanics, including possible source material, are remarkably similar to the Ordovician. As a consequence, the exploration potential of the Devonian should not be underestimated.

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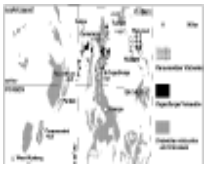


Fig. 8. Sample localities for recent Nd-isotope studies of igneous rocks in the LFB NGMA mapping area, and their εNd values. The distribution of volcanic units is interpreted beneath cover rocks. For the locations of samples analysed for εNd, see Wyborn & Sun (1993: op. cit.).

Nd-isotope systematics for Ordovician magmatic rocks

Ordovician volcanics and intrusives recently analysed for εNd (Fig. 8) include three samples from the Burranah Formation near Mudgee, two from the Tucklan Formation near Gulgong, and one monzonite from an intrusive complex in the Oakdale Formation at Comobella. All these analyses except one fall within or very close to the range of Ordovician igneous rocks (+5.7 to +8.0) defined by Wyborn & Sun (1993: op. cit.). The exception (+3.0) is from a hornblende basalt of the Tucklan Formation; though low, this value is still significantly higher than values obtained from Siluro-Devonian I- and S-type magmatic rocks in the LFB (0 to –10). This and another sample (from Gidginbung, south of West Wyalong; +4.2; Wyborn & Sun 1993: op. cit.) suggest that the lower limit of εNd values for Ordovician magmatism could be extended to +3.0.

The Cuga Burga Volcanics

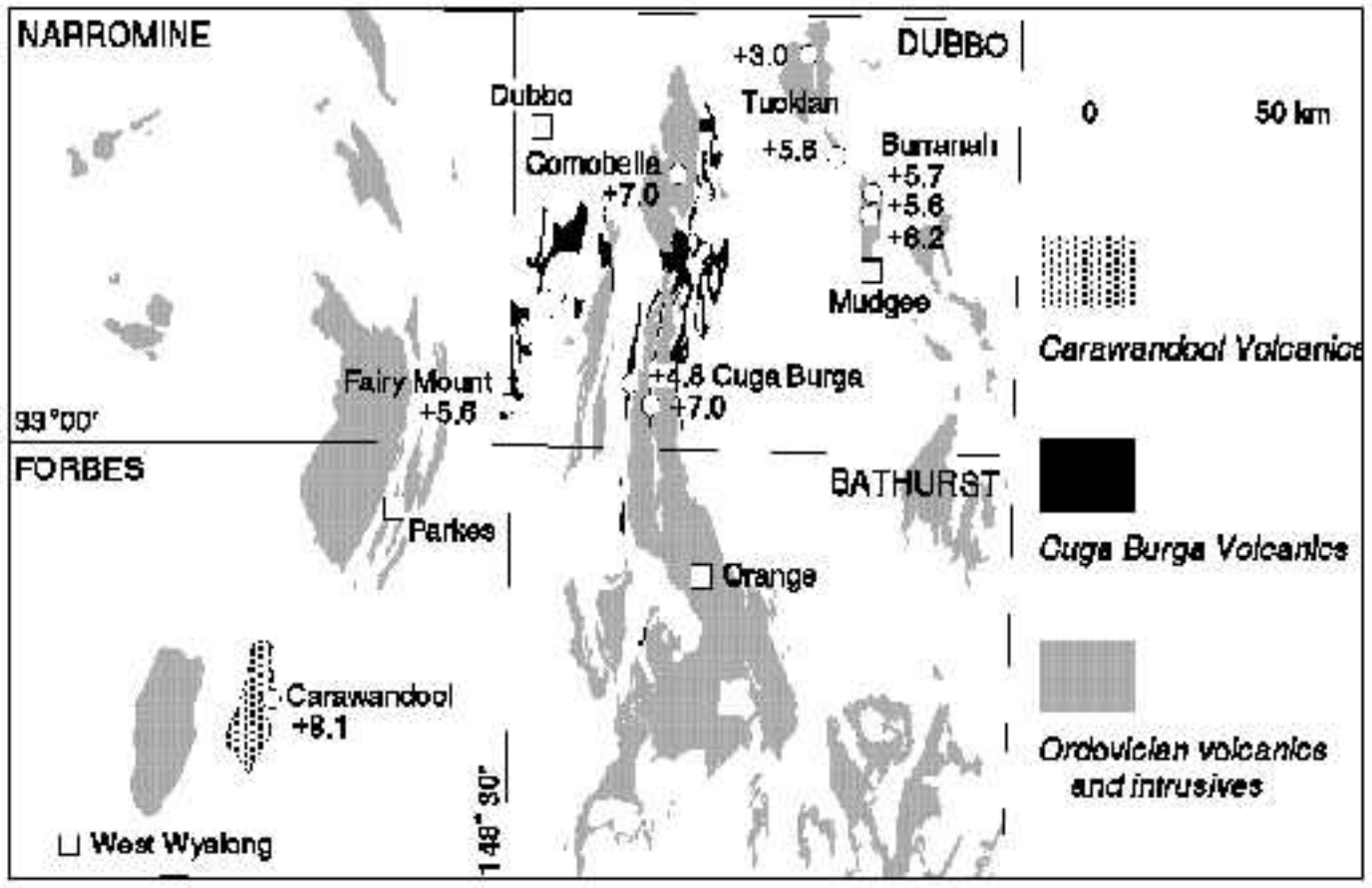
The Lower Devonian Cuga Burga Volcanics are intermediate to mafic volcanics which crop out mainly in the Dubbo 1:250 000 Sheet area in two discontinuous belts (Fig. 1). The eastern belt, located along the Molong High, is structurally complex, but provides stratigraphic control for the age of the volcanics. The western belt occurs around the western and northern margins of the Lower Devonian Yeoval granite complex. Included in this belt are the mafic volcanics hosting the Mount Aubrey gold deposit. Unlike the Middle Devonian A-type Dulladerry Volcanics, to which they were previously assigned (Lewis 1991: Minfo, 31, 6–7), these mafic volcanics do not exhibit A-type geochemical characteristics. Although stratigraphic control is lacking in the western belt, the volcanics appear to be comagmatic with more mafic phases of the Yeoval complex, which intrudes them (D. Wyborn, Australian National University, ANU, personal communication 1998).

Three samples of the Cuga Burga Volcanics were analysed for εNd (Fig. 8) — two from outcrops along the Molong High north of Orange and another (labelled Fairy Mount) on the eastern margin of the Narromine 1:250 000 Sheet area. The εNd values (+4.8 to +7.0) are within the range of Ordovician igneous rocks discussed earlier, and suggest that magmatism with a mantle-derived source was active during the early Devonian. The high εNd values may reflect a direct mantle source similar to the Ordovician magmatism (Wyborn 1992: op. cit.). Alternatively, mantle-like εNd values may be preserved during remelting of mantle-derived gabbroic material underplated to the lithosphere during Ordovician magmatism (Wyborn et al. 1987: Australian Journal of Earth Sciences, 34, 21–43).

Nd-isotope analyses of the Yeoval granite complex combined with Pb-isotope analyses may shed more light on the ability of the Nd-isotope method to indicate a primary mantle source. The Pb-isotope composition of Ordovician igneous rocks is similar to that of depleted mantle (Carr et al. 1995: Economic Geology, 1467–1505; Sun & Wyborn 1994: Geological Society of Australia, Abstracts 37, 421). Magmas generated from a mixed source of Ordovician igneous rocks and a crustal component (such as LFB granites) have Pb-isotope compositions between depleted mantle and crustal Pb represented by the growth curve of LFB VMS deposits.

The Cuga Burga and Ordovician volcanics also have similar major- and trace-element geochemistry. Spidergrams of basaltic to andesitic rocks from the two units show a remarkable overlap (Fig. 9): both are generally calc-alkaline in character; they have low levels of the high-field-strength elements (HFSE) Ti, Nb, Zr, and Y, and moderately high levels of the large-ion-lithophile (LIL) elements Ba, Sr, and K. Figure 10 emphasises the similar TiO_2 contents of Cuga Burga and Ordovician basalts and andesites; TiO_2 levels below 1% have been considered in the past as virtually diagnostic of Ordovician mafic volcanics. A small group of Cuga Burga samples with considerably higher TiO_2 (1.5–2.5%) and other HFSE resembles other post-Ordovician intraplate volcanics in the eastern LFB. Most of these samples come from a thin discontinuous belt of volcanics between Nurea and Three Rivers in the Wellington 1:100 000 Sheet area. This group of Cuga Burga Volcanics has a different mantle source and/or petrographic origin.

Further similarities between Cuga Burga and Ordovician magmatic rocks are seen in the levels of Pt and Pd (Fig. 11). PGEs are typically more concentrated in Ordovician volcanics than similarly fractionated younger volcanics with similar silica contents (Wyborn 1990: BMR Research Newsletter, 13, 8). The similar PGE range in the Cuga Burga Volcanics suggests that similar magmatic processes, including sulphur-undersaturated


NARROMINE
DUBBO
+3.0
Dubbo
Tucklan
0
50 km
Comobella
+7.0
+5.8
Burranah
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+6.2
Mudgee
Carawandool Volcanics
Fairy Mount
+5.6
+4.6 Cuga Burga
+7.0
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FORBES
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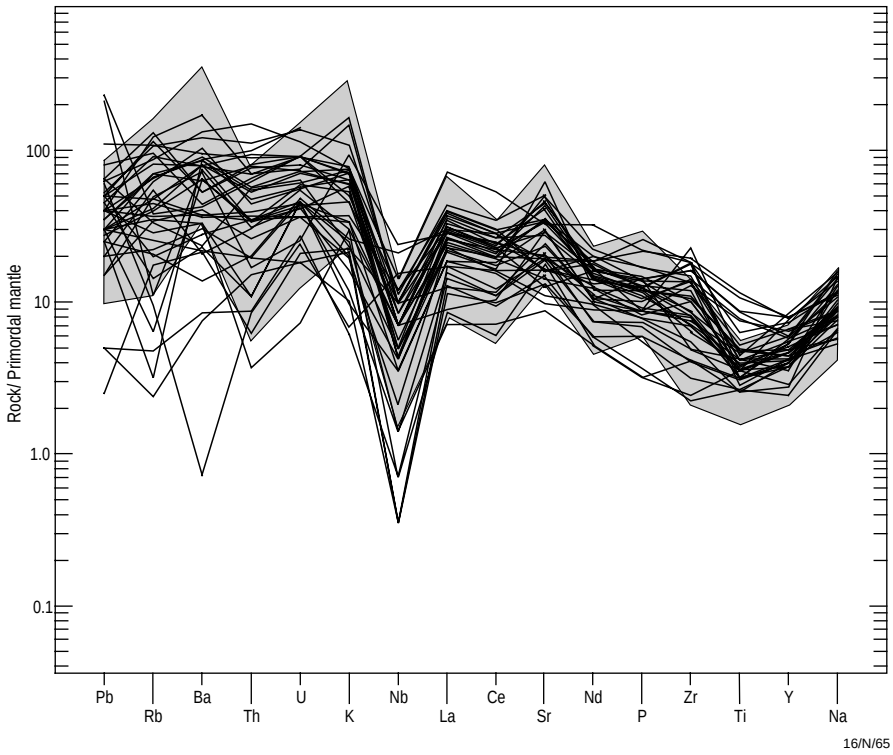

Fig. 9. Spidergram plot comparing basalts and andesites of the Lower Devonian Cuga Burga Volcanics with Ordovician igneous rocks of similar SiO_2 content (shaded area).

fractionation (Wyborn 1996: Minfo, 50, 4–6; McInnes 1997: Geological Society of Australia, Abstracts, 44, 49), also occurred in the Early Devonian.

The Carawandool Volcanics

The Carawandool Volcanics (incorporated as part of the Lower Devonian Milpose Volcanics by Bowman 1976: Forbes 1:250 000 metallogenic map, Geological Survey of New South Wales) form a broad syncline about 60 km southwest of Parkes (Fig. 8). They are primarily felsic volcanics with lesser basalts and andesitic lavas and breccias. NGMA mapping in 1997, and zircon U–Pb dating of the volcanics, have indicated an Early Devonian age (403.8 ± 2.1 Ma; L.P. Black, AGSO, personal communication 1998).

Regional magnetic response and εNd-isotope evidence had led researchers and explorers in recent years to regard the Carawandool Volcanics as Ordovician. Thin highly magnetic basalt layers in the largely felsic volcanic pile cause a strong magnetic response in regional magnetic surveys. This is similar to the strongly magnetic character of many Ordovician volcanics and has been used to interpret their distribution under cover. The linear magnetic anomalies due to the Carawandool basalts contrast strongly with the surrounding weakly magnetic rhyolites, and are much wider than the outcrop of the thin basalt flows. As a result, the strong magnetic signature of the volcanics seen on regional surveys is not particularly representative of the volcanics as a whole. Recent mapping of strongly magnetic rocks north of West Wyalong, also previously regarded as of Ordovician age, has shown that most are probably Silurian or Devonian. Many linear magnetic anomalies are structurally related rather than stratigraphic, emphasising the need to critically evaluate the interpreted distribution of Ordovician rocks based on regional magnetic response.

A single εNd-isotope analysis of a Carawandool Volcanics basalt returned a value of +8.1. Its strongly positive mantle-like character is similar to that of Ordovician magmatic rocks. Wyborn & Sun (1993: op. cit.) obtained an εNd value of +6.5 from a tourmaline-bearing hydrothermal breccia at Porters Mount associated with a buried intrusion on the southern edge of the Carawandool Volcanics. This result was assumed to indicate Ordovician-related mineralisation, and the Carawandool Volcanics, by analogy, were interpreted as Ordovician by later workers. However, analyses of the Cuga Burga Volcanics, discussed above, have shown that other geological features must be considered before an Ordovician age can be assumed. The εNd results appear to be reflecting a similar source for both Ordovician and Devonian magmatism.

The foregoing similarities between the Carawandool Volcanics and Ordovician Volcanics are not reflected in their major- and trace-element geochemistry. The Carawandool Volcanics have SiO_2 mostly above 65%; by contrast, from over 300 analyses of eastern LFB Ordovician igneous rocks in the AGSO/NSWDMR database, less

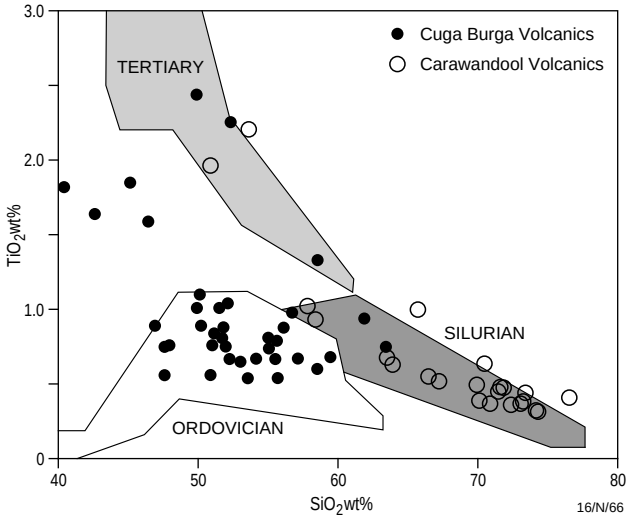

Fig. 10. Plot of TiO_2 vs SiO_2 comparing the Cuga Burga and Carawandool Volcanics with Ordovician, Silurian, and Tertiary igneous rocks from the eastern LFB.

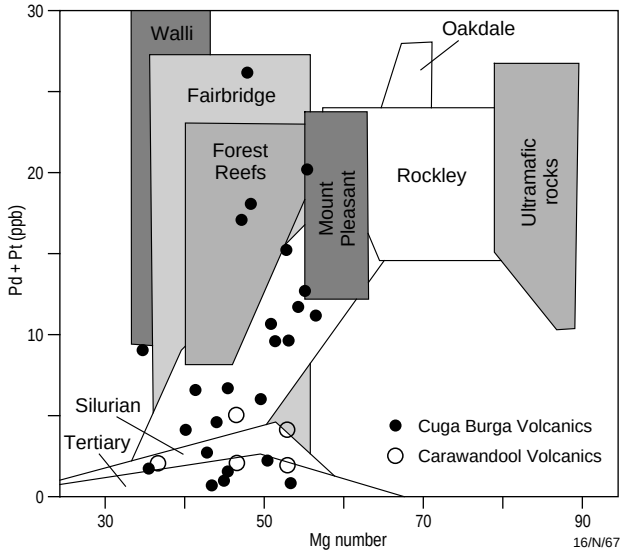

Fig. 11. Plot of (Pd + Pt) vs Mg number. Ordovician volcanics are from the Fairbridge, Forest Reefs, Mount Pleasant, Oakdale, Rockley, and Walli units, and from ultramafic rocks.

than 10 samples have SiO_2 greater than 62%, indicating the almost exclusively intermediate to ultramafic nature of Ordovician magmatism. Compared with Ordovician rocks of similar SiO_2 content, the Carawandool Volcanics have noticeably higher HFSE and show fractionation trends more akin to younger Palaeozoic and Cainozoic intraplate magmatic rocks in the LFB (Fig. 10). They also have generally lower levels of LIL elements and do not show calc-alkaline characteristics. The small amount of PGE data available for the mafic members of the Carawandool Volcanics shows low levels of Pt and Pd (Fig. 11) — a further contrast with the Ordovician volcanics.

Conclusions

Geochemical, isotopic, or magnetic evidence cannot be considered in isolation when interpreting the distribution and character of Ordovician magmatic rocks in the eastern LFB. Some previously applied discriminants of Ordovician magmatism may not be as robust as first thought, and several methods may have to be applied in concert. The sources and/or processes that contributed to the generation of magma during the Ordovician may have been duplicated during the Early Devonian, highlighting the economic potential of the Devonian in the eastern LFB.

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