The Delamerian NDI: Linking South and eastern Australia.

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SUMMARY

The western Murray Basin obscures the interpreted transition between Proterozoic and Phanerozoic rocks of Australia in the upper crust, often referred to as the Tasman Line. The South Australian part of this continental margin has been interpreted, based on sparse extrapolated constraints, to have sat in various geodynamic settings associated with a Cambrian subduction system. We use newly acquired multi-disciplinary datasets and the results of the MinEx CRC Delamerian National Drilling Initiative program to elucidate the architecture of this hidden Cambrian margin, revealing unrecognised potential for a spectrum of mineral systems.

Whilst it has been accepted for a number of years that the Stavely Zone in western Victoria represents a volcanic arc in the mid-Cambrian, continent-ward belts to the west (beneath the Murray Basin), have had uncertain affinities. With the results of recent drilling, we show that both regional, and highly partitioned back-arc extension were present in the period 515-500 Ma, and speculate that inherited structure in pre-Cambrian basement rocks are responsible for the variation in deformation styles present in drill core.

Key words: Delamerian, Drilling, Tectonics, Mineral Potential.

INTRODUCTION

On the eastern edge of the Mount Lofty Ranges, Cambrian to Ordovician rocks crop out on the western margin of the Murray Basin. As the thickness of the Murray Basin and late Palaeozoic-to-Mesozoic sedimentary successions increases to the east, knowledge on the nature and distribution of the basement rocks decreases. Limited historic exploration and government drilling programs provide geological (lithological and in some cases stratigraphic) constraint with which to interpret regional geophysical images. Beneath sedimentary cover of the Murray Basin, a series of curvilinear geophysical anomalies define belts of basement rocks trending from northwest in southeastern South Australia, north-south between the towns of Loxton and Morgan, and northeast to link up with the Loch Lilly-Kars Belt in far southwestern New South Wales. New drilling samples providing geological information, as well as geochronology on legacy samples provide the first regional-scale package of data with which to constrain the geological setting of Cambrian-Ordovician basement rocks of the Delamerian Orogen beneath the far western Murray Basin.

Evolving from an extended margin through the Neoproterozoic, the Delamerian Orogen in South Australia records extensive sedimentation through the Cambrian, and a protracted period of pre-, syn- and post- tectonic magmatism in the period 515-490 Ma (Foden et al., 2020). The geodynamic setting of the Delamerian Orogen during the period 515-490 Ma has been widely debated (summarised in Foden et al., 2020), with disparate lines of evidence centring largely on where outcrop is present in western Victoria (Stavely and Glenelg River Zones), western New South Wales (Koonenberry Belt), Tasmania, and the Adelaide Fold Belt in South Australia.

RESULTS

Twenty-four holes were drilled beneath Murray Basin cover in eastern South Australia (Figure 1; Table 1). Holes were located to characterise a variety of geophysical (potential field) signatures that were interpreted to represent different stratigraphic units, alteration zones and major fault structures. The location of hole placement was also designed to test hypotheses of differential partitioning of Delamerian Orogeny-aged deformation across north-south striking geophysical domains. Table 1 summarises cover thickness and Cambrian-Devonian (?) basement lithologies, with an interpretation on the geodynamic setting of the rocks intersected. Whilst geochronological analyses are pending, Cambrian-Devonian possible ages are assumed, in keeping with published works (e.g. Foden et al., 2020; Turner et al., 2022).

Figure 2 shows a zoom into the southern series of drilled holes (Figure 1). As visible in the magnetic imagery, curvilinear belts in the west of the image are comprised of sheared mafic-felsic volcanics (drillhole NDIAW_D06; Table 1), clastic-carbonate sediments and diamictites (drillhole NDIAW_D05; Table 1), and likely represent a volcano-sedimentary graben that was subsequently inverted. When viewed with the regional gravity imagery (Figure 1), long-medium wavelength positive gravity anomalies likely represent mafic material in the middle crust that fed the volcanism. To the east of the long-medium wavelength positive gravity anomalies (Figure 1), are largely un-deformed (save for minor brittle fracturing) felsic volcanics and granitoids (Figure 2). Deformation is therefore interpreted to have been partitioned into a zone where greater volumes of magmatism and sedimentation were accumulated.

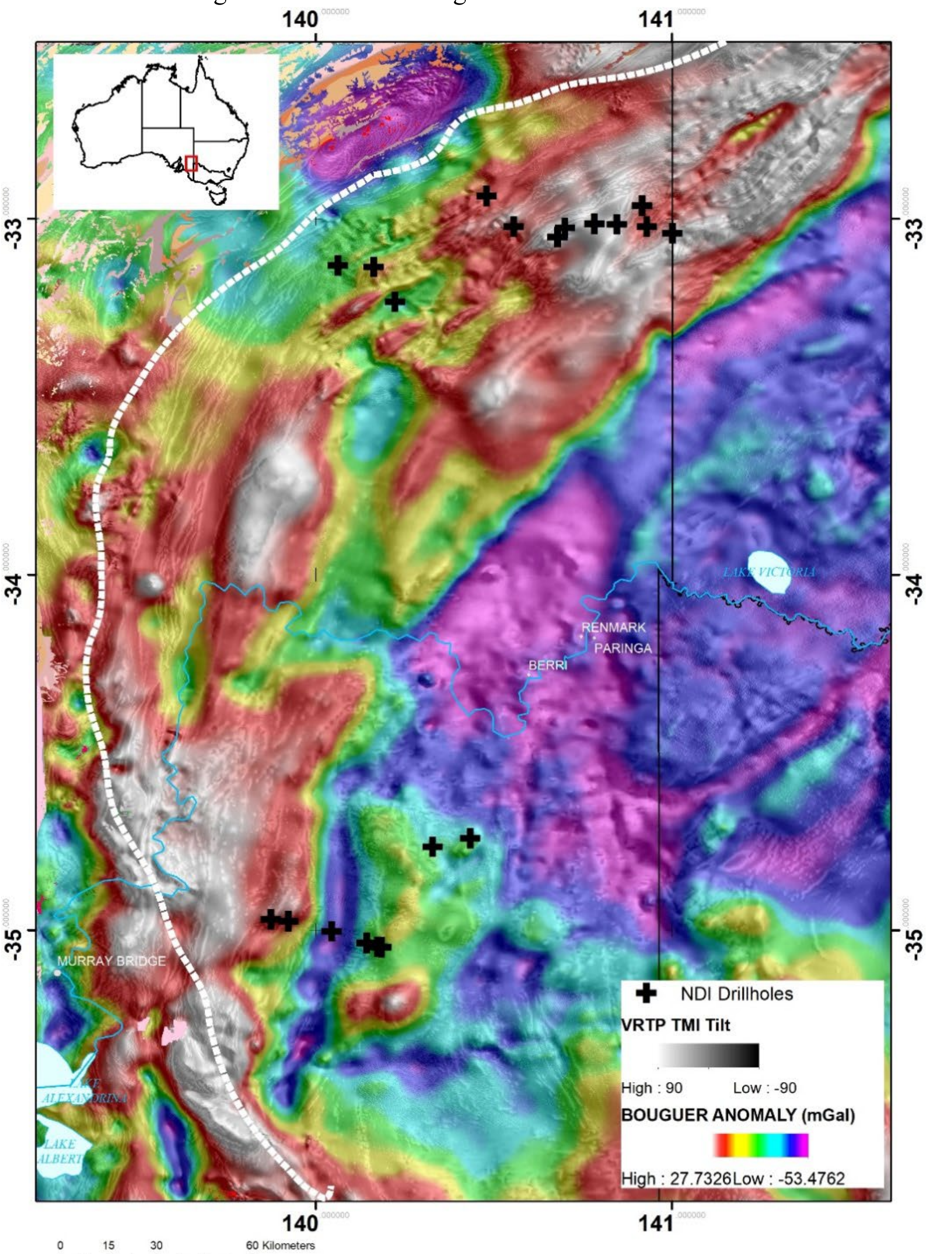

Figure 1. Bouguer Anomaly map of the western Murray Basin (REF), showing locations of drilled holes. White line represents the western extent of the Cenozoic Murray Basin.

DISCUSSION

The Stavely Zone in western Victoria has been identified as a Cambrian (510-503 Ma) volcanic arc, developed above a west-dipping subduction zone (e.g. Cayley, 2011; Schofield et al., 2018). Similar timing of volcanic arc magmatism has been proposed for the Koonenberry Belt (Mount Wright Volcanics) by Johnson et al., (2016). The position of eastern South Australia with respect to a west-dipping subduction zone has been the subject of debate, with arc and back-arc locations proposed based on geochemical and isotopic lines of evidence from magmatic rocks (e.g. Foden et al., 2020). Based on lithological and relative timing constraints, we propose that predominantly, eastern South Australia sat in a back-arc to the Stavely volcanic arc to the east. Modes of back-arc extension however, seem to vary. There appears to be an early phase of back-arc opening, recorded by dominantly clastic sedimentation of the Kanmantoo Group, thickest in the southern Mount Lofty Ranges, South Australia. Deposition of this sequence spans a wide geographic area (Figure 3), across to equivalent rocks of the Glenelg River Zone in Victoria (e.g. Gibson et al., 2015), and recently confirmed under cover of the Murray Basin (Brotodewo et al., 2020). The Kanmantoo Group sediments are highly deformed, and metamorphosed where the rift got deepest (southern Mount Lofty Ranges; Alias et al., 2002), whilst Kanmantoo Group rocks beneath the Murray Basin (e.g. near Loxton) are undeformed (Brotodewo et al., 2020). It is interpreted that pre-existing architecture controlled the development of the early phase of this back-arc (Flöttmann et al., 1998), as well as subsequent inversion.

A second phase of back arc development is proposed here for a belt of bimodal volcanics-intrusives and sedimentary rocks intersected in drill holes here (Table 1; Figure 1, 2). Partitioned extension focussed at the western edge of a low-density, strong, crustal block (Figure 1, 3) appears to superimpose earlier sedimentation of Kanmantoo Group rocks, and provide significant magmatism and synchronous sedimentation. Likely to have followed on rapidly after partitioned extension, was partitioned contraction in the recently developed rift, inverting sediments, volcanics and intrusives (Figure 2, 3; Table 1).

Facilitating rapid changing in how back-arc extension is partitioned, is likely to be the fundamental crustal/lithospheric architecture (e.g. Flöttmann et al., 1998; Figure 3), as well as subduction zone dynamics (e.g. Cayley, 2011).

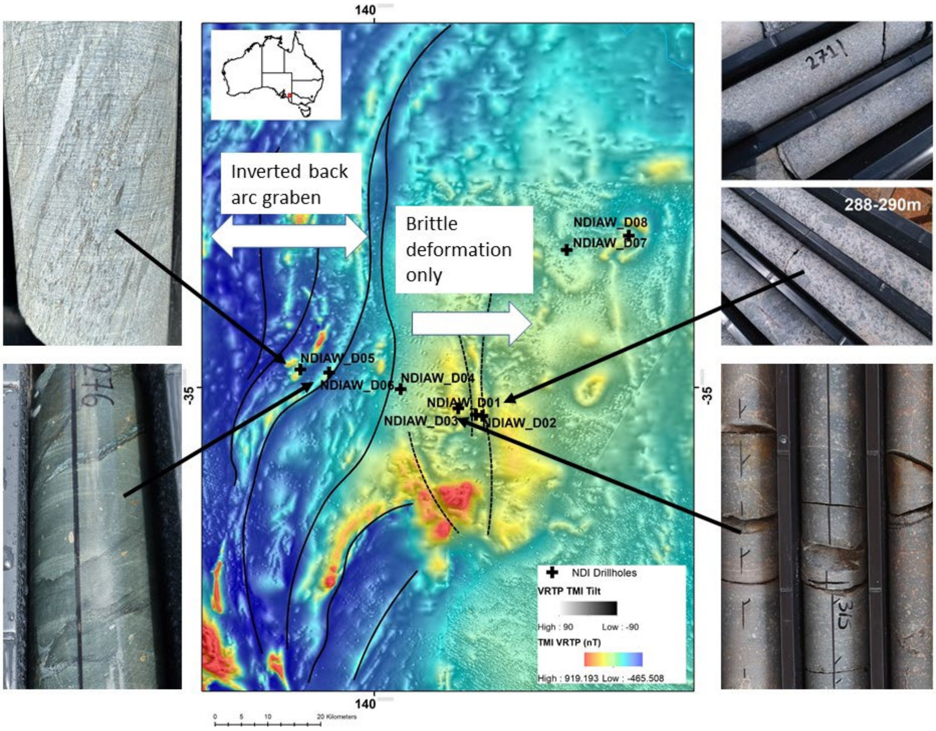

Figure 2. Differential deformation visible across a series of drillholes. Westerly drillholes are highly sheared and inverted, whilst drillholes to the east show only weak brittle fracturing.

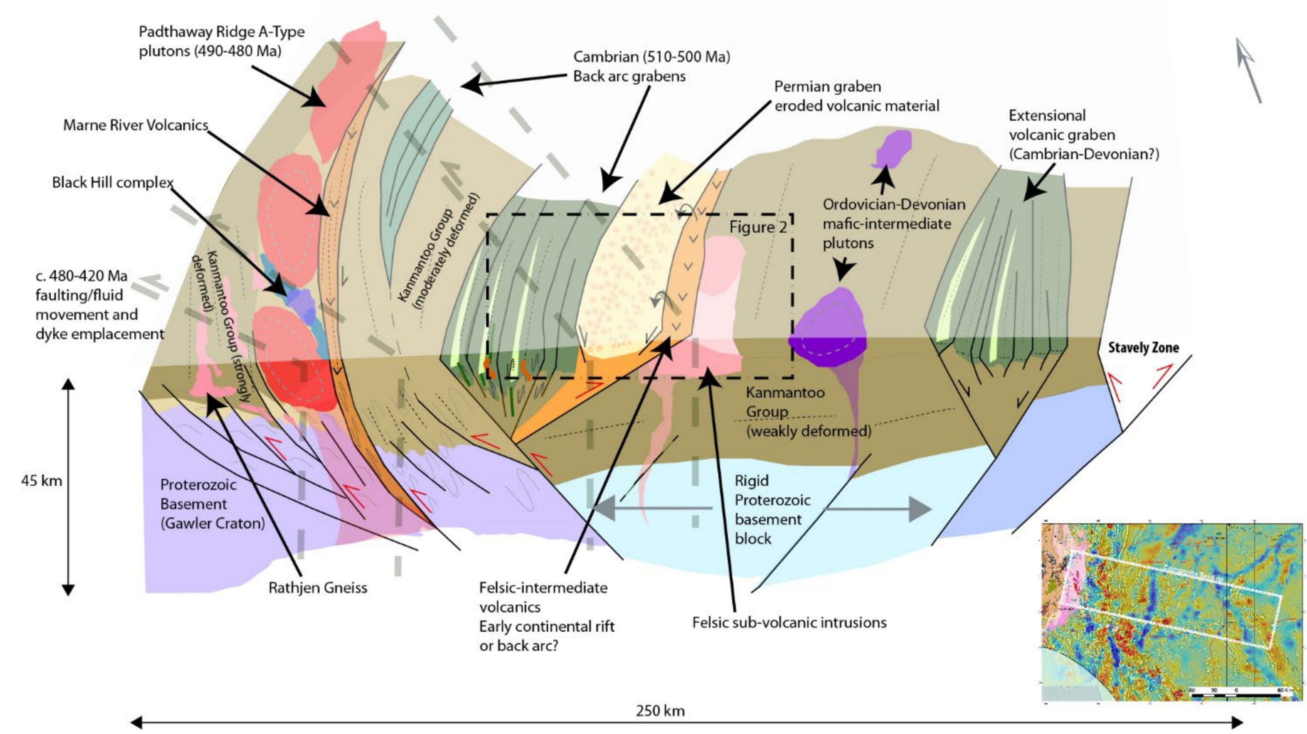

Figure 3. Cartoon model illustrating crustal elements in the Delamerian Orogen and how pre-existing structures control how back-arc extension is facilitated, and subsequent extension is partitioned. Easterly extent represents the present position of the Stavely Volcanic Arc. Westerly extent represents the Mount Lofty Ranges, east of Adelaide.

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Table 1: Drilling results summary.

Drillhole	***Cover Thickness (m)***	***Easting (m; GDA94 MGA54)***	***Northing (m; GDA94 MGA54)***	***Basement Lithologies***	***Interpreted Geodynamic Environment***
NDIAW_D01	252	425583	6121230	Actinolite-sericite-chlorite altered biotite-hornblende monzogranite	Shoulder of back-arc rift
NDIAW_D01_CT	267	425583	6121430	Monzogranite	Shoulder of back-arc rift
NDIAW_D02	262	424538	6121430	Sericite-chlorite altered biotite monzogranite	Shoulder of back-arc rift
NDIAW_D02_CT	280	424538	6121430	Albite-chlorite-zoisite altered metagranitoid	Shoulder of back-arc rift
NDIAW_D03	291.4	421839	6122620	Albite-chlorite-biotite-sulfide altered meta-rhyodacite porphyry; volcanogenic breccia; Chlorite-biotite meta-acid volcanic rock	Back-arc rift?
NDIAW_D04_CT_80	300	412836	6126160	Argillite; Siltstone	Post-Delamerian trough
NDIAW_D04_CT_90	301	412836	6126160	Sandstone with argillite laminae	Post-Delamerian trough
NDIAW_D05	308.4	397196	6129730	Weakly foliated meta-laminated Sandstone; Foliated sulfide-bearing metadiamictite	Back-arc rift
NDIAW_D06	227	401687	6129160	Foliated meta-rhyodacite; Foliated meta-basalt; meta-?rhyolite breccia; Foliated meta-crystal-lithic arenite	Back-arc rift
NDIAW_D07	272	438492	6152680	Biotite monzogranite; granodiorite	Shoulder of back-arc rift
NDIAW_D08	223	448185	6155430	Biotite-rich granite	Post-Delamerian (Siluro-Devonian) intrusion
NDIQV_D08	197	412486	6333720	Chlorite-talc altered mafic volcanic?	Back-arc rift?
NDIQV_D09	216	427539	6322450	Biotite granodiorite	Post-Delamerian (Siluro-Devonian) intrusion
NDIQV_D10	169	421940	6333300	Aphanitic felsic volcanic-volcaniclastic	Back-arc rift
NDIQV_D12	218	500157	6344120	Green-grey-black, aphanitic felsic volcanic rock.	Back-arc rift
NDIQV_D13	155	493471	6346196	Green, aphanitic felsic volcanic rock.	Back-arc rift
NDIQV_D14	153	492293	6352669	Aphanitic felsic volcanic-volcaniclastic	Back-arc rift
NDIQV_D15	177	479647	6346944	Finely laminated clastic sediment	Back-arc rift
NDIQV_D16	205	472004	6345738	Ophitic-textured gabbro	Back-arc rift?
NDIQV_D17	210	469997	6342830	Ophitic-textured gabbro-dolerite	Back-arc rift?
NDIQV_D18	201	458579	6346110	Dark olive-black fine grained (aphanitic) felsic volcanic	Back-arc rift
NDIQV_D19	196	427539	6322450	Medium-grey very fine- to fine-grained intermediate volcanic?	Back-arc rift
NDIQV_D20	210	451391	6355550	Foliated sulfide-bearing metadiamictite	Back-arc rift