Drillhole constrained 3D basement model of the Surat and Gunnedah basins

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Abstract

A drillhole constrained 3D basement model has been developed for the Surat and Gunnedah basins in New South Wales. The model is aimed at recognising the thickness of post-Carboniferous cover overlying the Lachlan and Thomson orogens. The model is based on data from a number of previous studies, supplemented by additional drillhole constraint in key areas to the south of the Surat Basin where cover is expected to be relatively thin, and where potential may exist for mineral exploration. The development of the basement surface involved validating pre-existing datasets against the Geological Survey of New South Wales (GSNSW) drillhole database and GS reports, and filling gaps in the constraining dataset by assessing and collating further drillholes from the GSNSW records. The constraining data was used to create 2 geological volumes: Basin (Surat, Gunnedah and Bowen Basins) and Basement (Lachlan and Thomson orogens). A 2D contour map was produced by calculating the vertical distance between the topographic surface and the basement surface and is included along with the lithological volumes and model confidence volumes in the accompanying data package.

Introduction

This document outlines the development of a 3D volume model of the Surat, Gunnedah and Bowen basins in New South Wales (Figure 1). The model is aimed at constraining the thickness of Permian to Quaternary cover overlying orogenic basement (Lachlan and Thomson orogens). The work builds on a number of previous basement studies in the Surat and Gunnedah basins (Encom 1995, SRK 2004) that were focussed towards hydrocarbon exploration, and therefore on the deeper parts of the basin. This model will bring together the previous basement interpretations and provide further regional scale basement depth constraint in the southern Surat Basin and south-western Gunnedah Basin (Nyngan, Narromine, Dubbo and Gilgandra 1:250 000 map sheets), which were not examined in the previous studies.

The southern and western margins of the Surat Basin are the particular focus of this study due to potential relatively shallow cover, and therefore opportunities to explore for mineral systems undercover. The north- to north-northwest trending Ordovician to Devonian rocks of the eastern Lachlan Orogen, which host a wide range of gold and base metal systems, plunge undercover on the Narromine and Dubbo 1:250 000 map sheets. Magnetic and gravity data show the structural trend of the eastern Lachlan Orogen is continuous to the north below the Surat Basin. Given the mineral endowment along structural trend to the south, it is not unreasonable to expect significant mineral systems to exist below the Surat Basin. However, the key first step in assessing any opportunity for economic mineralisation below the Surat Basin is recognising the thickness of the overlying cover.
Figure 1: Exposed extent of the Surat and Gunnedah basins in NSW. The Surat Basin stratigraphically overlies the Gunnedah Basin (in the southeast) and the Bowen Basin (in the northeast).

Modelling Workflow

The 3D mapping process under-development by GSNSW involves a broad project workflow (Figure 2) that sets out different stages of model development, with a series of sub-workflows that deal with specific aspects of the modelling. Sub-workflows are being developed for stages 4, 5 and 6 of the project workflow. Much of the work described here is focused toward stage 4b of the project workflow (basin volume modelling), and therefore on the requirements of constraining the contact between the pre-Permian basement (Lachlan, Thomson and New England orogens) and Permian to Cretaceous basin cover (Gunnedah, Bowen and Surat basins). This workflow is detailed in the basin volume modelling section.

The 3D project workflow recognizes the scalar and interlocking nature of orogenic provinces and basins, as well as the structures and stratigraphy contained therein. It aims to prioritize the large scale features then work down in scale to infill with increasing detail. That said, it is expected that additional constraints and improvements in interpretation (resulting from
more detailed modelling) will be fed back up the workflow to refine the large scale features where applicable.

A key feature of the workflow is the confidence model, and all stages of interpretation and modelling feed attributed point data into the confidence model. Any model produced will include a confidence model, irrespective as to whether subsequent stages of the workflow have been completed (i.e. if a model has been produced it will have a confidence model).

The outcome of the 3D project workflow is an integrated model. This may comprise as little as a crustal structure model or basin volume and corresponding confidence models. However, it is intended that all models produced within the workflow can be visualized together to form a single, seamless model.

Figure 2: GSNSW 3D mapping project workflow. The work stage highlighted in blue is the primary focus of this document and the sub-workflow will be set-out in more detail.
Pre-model planning

This model was initiated due to a request for information on cover thickness overlying the northern extension of the Lachlan Orogen below the Surat Basin. A previous, first pass model of the pre-Permian basement surface across New South Wales (Robinson 2014) did not contain any constraint on the shallow southern extent of the basin between the exposed Lachlan Orogen and the Thomson Orogen bore hole study (Dick 2009).

During scoping of possible constraints on the basement in the area, a number of pre-existing basement studies were identified (Encom 1995, SRK 2004, SRK 2010), along with a significant number of drillholes that would add solid constraint to the basement interpretation. Due to timing constraints and given the pre-existing basement constraints, interpretations, and the objective of constraining the shallow southern extension of the basin, the focus of this work was set on filling the interpretation gap between the Thomson Orogen/Encom basement studies and the northern margin of the Lachlan Orogen (essentially basement on the Nyngan, Narromine, Dubbo and Gilgandra 250K map sheets). However, the pre-existing basement interpretations would be checked against drillholes in the GSNSW database.

While some further constraint may be gained from reflection seismic surveys and depth to magnetic source modelling, this model will focused on identifying, interpreting and digitizing drillhole data. The integration of drillhole data is a very time consuming process, but will provide constraint for any further geophysical modelling (seismic, magnetics and gravity) in later model updates.

The northeastern extension of the Surat Basin in NSW was modelled as part of the Southern New England Orogen model. The Mooki Fault should be a common surface to both models allowing integration of the two (provided translation to a common coordinate system is undertaken).

The coordinate system for the model will be GDA 94, MGA zone 55. The easternmost extension of the model actually occurs in MGA zone 56. However, as the majority of the model occurs in zone 55, and no joins or breaks are to be include in the model, all data will be translated to zone 55.

Data sourcing and integration

The current Surat-Gunnedah basement model has been developed using the integration of data from a number of previous studies, GSNSW mapping data, and drillhole constraints identified and compiled during this work. Some seismic data merged from the Southern New England Orogen modelling has also been used, however, further seismic interpretation and magnetic or gravity modelling needs to be added in future updates. A summary of the data used to constrain the basement model is provided in table 1.
### Table 1: Summary of source data

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<thead>
<tr>
<th>Data Type</th>
<th>Name</th>
<th>Source</th>
<th>Date</th>
<th>Notes</th>
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<td>Numerous</td>
<td>DIGS</td>
<td></td>
<td></td>
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<tr>
<td>Petroleum drillholes</td>
<td>Numerous</td>
<td>DIGS</td>
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<td>Numerous</td>
<td>DIGS</td>
<td></td>
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<td>Surat Basin Geophysical Reprocessing and assessment (Encom Technology)</td>
<td>Encom/DIGS GS1996/049</td>
<td>1995</td>
<td></td>
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<tr>
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<td>SRK</td>
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<td>2006</td>
<td>11 lines</td>
</tr>
<tr>
<td>Seismic</td>
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<td>Eastern Star Gas Ltd/DIGS GS2012/0140</td>
<td>2009</td>
<td>2 lines</td>
</tr>
<tr>
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<td>Surat Gunnedah DTM 1000m</td>
<td>Geoscience Australia 9s DEM (GADDs)</td>
<td>2008</td>
<td>Regrid of the 9 second DEM data</td>
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<td>Map</td>
<td>Surface Geology of New South Wales 1:1500000</td>
<td>GSNSW</td>
<td>2010</td>
<td>Basin boundaries</td>
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</table>

### Previous studies

Five previous studies of basement depth and/or geology within the area of the Surat, Gunnedah and Bowen basins were identified while searching the GSNSW records. A validated merge of some of these datasets was used as the base constraining dataset to produce a pre-Permian basement surface in this study. A summary of the basement interpretations and their use in this study is provided below.

**ENCOM 1995**

A basement interpretation and depth contour map was produced as part of an investigation of the Surat and Gunnedah basins aimed at evaluation of the petroleum potential and constraining geophysical datasets that existed at the time. The basement surface interpretation was based on approximately 300 petroleum wells and water bores. Drillholes in this study were examined for basement and used where the basal intersection could be identified as metasediments, granites or probable igneous intrusions. Other holes were recorded where they contained basal volcanics (of Carboniferous or early Permian age) and used to constrain the minimum depth to basement.

Checking of the petroleum holes and some water bores used in this study was undertaken to confirm the validity of the basement interpretation. Drill logs for holes used in the study were
accessed via DIGS, checked, digitised and plotted in 3D against the basement contours (Figure 3). Checking of holes used confirmed the accuracy of the basement depth recorded for the drillholes (relative to the topographic height of the collar). When more drillholes were later imported into the model, the basement interpretation was found to be valid where a good distribution of drillholes constrained the original interpretation. Some areas in the south that did not have good constraint in the original study were found to be inconsistent with basement recorded in the additional drillholes. Basement contours were removed from the dataset in the poorly constrained areas of the original study.

Figure 3: Extract from the basement contour map produced by Encom (1995) validated against petroleum drillholes sourced from DIGS. Drillhole reports from holes used to constrain the original contour map were examined against the basement depth and contours on the map. An initial basement surface was generated from the contours and validated against the imported drillholes.

SRK/SeeBase™ contours

Two SRK studies produced Seebase™ (economic basement) contours of the Gunnedah basin. The SeeBase™ modelling used magnetic and gravity modelling constrained with open file bore hole and seismic lines as well as regional structural and tectonic interpretation. In the 2004 study, economic basement was defined as the base of the Permian and the early Permian volcanics were included in the basin sequence. However, in the 2010 study, economic basement was defined as the top of the early Permian volcanics or the base of the Permian where the volcanics are not preserved. Therefore, where the two basement interpretations overlap, there is some difference in the surfaces due to the ‘basement’ definition (as well as possible non-unique solutions from the magnetic and gravity modelling). In the 2004 study 7 drillholes intersecting pre-Permian basement below the Gunnedah Basin were recognised, while in the 2010 study, 8 holes were recognised as intersecting pre-Permian basement and 67 intersecting the early Permian volcanics.
The basement contours from the 2010 SRK study were not used to constrain basement in the current modelling as the target basement of the study was the top of the early Permian volcanics.

Relative to the Encom (1995) contours, the basement contours from the 2004 SRK study appear to be a better fit to most of the drillholes (coal and petroleum) imported in the current study in the central and eastern Gunnedah Basin. On the western side of the Gunnedah Basin, the interpreted basement depth is broadly similar in the two interpretations. As such, contours from the 2004 SRK basement study were used as the base constraints in the deeper Gunnedah basin. However, it is found that the shallow margins of the Gunnedah and Sydney basins are poorly constrained in this dataset (relative to drillholes imported in the current study and to the topographic surface). Therefore most of the shallow contours (greater than 200m above sea level) were removed from the data.

DICK 2009

This study produced an economic basement surface for the Surat and Eromanga basins based dominantly on drillholes (petroleum, mineral and water bores) along with a limited number of seismic lines. Many of the drillholes used in the Surat Basin are the same as those used in the Encom (1995) study, and as such the basement contact points are generally consistent. There are 9 contact points in a small area in the northwest of the basin that differ significantly from the Encom contours by between 300 to 500m vertically. The drillhole logs for these holes recorded ‘rock’, ‘shale’ or ‘sandstone’. The holes are on an elongate magnetic high, however, other drillholes on the same magnetic high to the north-northwest do not intersect anomalously shallow basement. Because of the low confidence in the rock descriptions in the drill log, and the lack of correlation with any geophysical anomaly, these points have not been used in current basement model.

HILYARD ET AL, 1996

This study produced a basement geology interpretation on the Narromine and Nyngan 1:250 000 map sheets from magnetic and gravity data but did not estimate cover thickness. However, a number of stratigraphic drillholes were drilled based upon this interpretation and were reported in the work (and used in the current study).

Data/drillhole searching and filtering

Vast geological regions such as the Surat and Gunnedah basins can have considerable amounts of sparsely distributed data. It is estimated that there are at least 20 000 drillholes in the focus area of this study. Finding, reducing and digitising the drillholes that will aid the objectives of the work is a key aspect of the workflow (and the majority of time spent).

Most of the map data and seismic lines can be filtered in ArcGIS using spatial queries/selection. In the current work for example, bedding measurements from the map data were selected within a 1km buffer of the mapped basement-basin interface, and then refined
by selecting only those that occurred within the basin (to attempt to get representative dip measurements of the basin around its margin).

The following procedure summarises the method used to search, filter and record drillhole data to constrain basement. Most of the new basement constraint produced in the current study was collected following this procedure:

1. Identify a 250k map sheet to work on.
2. DIGS search for reports and previous studies on the map sheet that may be useful in constraining basement. Start with the old DIGS system and search by Map Sheet and only search for “Department Map Collection” and “Department Publications” using the check box on the right hand side. Datasets that will be useful include:
   - GIS data packages
   - Drillholes or drillhole records
     - You can find previous studies which may list basement intersecting drillholes known at the time of the study.
   - Basement contour maps
     - Some old reports contain basement contours maps developed from drillholes and geophysics
   - Geophysical interpretations
     - In some cases geophysical interpretation of basement rocks has been undertaken in previous work. This is very useful for the interpretation, and also for records of what data was used.
   - Geoscience data packages
     - These may contain a lot of the data you are looking for already compiled.
3. Database query and select all drillhole records on the map sheet.
   - Use the maximum and minimum latitude and longitude for the target map sheet.
   - Export the data into a spreadsheet.
4. Add the drillholes to an GIS project containing a polygon of the basin. Save the drillhole collar points as a shape file (and add to map).
5. Make the drillhole collars the only selectable layer and select the collars inside the basin polygon (using select by location). Export the selected points and open as a new layer. Export the attribute table to a new spreadsheet.
6. Start looking at drillhole reports, begin with minerals holes (so query the holes by the project field), then by petroleum holes and finally coal holes (but start with the deepest coal holes as most will only be shallow and not help constrain basement).
   - When looking for basement intersections you can essentially remove all the mineral sands drillholes from the dataset.
   - It is best to import all coal drillholes into the model once a preliminary basement surface is constructed. This is described further in the section on use of non-basement intersecting drillholes.
   - Look at DIGS reports for each drillhole sourced using the GS report number or license/tenement number where no GS report number is provided.
- Mark each drillhole in the spreadsheet as it is checked with an additional field indicating basement intersecting, non-intersecting or unknown (where the log can’t be found or deciphered).

7. Generate new collar, survey and interval files for the data. Include only the holes that are found to intersect or not intersect basement (do not use the unknown holes).
   - In the interval table, use a lithology field that contains only ‘Cover’ or ‘Basement’.
   - Additional fields can be added to the lithology table, however, a good idea is to record the basement lithology (even if just the lithology at the fresh basement interface). This information may be useful for geophysical modelling and regional basement geology interpretation.

8. Note that where masses of drillholes exist in a small area it is probably only necessary to collect a representative data set. For a regional scale model highly detailed information on a single exploration target area is not necessary and it is better to focus on a broader distribution of constraining points. Where concentrated drillholes occur, select specific (and spatially distributed) holes using the drillhole collars plotted in the ArcGIS workspace.

9. When all data on the map sheet is compiled, import into the 3D package and check for errors. In Leapfrog® Geo the drillhole error checking can be used to identify errors in the data, which are best fixed in the original spreadsheets.

Data interpretation and gaps analysis

The current basement interpretation is driven dominantly by the drillhole constraints. The interpretation of basement relative to cover rocks within drillhole logs is the key variable in developing the basement surface. In some logs the intersection of basement will be noted, while in others the contact needs to be interpreted from the lithological and structural descriptions.

The main descriptive indications of basement intersection noted in the Surat-Gunnedah basement study are:

- Entering a palaeoweathering profile at depth
- Intrusive rocks
- Metamorphic rocks (slates, schist)
- Cleavage or schistosity
- Major changes in core-bedding angle over short intervals

All contacts are attributed with a confidence level. Most of the indicators listed above would provide high confidence (levels 1 or 2), particularly when combinations of these indicators are noted. There are other indicators that may be encountered, but which may not provide a definitive indication of basement. In these cases the contact points are attributed with a lower
level confidence (levels 2, 3 or 4) so they can be retained in the dataset. Some examples may be:

- Intersection of thick volcanics at the base of the hole.
  - This could be basement, or the volcanics known to occur at the base of the Gunnedah Basin. Examination of the mapped distribution of basal volcanics in SRK (2004) or Encom (1995) reports may assist in recognising if the volcanics are likely to represent basement.

- Conglomerate with intrusive or metamorphic clasts.
  - Basal conglomerate with basement clasts are common in the Surat Basin and may be an indicator of proximity to basement.

**Using non-basement intersecting drillholes to constrain basement**

Drillholes that do not intersect basement provide valuable constraint on the minimum possible depth of cover and have been added to the Surat-Gunnedah basin model. As illustrated in figure 4, the use of holes that do not intersect basement can dramatically improve the basement interpretation by forcing the surface downward below known cover. Two types of non-basement intersecting drillholes are used to constrain the model: coal drillholes and viewed minerals and petroleum holes.

**Minerals and Petroleum holes**

For the minerals and petroleum holes, only those that have been checked and confirmed as either intersecting or not intersecting basement are used to constrain basement. Holes that are not checked cannot be used as these drillholes could potentially extend to significant depths into basement.

**Coal drillholes**

Coal drillholes provide an easy constraint on minimum basement depth without the need to look at most drill logs. They are particularly useful for forcing the basement surface down around the shallow basin margins. All coal holes are imported initially with the lithology table containing only ‘cover’. It is assumed that most holes will not enter basement, and if they do, will terminate at or very close to the basement contact. The coal holes should therefore all be contained in the basin volume when the interpolation is completed.

After a first pass basement surface interpolation is complete, holes that are close to or intersect the basement surface should be checked for basement. Some holes will intersect basement, modelling using all the borehole data prior to checking the drill logs filters the dataset significantly.
**Figure 4:** Schematic example of the influence of including drillholes in an interpolation that do not intersect basement. The first interpolation will be based on 3 points that the surface must conform to. With no constraint in between the basement intersecting drillholes the resulting basement surface will largely be planar. The second interpolation uses drillholes that do not intersect basement and while there are no contact points in the drillholes to conform to, the surface must occur below the drillholes. This combined with the basement intersection points will produce a much better result.

**Data Gaps**

Figure 5 plots the distribution of significant gaps in the drillhole basement constraints. The gaps are ranked with priority towards the likely shallow parts of the basin. No seismic data exists in the 3 priority 1 areas, and constraint may only be provided by identifying any further basement intersecting water bores, or through modelling of the gravity and magnetic datasets.

The 9 rock/basement intersecting holes in the Thomson Orogen dataset (Figure 5; Dick 2009) may warrant further investigation. These basement intersections if correct indicate a significant basement high and potential shallow cover.
Figure 5: Summary of significant data gaps in basement constraints across the Surat Basin.

Basin Volume Modelling Workflow

The basin volume modelling workflow (Figure 6) sets outs the basic process and constraint requirements to generate a 3D basin volume model as applied to the Surat-Gunnedah basement model. This workflow is focussed towards a dominantly drillhole constrained basement model and some additional stages may be required in other basins (for example in basins constrained dominantly by seismic). Further stages or sub-processes are likely to be added in future modelling where additional datasets and methods are available (e.g. addition of magnetic and gravity modelling).

Figure 6: (Pages 15 to 18). Workflow used to generate Surat-Gunnedah basement model.
Search DIGS for relevant reports using key words (e.g. basin, province etc) and by individual map sheets. Look for pre-existing basin and basement interpretations. Existing work may provide constraints for a working basement surface and name drillholes and seismic lines used to constrain basement.

Software: Web-browser
pdf reader
ArcGIS®

DIGS search on “Surat Basin” then “Narramin” sheet identified pre-existing basement interpretations with names and details of constraining drillholes.

Query drillhole database, filter drillholes and check for basement intersections. This is a very time consuming process and best done by prioritizing mapsheets and deeper holes. Drillholes will need to be checked from the DIGS records and tables of collar, survey and lithology intervals (cover or basement) recorded.

Software: Web-browser
pdf reader
ArcGIS®
Spreadsheet

Subprocesses: Spatial searching and filtering
Depth filtering
Location checking
Coordinate system translations
Drill hole lithology interpretation
Confidence attribution
Generating collar Z coordinate from topography

See detailed notes on drillhole searching and filtering

Geoscience Australia 9 second DEM data converted to point (X,Y,Z) data and resolution reduced (to 1000m grid). Point data imported into Leapfrog and used to generate topographic surface.

Software: ArcGIS® (DEM to ascii pointset).
Leapfrog® Geo (Surface interpolation and clipping)

Subprocesses: Coordinate system translation.
Conversion of raster to point or multipoint data.
Surface clipping using geographic boundary cutters (e.g. coastline, state border).

Regridded 9s DEM
X, Y, Z 1000m DTM Pointset
1000m DTM Mesh

Holes collared in target basin checked in DIGS reports, DH data recorded in spreadsheet (both basement intersecting and non-intersecting).
Lithological (basin margin) linework extracted from seamless geological mapping along with any contact bedding measurements. Linework imported into leapfrog (as shape file), draped onto topographic surface and polyline extracted. Structural data formatted in spreadsheet and imported. Check that the linework has draped onto the topography perfectly (to avoid later interpolation issues).

**Software:** ArcGIS®, Spreadsheet, Leapfrog® Geo.

**Subprocesses:** Linework merging and removal of excess nodes
- Generate Z coordinate for each datapoint by importing as pointset, draping on DTM re-exporting. Merge with original data in excel/csv file.

Seismic basement interpretation constrained against drill holes and basin margins at surface. Time depth conversion of seismic basin line work.

**Software:** SKUA®

**Subprocesses:** Seismic velocity data collection
- Seismic velocity model generation

Faulted basement interpretation

Import all drillhole data, basement contour points (from previous studies), depth converted seismic linework/points into leapfrog and check data consistency. Check or recheck drillholes and contour data or remove constraining points that conflict with confirmed drillhole contacts.

**Note:** both basement intersecting and non-intersecting drillholes should be imported (See detailed notes on use of non-basement drillholes for constraining cover).

**Software:** Leapfrog® Geo, Spreadsheet, ArcGIS®, DIGS.

Checking imported drillholes against basement contour sourced from DIGS reports. Holes are checked and confirmed and basement contours in affected areas removed when they do not match confirmed drillholes.
Import any basin bounding faults as a mesh from adjoining models. Faults can be constrained and generated within the basin model, however, given the relative shallow nature of basins in comparison to major terrain bounding faults they are best developed in deep crustal models and transferred to adjoining models.

**Note:** The same mesh must be used in both models so that the models can be joined with precision.

**Software:** Leapfrog® Geo, FME® workbench

**Subprocesses:** Coordinate system translation

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Set up geological model encompassing the objective X,Y,Z extents of the basin. Set topographic and lateral extent surfaces to further control model boundaries (such as state borders)

**Software:** Leapfrog® Geo

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Generate any bounding faults in geological model from imported fault meshes. Activate the faults in the model (and apply chronology if cross cutting relationships exist). The model will now be sub-divided into a number of fault blocks in which the lithological modelling will be undertaken.

**Software:** Leapfrog® Geo

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Generate new lithological interface in the target fault block using the basin margin lineework, depth converted seismic basement linework and drillholes. The drillholes should only have 2 lithologies (basement and cover) which can be done either in the original imported logs or by grouping lithologies. Model the drillholes using base lithology contacts. This way the holes that only contain ‘cover’ will influence the interpolation of the basement surface.

**Software:** Leapfrog® Geo
Refine the interpolation. Ensure the surface is snapping to the drillhole contact points and surface linework. Check the input data relative to the surface generated and re-examine drill holes where necessary.

**Software:** Leapfrog® Geo

Generate cover thickness contour map. Done by calculating the vertical distance from the basement to topographic surface.

**Software:** SKUA®

Contoured vertical distance between basement and topographic surfaces draped on topography and exported as 2D contour map.

All constraining linework should be attributed in object naming with confidence level. Export all constraining lines, points and structural data to spreadsheets and merge all data together using the confidence attribute and a new field corresponding to each node (X,Y,Z) in the spreadsheet.

**Software:** Leapfrog® Geo, SKUA® (attribution in naming of constraints) ArcGIS® (filtering and export of attributed map line work) Spreadsheet

**Sub-processes:** File organisation and merging process. Merge all files of the same confidence level together (using dos) then import into excel and attribute in additional field against each X,Y,Z point.

Re-import the confidence attribute file into Leapfrog® and use to generate interpolation within the model volume.

**Software:** Leapfrog® Geo

Attributed point data which is then interpolated to produce 3D contours of confidence (volumes)
Confidence Model

The aim of applying interpretation confidence mapping to the 3D modelling is to develop a standard system to visually represent constraint location, and constraint quality within models that is broadly similar to the representation of confidence in traditional mapping. The confidence model will allow end users to quickly identify areas of the model that are well constrained, and those that are poorly constrained with a scale in between of incrementally reducing confidence.

Constraint confidence is rated on a 1 (high confidence) to 5 (low confidence) scale. The constraint attribution scheme used for all data types is shown in Table 2. Attributed constraining points are imported into the model as points then interpolated to produce six 3D volumes (Figure 7c).

Table 2 (Page 20): Standard confidence attribution scheme at July 2015.
<table>
<thead>
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<th>Data Category</th>
<th>Data Type</th>
<th>Confidence Level</th>
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<td>From seamless attributes</td>
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<td>Approximate</td>
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<td>Measurement is inferred from nearby measurements</td>
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<td></td>
<td></td>
<td>Inferred</td>
<td>5</td>
<td>Measurement is estimated base on broad architecture and distal constraints on object strike and dip.</td>
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<td>Accurate</td>
<td>1</td>
<td>Contact or specific fault zone recorded or observed in drill hole record</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Approximate</td>
<td>2</td>
<td>Contact or fault zone recorded or observed in drill hole record that is likely to be the target contact or fault</td>
</tr>
<tr>
<td></td>
<td>Geophysical processing</td>
<td>Constrained</td>
<td>2</td>
<td>Contact/fault constrained by other data (Drill holes, Mapping, seismic)</td>
</tr>
<tr>
<td></td>
<td>Multiscale edges</td>
<td>Constrained</td>
<td>2</td>
<td>Contact/fault not exposed at surface but is consistent with other nearby contacts/faults or is evident in other datasets (e.g., seismic)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constrained concealed</td>
<td>3</td>
<td>Contact/fault inferred only from the Mag or Grav data.</td>
</tr>
<tr>
<td></td>
<td>Forward modelling</td>
<td>Constrained</td>
<td>3</td>
<td>Constrained by other data</td>
</tr>
<tr>
<td></td>
<td>and inversion</td>
<td>Unconstrained</td>
<td>5</td>
<td>Not constrained by other data</td>
</tr>
<tr>
<td></td>
<td>Geological Cross sections</td>
<td>Constrained</td>
<td>2</td>
<td>Section constrained by surface mapping and measurements, seismic and/or drillholes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Map/Geophysics Constrained</td>
<td>2</td>
<td>Section constrained by surface mapping and geophysical modelling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seismic constrained concealed</td>
<td>3</td>
<td>Section produce from seismic data +/- drillhole data in concealed terrain.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Map Unconstrained</td>
<td>4</td>
<td>Section produced only from surface data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unconstrained</td>
<td>5</td>
<td>Interpretive section where surface mapping or seismic data is unavailable.</td>
</tr>
</tbody>
</table>
Integrated model (preliminary)

Outputs of the Surat-Gunnedah basement 3D model are shown in figure 7. The model consists of basin and basement volumes bound to the east by the Mooki Fault (Figure 7A). A 2D cover depth contour map has been generated by calculating the vertical distance between the topographic surface and the basement surface (Figure 7B). All the attributed constraining points used to generate the lithological volumes have been interpolated to produce a confidence volume model (Figure 7C).

Figure 7 (Page 22): Outputs of the Surat-Gunnedah basement 3D model. A. Basin and basement lithological volumes. B. 2D contour map of cover thickness draped on the digital terrain model. C. Confidence volume model.
References


