

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

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General comments

This is an interesting manuscript which in my opinion will be a valuable contribution. I enjoyed reading how the authors have tackled a challenging problem which commonly presents itself in observed data. That is, how do you explain potential field anomalies which can't be explained by outcropping geology? I have tried to make some comments below which I hope will assist with clarity. There are a number of minor changes and also suggestions for the authors to consider regarding the figures which I think will improve the MS. There are no major changes suggested.

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After reading the introduction, I have an impression that I'm going to be reading a methodology paper about how to tackle geological problems. Certainly no problem with that, but having read the MS, I now know that the focus of this study is explaining a high amplitude gravity anomaly over the Yerrida Basin and what the implications are for the presence of interpreted mafic rocks, but there is little mention of this in the introduction. For this introduction, I would've expected enough geological background to have been covered so that the reader is led to the aims and the focus of the study. The summary of geophysical techniques in the introduction is valuable, but I suggest that it could be cut back in exchange for some details about what this paper is focussed on.

A detailed structural interpretation is presented in figure 7. It looks like an impressive piece of work, but it wasn't really clear to me why the structural interpretation was required for the aims of this research. This paper is primarily about modelling the proportion of mafics in the crust. True, structure can affect the sub-surface distribution and some discussion about the Goodin Fault for eg was made regarding this, but there is a lot of detail in this interp which didn't seem to be required to support the conclusions. I'm not necessarily suggesting the interp should be removed, but in my view the paper could probably stand alone without the structural interp.

3.1 Rock properties: This section describes the importance of rock properties and how they were used, but there is nothing explaining how these data were obtained. What workflow did you use to measure density? Was there a standard that was followed? Instrumentation for both density / mag susc? How many measurements per sample/outcrop for mag susc/density? Etc.

3.6 Geochemistry: Its not clear to me why this section is here. All of the other sections contribute to an understanding of geometry and crustal architecture. Geochem can of course complement understanding of crustal architecture, but as it stands, this section is very brief and seems out of context to me. But more importantly, there is no geochemistry section in the results, I presume because there wasn't actually any geochem

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done as part of this research. – ie. The geochem has been referenced from other work, so the geochem isn't really part of your methodology. Personally, I think its ok to introduce the geochem in the discussion if its referencing other people's work, but if the geochem is your work, then the method and results of it needs to be elaborated.

Given the volume of mafics is the focus of this study, I wonder whether its worth introducing something quantitative into the results section how much mafics have been interpreted to exist. I am only thinking of a few sentences (maybe a paragraph) which describes (and quantifies in cubic km) how much mafics were previously interpreted from the starting model, and how much more are required following inversion modelling. At is stands, its difficult to appreciate the volume of mafics from a qualitative assessment from looking at small, static, images of the model.

Specific comments

Line 16: I'm uncomfortable with the phrase "high amplitude density anomalies". Density is a parameter measured in g/cm³ (for example) and in my view, typically isn't referred to as having amplitudes (or wavelengths). It makes me think you're talking about a gravity anomaly - are you? At least for the purposes of clarity, I suggest the authors keep these two things distinct (density and gravity) since a gravity anomaly is caused by high density rocks. Please check throughout the MS.

Line 17-18 – Similarly, "The density anomalies infer an abundance of buried and high-density material that is not indicated by the surface geology" – I think should read "the gravity anomalies infer an abundance of buried and high density material."

Line 24: add 'the' before 'Archean'

Line 90: change to 'of the Yerrida Basin by Occhipinti et al. (2017)'

Line91: not sure I can see the 'Yilgarn Craton granite-gneiss' on fig 1??

Line 106: I can see Windplain and Mooloogool Gps on fig 2, but how come Bryah isn't there?

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Line 133: Change to 'than drillcore'

Line 139: please check that the data were gridded at 80m cell size. I'm guessing this is a compromise between the 200m and 400m line spacing which is fine, its just that this is a very common for the flying elevation. If the cell size is indeed 80, what is the flying elevation of the survey? I also think its worth specifying the year(s) the surveys which make up this mosaic. le – add the phrase somewhere in this pargaraph 'flown between 19xx and 200x' (for eg)

Line 144: Pretty sure this should be the 'Australian National Gravity Database'.

Line 148: Is this 11km data helicopter land-based gravity? Like the mag, I think its worth specifying the years (or even decades) that these gravity stations were acquired. Elevation is a critical component to gravity data, and accurate elevations were much more difficult before GPS.

Line 149: I think its worth listing some of the processes that were applied to this gravity data in a sentence or 2. Tide, drift, theoretical correction formula used, gravity datum, FA correction and the density used for terrain/Bouguer corrections.

Line 168: whats the superscript '44' on this line mean?

Line 179: A sentence or 2 here about what potential forward modelling actually is and how its done would help readers who aren't familiar with the technique. le – the objective is to iteratively adjust the geometries/rock properties to obtain a match between the observed and the calculated response etc.

Line 216: I don't get why you've used gms/cm³. The SI symbol for grams is 'g'. I suggest you stick to this and leave it as 'g/cm³'. Please check throughout the MS.

Line 223: Please specify that fig 5 is for mag susc as you have done for fig 6 and density. Also, you're referring to fig 5 and 6 here, but I haven't seen any reference to figure 4. The figure numbers may need re-ordering so they're sequential?

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Line 245: Why is 'figure 5' in bold? Same with figure 5 and figure 6 on line 223

Line 251: You say that lithological interp relied on datasets OTHER than potential fields – but then you go on to say that you can remove near surface features by upward continuation – so did you use mag data for interp of lithology? or something else?

Line 259: please re-phrase: 'in some cases bedrock geological could'. Do you just mean bedrock geology?

Line 260: Ok, so you're saying that AEM data can help with interpretation of the bedrock even though you're imaging in-situ regolith – I'm still not clear how figure 8 is showing this. I think some more description of how you used the AEM data might help. This figure doesn't seem all that self explanatory on its own to me.

Line 265-268: You say that your interp differs little from existing mapping – so its not clear to me that the comments made here about the Juderina Fm, and JK fm are differences? Or similarities with existing mapping?

Line 275: 'density anomaly' do you mean gravity anomaly?

Line 305: Ok cool, so why didn't you generate a model which had the Killara Fm with at thickness of 1000m if this is the currently mapped thickness? Ie – if 500m didn't work, and 2000 did, does the currently mapped thickness of 1000m fit the observed?

Line 321: should be 'two scenarios were examined'

Line 319: its not clear to me how the sensitivity of the dip direction of the Goodin Fault is relevant to the subcrop distribution of the Killara Fm.

Line 326: do you mean 'potential field geophysical data'?

Line 332: you seem to be referring to the geological section (line 328) and petrophysical model (line 332) interchangeably. Suggest you keep this consistent. Calling it a petrophysical model makes sense to me.

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Line 366: Do you mean 'figure 10a and b'??

Line 383: please change to 'explain the anomalous gravity signature'

Line 393: should be 'The maximum number of iterations was set to 1M'

Line 436: should be: '...communicated so others benefit'

Line 459: Please check the figure references here – doesn't makes sense. Do you mean figure 14 a and b?

Line 474: '... These views are all from the southwest...'. I get what you mean, but just looking at these its difficult to get your head around. Certainly A & C makes sense. But because B and D are views from underneath, its tricky to visualise with a static image. Suggest you mention in the caption that B and D are views from under the model.

Line 478: ok – but what DO the colours mean then? I'm still a bit confused.

Line 483: Is the Juderina Formation the aqua colour here? I think a legend would help with clarity of these figures.

Line 495: should be: '...we checked whether any...'

Line 545: I understand that the Goodin Fault is structure which is interpreted along the boundary of the Bryah, and text on line 343 suggests its geometry is difficult to determine, however can an inferred location of this fault be included on figure 7a? There are several other faults labelled on this interp, but this is clearly one of the major ones and important to this research. Figure 19 is the first place I've seen a location of the Goodin Fault (in map view) which I suggest is too late in the MS.

Line 577: should be '... datasets have been used...'

Line 586: should be '...3D forward modelling showed that a layer...'

Line 600: ok cool – I think its worth adding something here in the conclusions about prospectivity. Even if the spider diagrams for the mafics you've modelled show inclined

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REE profiles and therefore VMS-unprospective, I suggest its still a valuable conclusion.

Line 819: ‘...proved less useful compared to the AEM...’??

Line 820: fix typo: ‘imageing’

Line 860: Caption is incomplete.

Figures

Figure 1 - Some of the colours in the legend for the geological map are indistinguishable. The Greenstone – gneiss and Greenstone – metasedimentary for eg. Can this be improved?

- Please reference the geological and gravity data in this figure caption
- Whats the shaded region on both of these images? It looks similar, but not as detailed as the white line on fig 3a&b and also 7b&c.
- You’ve said that the geology is on the left, need to specify that the gravity is on the right for consistency. (or subdivide these figures in to a and b).
- I’m not sure what the minimum text size is, but the font in the legend appears small to me?
- Regarding the surface sample locations, I think its worth including some sort of link between these locations, and the measurements you’ve made in figs 5&6 plus table 1. Otherwise showing these sample localities is only showing where ALL the sample localities are without distinguishing them which isn’t much help. Problem is, I’m not sure how you achieve this. Including a sample number would make a mess of the map. Possibly including another (larger) figure might help? I’m not necessarily insisting on this, but I think it would add value.

Figure 2 - Can the colours on this figure be made consistent with those on figure 1? Or vice-versa? Its pretty confusing to have different colours between figures for the same

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rocks. The Killara Fm for eg is blue here, but grey on fig 1. Other cases, the colours are similar, but slightly different (light vs dark green).

- I think it would help with clarity if ages were added to this strat column.

- I realise the white spaces have been included to show that there are mafic intrusives, but this seems like an unusual way of visualising it to me in a strat column – I was expecting a blobby pluton shape of some sort to represent granites? My first thought was that the white spaces were separating the groups until I read further and realised which formations belong where. I think it would help with understanding the regional geological context if this figure was made more like a standard strat column with ages and graphics to represent overprinting (from granites for eg).

Figure 3 - what is the white polygon on this image? Please specify in the caption or in the legend. I can see the phrase “RoI for interpretation and inversion” What does ‘RoI’ mean? It doesn’t appear anywhere in the MS.

- Its probably personal preference, and I get that sometimes greyscale can help draw out specific features, but there is a lot of variability in this dataset that could be visualised with a pseudo colour ramp (or similar) with a sun angle. I know the authors are aware of this, I guess its just something I think they should consider.

Figure 4 - The caption says that the 500m UC is on the right, when its in the center. Please fix (or just subdivide these figures into a, b and c).

- should read : ‘examples of types of anomalies’

- I get that you’ve included the coords for the location center, but ideally these figures should have coordinates.

Figure 6 Fix units – should be ‘g/cm³’

Figure 7 - There is almost no difference between the lines representing the dykes, compositional layering and the fault/fracture. I also think this figure is way to small -

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there is an impressive amount of detail here in the structural interpretation, but the value is lost in my opinion because the figure is too small to appreciate it. The dykes have a dot to discriminate them, but again, they're so small on the map, you can't tell which is which. Making it larger would help discriminate between these lines, but even then, I still think it would be difficult. Suggest the interp is made larger AND the colour of the lines is changed so its more obvious.

- Yellow lines are explained in the text, but please include a description in the caption here (or in a legend)

- I also think these potential field images (especially the mag) could do with a different colour stretch. The colour table is fine, but it looks like a linear transform was used to distribute the colours? Changing this to an equal area transform (or similar) would distribute the colours much more and highlight more variability. As is, its very difficult to see how the structural interpretation was made from the imagery.

- There is no legend for figure 7a - what do all the colours mean? Is the legend the same as for fig 1? The colours and shapes of geological units look very similar to figure 1, but some of the colours look different to me. For example, the Miningarra Gp (I think it is?) which is mostly to the east of the Yerrida Basin is a greyish-blue colour in fig 1, but is different here in 7a. Same thing with some of the Bryah rocks on the NW margin of the Yerrida Basin. I suggest the colours be made consistent, and the caption at least refer to the legend in figure 1. Otherwise what's the point of having this geological data here at all?

Figure 8 - What are all the dashed lines? Faults? If so, how have they been interpreted? From this AEM data? Or were they interpreted from some other dataset and included here?

Figure 9 - Love a good Noddy model

- Change 'gm/cm3' to 'g/cm3'

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- Ideally, the figure in 9a should have a colour bar showing magnitude of gravity values.
- Is there any significance of the colours here in 9c? Why is the side of the model blue (and part of the dome?)

- Please add specifications of the model either here or in the text. What is the cell size for the model? What are the dimensions of the block?

Figure 10 - Is there any vertical exaggeration on these models? Or are they all 1:1? There is a vertical dimension, but no horizontal dimensions.

Figure 11 - Nice model – shows a pretty good fit to both the mag and gravity data.

- I think it's best to keep the units consistent. All your density measurements above have been presented in g/cm^3 , but here you have the densities in kg/m^3 . Suggest choosing one, and sticking to it.

- It looks like there is topography included in this model and I'm guessing that you're modelling Bouguer gravity data? If so, you either need to use residual densities (measured density – terrain correction density), or make the air block zero g/cm^3 . I don't necessarily think this needs lengthy explanation, but it's not clear to me how this was handled.

- I really like how the petrophysical data are visualised here in 11c, but I'm a bit uneasy about not seeing the modelled petrophysical values. It's very difficult to appreciate what the actual values are from looking at the colour legend bar for mag susc/density. Do ALL petrophysical values come from the mean values in table 1? I'm guessing a range of values was chosen within reasonable bounds of these petrophysical values? Perhaps if another column was added to table 1 to show what the range of modelled values were?

Figure 12 - I'd prefer to see this figure as large as possible (full page width). There is a lot of detail and it's very difficult to see as is. This would enable you to label all the units instead of just the main ones. What are the pink/orange units for eg?

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Figure 13 Its difficult to see some of the details in this figure – particularly the distribution of mafics, and even more tricky in the circled areas of interest. Ideally it should be bigger, but I’m not quite sure how you manage this though. The only way I can thin of is to split the figure, but there is value in having them all together as I’m sure the author’s have surmised.

Figure 14 - Presume the top figure is ‘14a’ ? Please include a label.

- you say here in the caption ‘ blue = density lower than that required by observed gravity’ and then go on to say ‘ . . .the white dashed line that indicates the position where a portion of material needs to be removed to result in a reduced mis-fit’. This area is blue, so I presume this area has a density lower than that required by the observed gravity? Doesn’t this mean you have to add material?

Figure 15 Why are the cells here different colours? What do they mean? You say they’re colour coded, but where can we see what the colours correspond to? I’m happy with these cells showing the increased distribution of mafics from what was previously interpreted, but if there is no mention of what these colours are, why bother distinguishing them at all?

Figure 16 Like the others, I think it would help if this figure was larger. Perhaps a full page figure with the 4 parts in one column? As is, its difficult to see the details.

Figure 19 Please label these with A and B.

Table 1 - The units here for density are listed as gm/cm³ which is inconsistent with what is in the text (gms/cm³). Besides, as mentioned above, I suggest you align to the SI symbol for grams and use ‘g/cm³’

- Please correct spelling ‘Susceptibilty’ should be ‘Susceptibility’

Appendix - I don’t get what Rock W and Rock E mean? Is this just the rocks that are east or west of the specified structure? If so, suggest replacing ‘w’ with ‘west’ would avoid confusion here (same with ‘E’).

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