# A Mesoproterozoic continental flood rhyolite province, the Gawler Ranges, Australia: the end member example of the Large Igneous Province clan.

Pankhurst et al.

## Author response to reviewer comments

My co-authors and I have distilled the reviewer comments into the following statements. We would like to take this opportunity to thank those who contributed their impressions and thoughts to this manuscript. Each statement is addressed as follows:

| Statement # | Reviewer and Statement | Response*<br>*(page:line) numbers refer to the discussion paper pdf |
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| 1 | Morgan, J.<br>"Apparent linkage of these volcanics with a 'classical' continental flood basalt setting. The geometry in Figure 1, in fact, looks more similar, in space and time, to a Yellowstone-Snake River Plain following the eruption of the Columbia River Flood Basalt, not the flood basalt event itself | We draw comparisons between the style of highly voluminous lava outpourings observed in CFBs with the Gawler Range Volcanics. Yellowstone-Snake River is certainly a useful comparison as well, however we have chosen not to discuss these specific similarities in great detail to help focus the drive of the paper; which is to compare terrain-wide magmatic expression using the primary physicochemical nature of those magmas. We feel that making the point that a low viscosity felsic lava can produce similar expressions to those of well characterised mafic lavas is of more interest. We also feel that comparing Yellowstone to the Gawler has more value in a separate contribution as we would have the room to develop the comparison more thoroughly. |
| 2 | Castro, A.<br>The interpretation of a single, or central, eruption for the whole rhyolite-dacite association needs a more careful examination of field and mapping relations. The aeromagnetic image is not clear to define precisely lobe geometries and the supposed radial distribution | We have provided a higher resolution image (updated Fig. 2) to better describe the lobate morphologies. We feel that the excellent mapping work by the CODES research group (University of Tasmania), which is cited within this manuscript, is of sufficient quality to guide our geophysical interpretation. |

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| 3 | Castro, A.<br>It is important that the selected composition corresponds to a liquid | This point is well made. We feel that the compositions do correspond to a liquid as they are within the normal range of A-type magmas within the province and throughout the rock record. See statement 6 for expansion of this response. |
| 4 | Castro, A.<br>Description of samples and their treatment needs to be more thorough | We have written additional lines into the text (6:18) to better elucidate sample description and treatment. Below is the updated section of text;<br>….Samples of Gawler Range Volcanics (Fig. 2) were assessed visually in the field, hand sample and microscopically to possess a high degree of homogeneity (phenocrysts of K-feldspar > quartz > pyroxene > Fe-oxides totaling ~20-25% within a microcrystalline matrix), an observation made more poignant given their wide geographical extent. Following petrological work to confirm the primary nature of their textures and low abundance of microphenocrysts within the microcrystalline matrix, the cores of twelve ~5 kg samples of unaltered upper Gawler Range Volcanics were analysed for major, minor (including halogens) and trace elements… |
| 5 | Castro, A.<br>Twelve samples were analyzed but no information is given on Table 2. Only two data. Are these averages? Or representative samples? Are rhyolites and dacites linked by fractionation form a common magma? | The data are averages, yes. We have updated the table to reflect this important point. The rhyolites are thought to be linked to the dacites by AFC processes. We feel the detailed petrogenesis of these rocks are reported adequately in the literature, and are not explored here. |
| 6 | Castro, A.<br>One of the two samples, the dacite, is too rich in Fe with molar Fe/Fe+Mg ratio >0.9. This sample is too poor in CaO (1.1 wt%) for a dacite and too rich in Fe for a rhyolite. It does not plot on a cotectic of alkali-calcic system. Likely, this sample was alterated ad is depleted in CaO. | We disagree that alteration has played a significant role in influencing the chemical composition of these rocks. CaO is uniformly low in all samples (on the order of ~200 km between the furthest spread points), and indeed the whole province (fresh cogenetic granites also have uniform CaO values of ~1%). It is unlikely that alteration has affected all the rocks to the same degree, given what we know about alteration of volcanic piles. The K and Na values are not unreasonable for the corresponding silica values. Low CaO is in fact a feature of A-type granites, which when plotted on a traditional alkali-CaO system tend to miss the cotectic. Why this is the case in A-types is currently unresolved, but extreme negative Eu anomalies suggest plagioclase |

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| | | settling plays an important role. While this issue is interesting, it nevertheless is of minimal importance in the context of this paper whereby the chemistry is used to calculate viscosities, not a petrogenesis. Plotting off the cotectic is not of major concern here because it not an indicator of alteration – it is merely symptomatic of being a typical A-type. |
| 7 | Castro, A.<br>Examination of variation trends and trace-element patterns for immobile elements (e.g. REE) may help to discern about the nature of these samples in order to select those representing liquids | We agree that analysis of REE is of important petrologic significance, although in light of the comments in statement 6, we feel that an exhaustive examination of these data would unnecessarily shift the focus of the manuscript away from its main drive. |
| 8 | Castro, A.<br>Abstract: the last sentence is not clear. " The erupted portion of the felsic end-member..." Also the meaning of end-member is not clear in the title | We are puzzled to why the usage of the term "end-member" is troublesome. In the first instance of use (the title), it is used in context with the "clan" of Large Igneous Provinces. Within any clan there are members, of which their intrinsic parameters must naturally define a spectrum. An end-member example is one which lies at an extreme end of this spectrum, and therefore describes the phenomena of the GRV (we feel), adequately, given its overwhelmingly felsic composition but similarities in all other intrinsic parameters. |
| 9 | Castro, A.<br>Introduction (and other parts). In general Ma is preferred instead of M yr | Corrected |
| 10 | Castro, A.<br>Section 2. Include in the heading "Age and morphology...." | Corrected |
| 11 | Castro, A.<br>Pag. 254 line 27: We consider this. . . (this refer to what?) | "this" deleted, "these orientations" inserted |
| 12 | Castro, A.<br>Pag. 255 line 2: . . . et al. (2008) See comments above about the interpretation of Fig. 2. | Comment referred in #12 is #2, we feel the response to #2 also responds to #12 |
| 13 | Castro, A.<br>Section 3 "Physicochemistry" Change this title for another one more accurate in relation to the content of this section. For instance, "Temperature and viscosity" or | "Physicochemistry" deleted, "Viscosity calculations" inserted |

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| | "geochemical and rheological properties" | |
| 14 | Castro, A.<br>The subheading 3.1 is not necessary. | Subheading deleted |
| 15 | Castro, A.<br>Pag. 256 line 12. ". . .data range over 200 ◦C. . ." this range is 100 ◦C according to data on line 8 on this page | The range of 100 °C on line 8 refers to the best estimate as this is where the data clusters. The 200 °C range refers to the data set as a whole. |
| 16 | Castro, A.<br>Section 4 Pag. 258 line 18: close MPa, not M Pa (correct throughout the text) | Corrected |
| 17 | Castro, A.<br>Pag. 258 line 20: The estimation of 1 wt% water is reasonable according to phase equilibria. However, the comparison of this figure with LOI is fortuity and nonsense in old lavas subject to weathering and possibly metasomatic transformations | We acknowledge that weathering and metasomatic transformations are indeed likely processes that will influence LOI numbers. However, we would expect both these processes to increase LOI past the numbers recorded (1-2%). We have reworded (7:7) this section to better describe the LOI numbers as consistent with low magmatic water content, rather than suggestive of low magmatic water content. |
| 18 | Castro, A.<br>An additional discussion that authors must take into account is about the implications for a large magma chamber beneath the volcanic system. The homogeneity in compo- sition and mineral assemblages, which produced homogeneous viscosity within large volumes of magmas, is compatible with a single magma chamber with the dimension of a large batholith. Are the plutonic rocks associated to the volcanics (they have the same age) representing this large magma chamber? Which is the driving force that triggered the eruption of a so large volume of low-viscosity magma? | We regard this collection of points as extremely interesting and thought-provoking. Indeed, the high degree of homogeneity over the entire terrain implies a very large, well mixed magma body. We view the evacuation of such a chamber to be fundamentally driven by the thermal anomaly and facilitated by the concomitant low viscosities calculated. The implications of the findings reported in this manuscript are currently driving further research in terms of the geodynamic constraints imposed locally as well as in other examples in the rock record. We have updated the discussion and conclusion to include lines better designed to outline these points and communicate our ideas to the literature.<br>Below is an updated section of text;<br>… The low viscosity magma erupted from a central cluster of feeder vents from which emanated large-scale lobate flows, representing a viable emplacement mechanism to produce a flood Rhyolite Province with volumetrically insignificant basalts and andesites. The volumes considered and high degree of homogeneity reported here and elsewhere in the literature (e.g. Allen et al. 2003) are suggestive of a well |

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| | | mixed magma system/chamber of batholitic proportions. The geodynamic implications of the production and expulsion of such extreme quantities of felsic magma in such a short time frame are non trivial. The volume and areal extent of such a flood rhyolite is directly analogous to that of preserved mafic Large Igneous Provinces, which are present throughout the geologic record, and are often attributed to upwelling of anomalously hot mantle in the form of mantle plumes. We view the fundamental driving force of the development of the GRV magmas to be a transient thermal anomaly analogous to such events. The evacuation of an anomalously hot and felsic (and therefore buoyant) magma chamber would be facilitated in this case by the low viscosities calculated, possibly at the expense of any cogenetic mafic magmas. We therefore present a viable mechanism for sustaining a large volume felsic igneous province, and suggest that the Gawler Range province represents an end- member of the Large Igneous Province clan… |