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Interactive comment on "Mapping undercover: integrated geoscientific interpretation and 3D modelling of a Proterozoic basin" *by* Mark Lindsay et al.

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Dear Reviewer,

Thank you for your insights and comments from your thorough review.

First, we respond to the main concerns listed in the Interactive comment, then to specific comments made in the marked-up manuscript supplied as a supplement.

Geochemistry and basin development interpretation The relevance of geochemistry has been questioned by the reviewer. We believe it is important to note the possibility that the additional high density material required to reconcile the observed gravity is

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Discussion paper

not just attributed to the Killara Formation. High density material is interpreted to be mafic rocks, and the geochemistry shows that different sources for these mafic magmas is possible. This means the basin evolution is more complicated than is currently proposed. Without the geochemistry, we cannot provide this insight with gravity modelling alone. However we do acknowledge the dearth of data and that two drillholes are used to make this interpretation. Nonetheless, it is clear from these drillholes that mafic rocks intruding into the Juderina Formation are not geochemically similar to the Killara Formation. Additional drillholes would not change this observation, so we maintain our assertion that our interpretations are supported. Olierook et al. 2018 also support the hypothesis that the magmatic history of the basin is more complex.

Manuscript organisation and length We accept the concerns of the reviewer that the manuscript can be improved with the removal or shortening of some sections. We do believe the geochemistry section can be shortened to provide a more concise manuscript. This is also in accordance with comments made by the other reviewers. We also agree that some descriptions provided in the manuscript can be significantly shortened or removed to improve clarity. In particular, methods and results related to the interpretation can be removed and shorten. Figure 8 and the details regarding the airborne electromagnetic interpretation are not relevant at the scale of this study. We will remove these.

Specific comments made in the manuscript We appreciate comments which aim to improve the clarity and length of the manuscript. Many of the comments make suggestions that we agree with, and thus won't directly address them here. Those we believe require some response, including significant changes to figures and table are listed below.

L95 Merging of Fig. 1 (map/geophysics) and Fig. 2 (stratigraphy) - agreed. This will be done and figure references updated. Various other comments further in the manuscript make suggestions to improve the stratigraphic representation which we acknowledge and will implement.

L112 Age of dykes: These dykes have not been dated due to a lack of zircon grains, however are considered to be between 2200 Ma and the next youngest radiometric age data known (likely to be the maximum depositional age of the Ravelstone Formation – 2014 +- 22 (U-Pb, Pb-Pb, ion probe). Text updated.

L120 "Implies there are no rocks between Juderina and Yelma - what happened to th rest of the Yerrida units" - there is an unconformity, and in this part of the region it is likely the basin didn't deepen enough for other units to form over the Juderina. Text updated.

L127 "Why?" Because the possible synchronous deposition of the Juderina and Johnson Cairn formations with mafic volcanic rocks has generated further interest in the Yerrida Basin for potential VHMS mineralisation. Text added for clarification.

L194 "why mention these ? or put them in the strat column" and "Finlayson is never mentioned again". Agreed, 'member' level descriptions of the stratigraphy is not needed. We will update the manuscript.

L205 "not of interest to the reader". We believe that the retention of geological plausibility is important during geophysical inversion, and is relevant to the geoscience community who we hope will read this manuscript. Thus the topological constraint is an important feature of the chosen method and is an important reason to justify our choice to use it. Given this justification is given in two sentences, we think these statements should remain.

Section 4.2. A rewrite of this section will be performed to clarify which datasets were used in what capacity to produce the interpretation, but specifically describing those of relevance the to the inversion modelling. Thus the current emphasis on the magnetic data will be removed and clarified. Other suggestions around the correct citation of datasets and display in figures will be addressed.

L277 We attempt to falsify our hypothesis using geophysical modelling rather than find

support for it. We believe this approach is in line with methods of scientific inquiry described by Karl Popper, and leaves us more accepting of alternative hypotheses when they become apparent.

L336 "how does it compare to your Noddy model?" This kind of comparison is difficult to make. Noddy is kinematic modelling platform that takes essentially conceptual inputs to produce a model. GM-SYS, while also driven at a higher level by concepts, is constrained with data. Thus the progression from Noddy to GM-SYS was performed to introduce the necessary detail to test the geological complexity that cannot be easily performed with a kinematic modelling platform. Noddy allows the introduction of simple flat and homogenous body of high density from which we can test the gravity response. GMS-SYS also allows this, but we can easily truncate, or fault, thin or expand the high density body in an explicit manner. Nonetheless, the two methods produce consistent results, and this will be added to the manuscript.

L356 "maybe add geophysical values to Fig 2" I believe the reviewer is suggesting that petrophysical values (not geophysical) could be added to the stratigraphic column (Fig. 2). With the aim of keeping the manuscript concise, and maintaining an accurate representation of petrophysical properties with histograms, we think the current state is acceptable.

L356 "where did you get the unmeasured values from?" where unavailable, generic values cited in the literature were assigned. Reference to "Telford, W. M., Geldart, L. P., and Sheriff, R. E.: Applied Geophysics, 2nd ed., Cambridge University Press, Cambridge, UK, 1990." added.

L369 "why not 2000m as in your Noddy model?" 2000m was an indicative thickness to produce an relative weak anomaly located over the Goodin Inlier. The purpose of the GM-SYS was to provide more precise while plausible estimates of thickness for the dense material that could then be input to 3D modelling. The result reported here shows that the Noddy thickness is likely more than needed. From this comment, we

acknowledge our logic in progressing from Noddy to GM-SYS to the 3D model needs to be better explained (see also our response to comments made in L336 above).

L374 "mafic sills in Juderina only observed N of Goodin Fault" Correct. There are Juderina rocks north of the Goodin fault at depth. See Occhipinti et al 2017.

L379 "earlier you say Killara is intrusive being sills" yes, this why this sentence makes the distinction to the extrusive component.

L398 "you must have allowed density changes as well to get high density units in areas where there were none to start with" We didn't allow high density values to be placed anywhere in the model. This is why the 3D geological and topological constraints are important. The ranges of petrophysics forbid values being assigned to voxels in the location of these bodies during inversion. This means that high density values are only allowed in locations as specified by the 3D geological model.

L466 "why not in Juderina?" The previous assumption was that the only mafic material in the Yerrida Basin could be attributed to the Killara Formation, or the late dykes. Thus we make comparison with the Killara to show the difference with the previous hypothesis, and the updated one provided by this study.

L497 (and further comments through this section) "So we are expecting DGDD to show Narracoota signatures?" yes, based on the surface geology, but drilling shows that Windplain Group rocks underlie rocks contained within the Byrah Basin.

L515 "this statement is quite a claim from only 2 holes one of which doesn't convincingly support your observations." We appreciate this insight, however it's not clear why the reviewer believes one drillhole (not specified) doesn't support the observation.

Section 5.5 Basin development A figure showing block diagram will be produced to support the interpretation in this section.

L538 "so Narracoota only flowed north and Killara only went south from the same vent system? How are you separating these spatially since you have said they are tempo-

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rally equivalent." The distinction here is that they may temporally overlap, however no dates on the Killara only makes this a suggestion. While overlap is suggested, we also think that Narracoota and Killara-related magmatism most likely did not start and end at the same time. Thus changes in palaeotopography due to a dynamic basin enviroment would have a strong influence on the direction of lava flow at that time. This clarification will be added to the revised manuscript.

L553 "hence unlikely to be in regions 2 or 3 as suggested above - need to explain why no vents in regions 2 and 3 are seen in Fig 19 " The premise is that vents must be distant to regions 2 and 3 given they are very likely sitting on Yilgarn Craton rocks given the structure shown in the 3D model. Thus, is vents were located in these regions, lavas erupted from these vents would have an Archean signature from interacting with Yilgarn Craton rocks.

L554 (and similar comment L555, L564) "are you suggesting the Goodin Fault is the edge of the craton?" No - we have evidence to suggest that, however the lack of an Archean signature suggests that there is an absence of Yilgarn Craton rocks. Where the boundary is located can be better addressed by further work.

L600 "and the origin of Killara mafics?" This is described by Piranjo and Adamides (2000) and Occhipinti et al 2020.

Section 7 Appendix "this is basic geological skills - unnecessary unless they are going to mark these features on any of the figures" These features are marked in Figure 11 and describe the source of the structure used to constrain the forward model. We provide this data to emphasise the model has geological constraint provided by field mapping, thus supporting the geological interpretation made from the petrophysical model. We would like to retain this table as an appendix and don't believe it detracts from the quality of the manuscript.

"not seen in fig 1 or 7 or 8" these could be labelled, however is not relevant given the scale of the study and would produce overly annotated and busy figures.

L763 Thank you for spotting incorrect referencing. This will be fixed.

Figure 4. Grey scale colour mapping is preferred due to better contrast and colour-blind readers. The point of the figure is that features in the magnetic data are hard to spot once the irrelevant near surface anomalies are suppressed through upward continuation.

Figure 6. "why are there no density measurements for all the units that you have mag measurements for?" lack of outcrop and what outcrop there is weathered. A limited selection of material was available from drill core due to company restrictions on destructive sampling.

Figure 7. "where is the colour Bouguer with the 1VD RTP which the authors said was particularly useful for the interp?" This figure will be added.

"Where are the major faults that were used in the 3D modelling?" labels to be added.

Figure 9. "could be merged with Fig 10" we tried this and the figure is quite large and doesn't fit into the manuscript while retaining legible labels.

Figure 11. "would be nice to see where the measurements that the authors made plotted on this diagram to verify that the units matched the geological interp in part d". This is the purpose of Appendix Table A.1. Clarification will be added to the caption.

Figure 16. The figure will be redrafted, along with comments supplied by the other reviewers.

Figure 17. "green area represents?" Figure will be updated.

Figure 19. Addressed in responses above to L553 and L554.

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