Tutorial case study F (Purnama)

Parent topic: 3D GeoModeller User Manual and Tutorials

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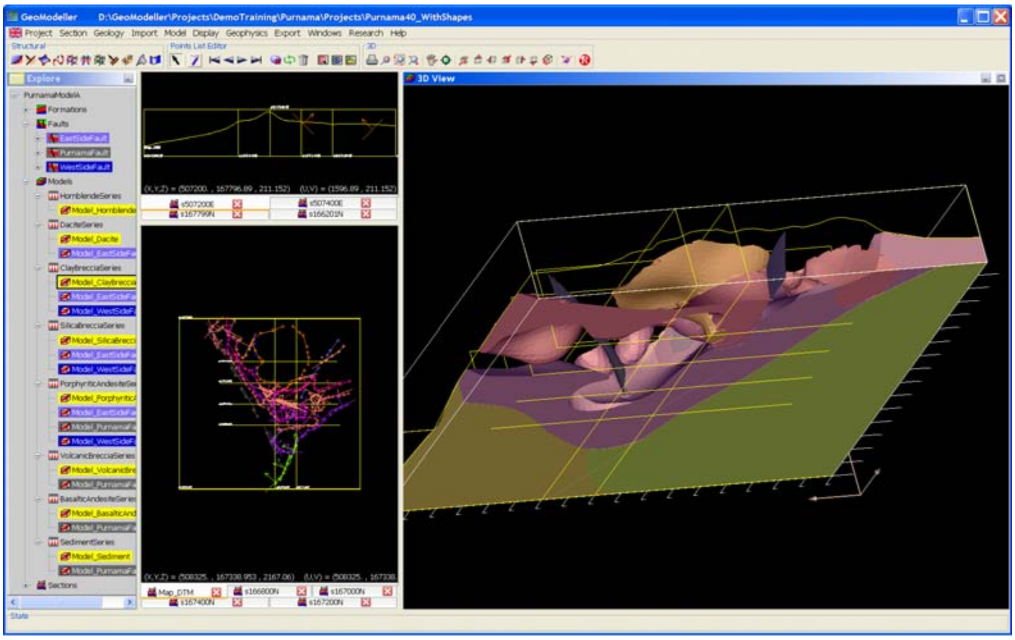
Purnama Gold Deposit
—Modelling complex, multiply-intruded, multiply-brecciated geology.

Case Study F Introduction

This advanced tutorial assumes the project geologist has a basic understanding of building a 3D geology model using the 3D GeoModeller software. Whilst the tutorial illustrates the building of a project from scratch, there is no commentary about how to do the basics. Rather, the emphasis is on the methodology of building a project – in an area of complex geology.

Note that this tutorial illustrates just one way to build a 3D model. Alternative approaches could be used. For example, the approach here has been to firstly model much of the geology, and add the faults towards the end of the model-building process. By contrast, there is a valid school of thought which would recommend modelling the major faults first, and then modelling the project geology around those.



A series of GeoModeller Projects have been created … so you can start with the basics … or skip to progressively more completed examples by opening subsequent model projects.

Geology of Purnama—Abstract

The following abstract is from Levet, B., Jones, M and Sutopo, B., 2000?, *The Purnama Gold Deposit in the Martabe District of North Sumatra, Indonesia*, currently published on the SMEDGE web-site:

The Martabe high sulphidation gold deposits are hosted in a sequence of Tertiary volcanic and sedimentary rocks proximal to a fault splay that forms part of the Great Sumatran Fault complex. Episodic fault activity, related to wrench tectonics associated with the oblique subduction of the Indian Australian plate below the Eurasian plate, has been responsible for pulses of high level magmatism and development of multi-stage phreatomagmatic breccias, flow dome complexes, hydrothermal alteration and gold mineralisation observed in the district.

Local structural architecture is consistent with the dextral strike slip tectonics observed on a regional scale with a major northwest to north-northwest fault set forming a prominent scarp that bounds the west side of the Purnama deposit. A well developed conjugate set of northeast extensional faults bisect the stratigraphy immediately to the east. These faults provide fluid channel ways that have localised and superimposed multiple alteration and mineralisation events on the rock mass.

As indicated, the principal host rocks are series of phreatomagmatic diatreme breccias and dacite flow domes. These have been intruded into and through a sequence of gently dipping mudstone, siltstone, sandstone and andesitic lava.

Multi-stage acid-leaching hydrothermal alteration events have produced widespread texturally destructive silicification. This has resulted in large volumes of vuggy silica with a tabular geometry cutting various lithologies and enhancing the permeability of these host rocks for later higher grade gold bearing fluids.

Gold mineralisation occurs in a number of deposits over a strike length of seven kilometres. The most significant and best defined of these is the Purnama deposit, where a resource of 66.7 million tonnes containing 1.74 g/t Au and 21.5 g/t Ag for a total of 3.7 million ounces of gold and 46 million ounces of silver has been defined by diamond drilling.

Purnama GeoModeller Tutorial—Preface

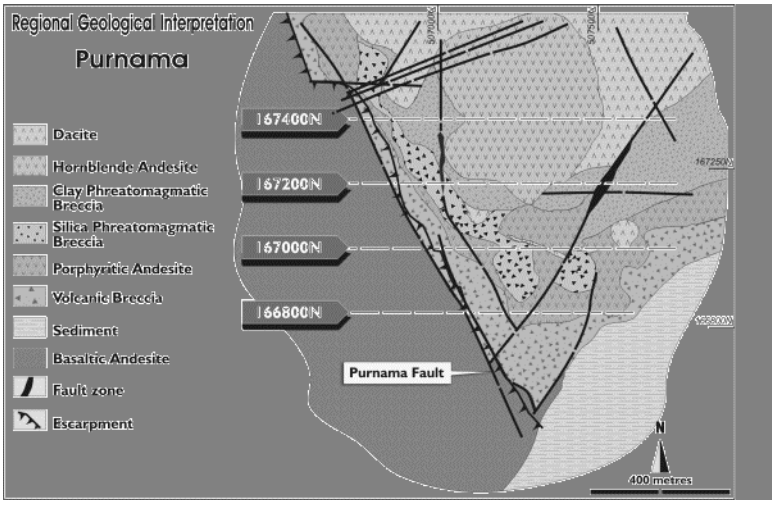
The geology ‘inputs’ to this tutorial are the simplified geology maps, sections and stratigraphic succession presented in the above Levet et al. paper. It is recognised that these are themselves an interpretation of original geology observations in mapping and drill-core – and thus are not ideal inputs to the process of building a geology model.

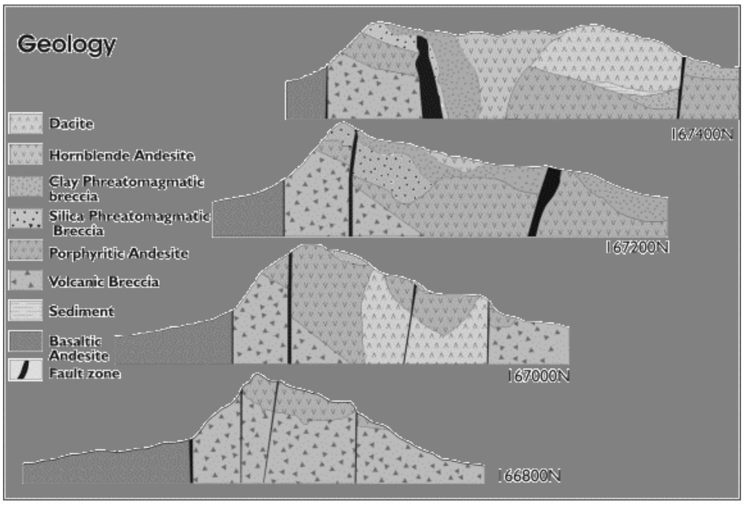
Nevertheless, these simplified data are publicly available – and the goal of the exercise is to demonstrate that a credible 3D model can be constructed rapidly even in an area of complex geology.

The source data, then, are five bit-map image files of simplified geology. The four geology cross-sections have been located as accurately as possible relative to the geology map image, and a rough topography DTM has been created to suit the elevations presented in the cross-sections. Thus – these datasets are suitable for model-building demonstration purposes only, and are not fit for any other purpose whatsoever!

Purnama Geology

The following illustrations show the geology of Purnama.





Tutorial F1—Modelling complex, multiply-intruded, multiply-brecciated geology

In this tutorial, you progressively add series into the stratigraphic column, include contact data and model each sequentially – taking the time to build the shape for each formation in a manner that you consider to be a credible distribution of rocks for that formation, and match those 'observations' that are available to you.

F1 stage 1—Create the project

Create a New GeoModeller Project—Purnama

The geology map image, and the topography datasets have been prepared for a GeoModeller project with the following dimensions.

x	Minimum	Maximum	Range
East	506,300.0	508,000.0	1,700 m
North	166,200.0	167,800.0	1,600 m
RL	0.0	300.0	300 m

Create a project that matches the dimensions.

Load the Topography DTM

As noted above, the prepared DTM data files are synthetic data only … suitable only for demonstration purposes within this GeoModeller tutorial exercise!

Load the following DTM as the topography:

GeoModeller\tutorial\CaseStudyF\TutorialF1\Data\1_Topography\RelativeTopo_25m_XYZ.semi

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A completed version of stage 1 of the tutorial is available:
GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_01_Topography\TutorialF1_01_Topography.xml
Do not overwrite it.

F1 Stage 2—Create sections and load image files

Create Four Cross-Sections

The supplied geology cross-section images have been approximately located. Create the following four GeoModeller project cross-sections – into which you will load and georegister these cross-section images.

Section	from	to	Image
s166,800N	506,672E	507,810E	**PurnamaGeologySection166800N.jpg**
s167,000N	506,671E	507,789E	**PurnamaGeologySection167000N.jpg**
s167,200N	506,680E	507,801E	**PurnamaGeologySection167200N.jpg**
s167,400N	506,664E	507,781E	**PurnamaGeologySection167400N.jpg**

Load Bit-Map Geology Image Files (Map, Cross-Sections)

Load and georegister the following surface geology bit-map image into the GeoModeller 'Map-DTM' 2D section-view:

GeoModeller\tutorial\CaseStudyF\TutorialF1\Data\2_GeologyImages\PurnamaGeology.jpg

Load and georegister the four geology cross-section images … each into the correct corresponding 3D GeoModeller cross-section 2D section-view (see table above). They are in the same folder as the surface geology image. Example:

GeoModeller\tutorial\CaseStudyF\TutorialF1\Data\2_GeologyImages\PurnamaGeologySection166800N.jpg

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A completed version of stage 2 of the tutorial is available:
GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_02_Sections\TutorialF1_02_Sections.xml
Do not overwrite it.

F1 Stage 3—Add structure and data

Modelling the geology—strategy

A useful strategy or 'rule' for building any model in GeoModeller is …

Work stratigraphically downwards through the 'erosional' or cross-cutting events

… and then …

Work stratigraphically upwards through any onlapping series occurring between these

This work order has the advantage that – by modelling the youngest, cross-cutting event or geological surface, and getting that right … then all subsequent modelling work on all other (older) events or surfaces will have no impact on that earlier modelling of the younger event.

Note that this tutorial follows one pathway towards building a 3D model of the Purnama project geology. Be aware that there are equally valid alternative approaches! This tutorial commences by modelling some of the geology, and adding the faults later; You might want to consider modelling the faults first. (Some would recommend this as a useful strategy).

Create Geology Formation Objects

Using the stratigraphic succession presented in the Purnama geology images, create a geology formation objects to be used in this project.

The completed version of stage 2 contains all required formations. We recommend that you use this as a start point for continuing the case study. Open:

`GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_02_Sections\TutorialF1_02_Sections.xml`

Do not overwrite this project file. Save a copy (**Project > Save As**) immediately and use this copy for your work in the case study.

Create An Initial Stratigraphic Pile

Create an initial stratigraphic pile. Make the 'top-bottom reference' the Bottom of formations … since intrusive and cross-cutting breccia units are more naturally contemplated in terms of the 'bottom' or the 'outside' of the unit.

Create the following series, each containing a single formation:

Series	Formation	Relationship
HornblendeSeries	Hornblende	Erode
DaciteSeries	Dacite	Erode

Note – important issue

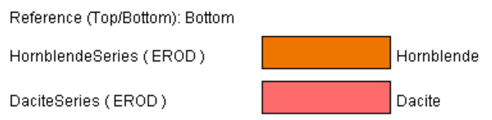
From my examination of the geology images, I chose to model the Hornblende Andesite as the 'youngest cross-cutting geological event' … and ignored the stratigraphic column presented by the project geologists (who had the Dacite as youngest). Perhaps I was incorrect in making this choice … but it seemed the more logical given what I could see in the geology image map and cross-sections.

These types of issues arise where the 'modeller' is not the 'geologist-who-knows-the-project' … and what it really highlights is that by far the better route in all 3D modelling of complex geology is that the 'model-builder' will ideally be the 'geologist-who-knows-the-project'! … then … these types of decisions are more expertly made by the person who best knows the rocks and the rock-relationships!

Note that in this project most (all?) of the geology 'events' are intrusive or brecciation events, so all of the rock-relationships are cross-cutting … and will need to be specified as 'Erod' in the stratigraphic pile.

Furthermore, there are no simple 'layered series' of geology units – so each geology formation must be modelled as a separate series, with each series consisting of a single formation only.

Note that to get started modelling just the Hornblende Andesite you could simply define that single series ('Hornblende') in the stratigraphic pile … or perhaps define a couple of initial series as illustrated below … or you can set up the entire stratigraphic pile.



Add Data (Geology Contact Points and Orientation Data) for the Hornblende Series

Using the geology images on the map and section views (Sections 167200N and 167400N), add some geology 'contact points' defining the boundary of the 'Hornblende' formation.

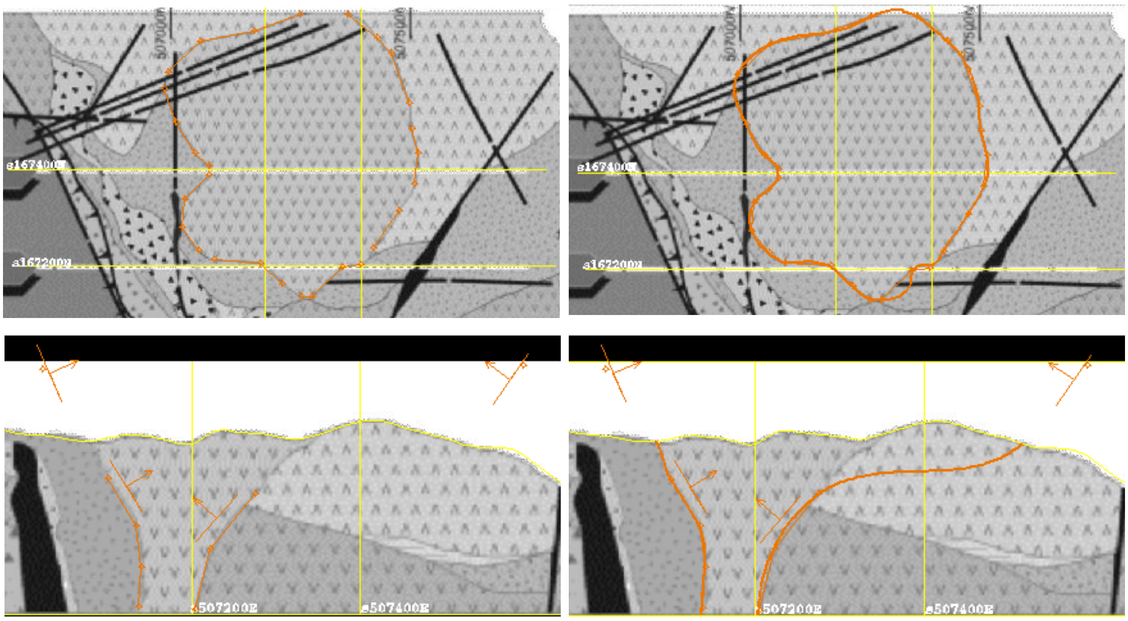
Note – important issue

You will need to create some orientation data also; try to do this in a way such that you are reasonably confident that you are indeed defining orientation vectors which are orthogonal to what you expect to be the geology boundary surface of the 'Hornblende' formation.

Note – important issue

You will also notice a discrepancy between the extent of the Hornblende as mapped on the surface, and as presented in Section 167400N. Such interpretative discrepancies are not uncommon when geologists are restricted to working in separate 2D sections. By contrast, GeoModeller guarantees that the geology on intersecting sections must be consistent – by definition … being derived via interrogation of a single 3D model.

Plot the model geology and compare to the source geology image.



Note the discrepancy between source plain and section

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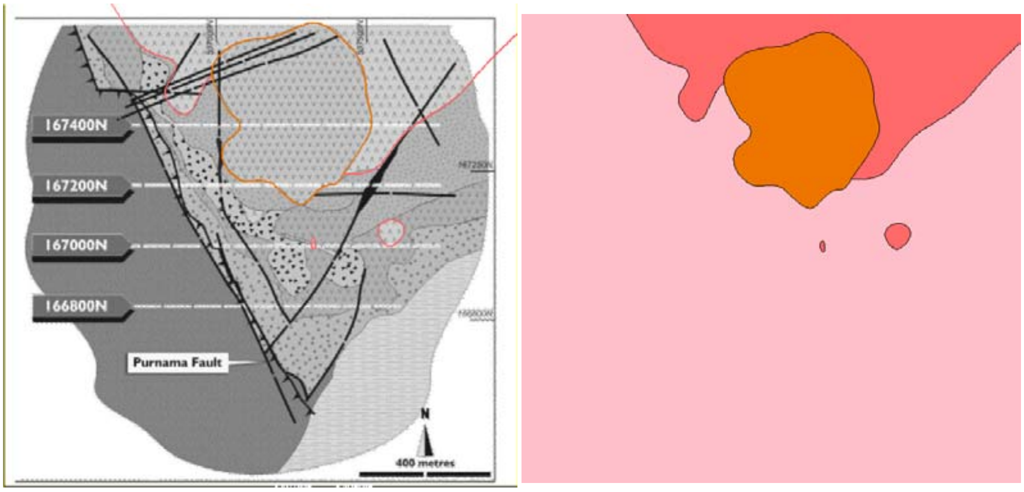
A completed version of stage 3 of the tutorial is available:
`GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_03_Add_Hornbl\TutorialF1_03_Add_Hornbl.xml`
Do not overwrite it.

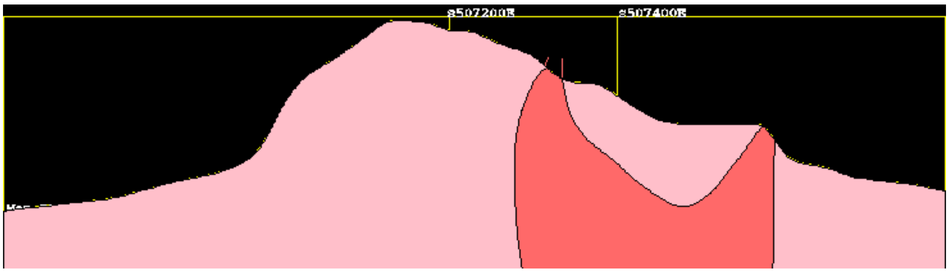
F1 Stage 4—Include Dacite geology

Add contact and orientation points for the Dacite series. Calculate the model, plot the model geology and compare the results with the source geology image.

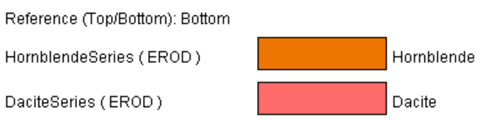
The following illustrations show the Dacite and Hornblende data.



Observe Section 167,000N:



Note that where the bottom-most series in the stratigraphic pile is used … and further geology formations are needed below that point – then the infilling 'dummy' geology will be assigned some arbitrary colour … in this case … the 'light pink' coloured surroundings.

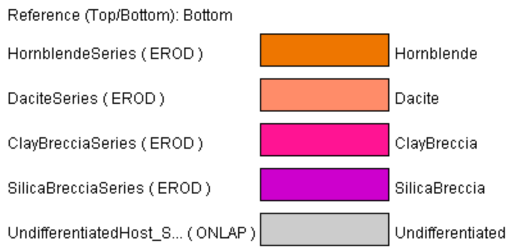


A completed version of stage 4 of the tutorial is available:
`GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_04_Add_Dacite\TutorialF1_04_Add_Dacite.xml`
Do not overwrite it.

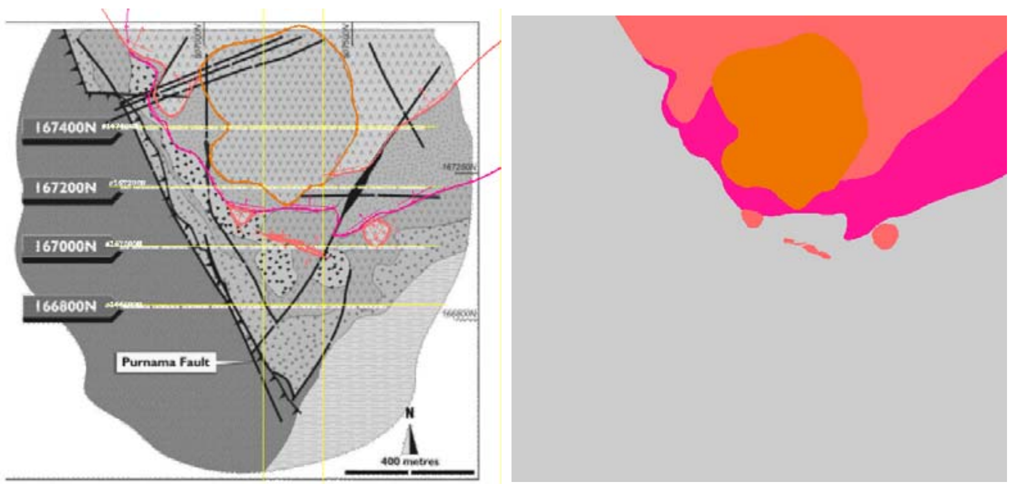
F1 Stage 5—Include Clay Breccia geology

Create the following series below the DaciteSeries, each containing a single formation:

Series	Formation	Relationship
ClayBrecciaSeries	ClayBreccia	Erode
SilicaBrecciaSeries	SilicaBreccia	Erode
UndifferentiatedHostSeries	Undifferentiated	Onlap



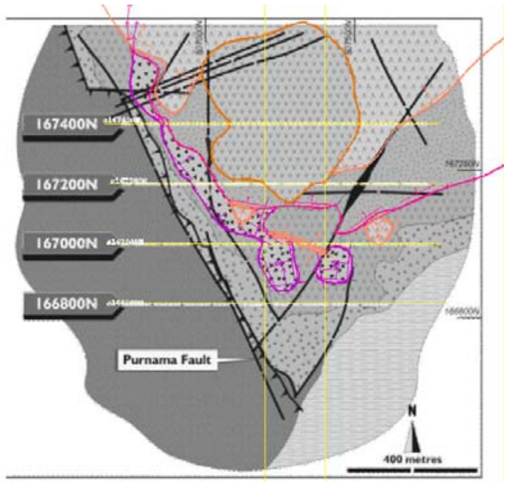
Add contact and orientation points for the ClayBreccia series. Calculate the model, plot the model geology and compare the results with the source geology image.



A completed version of stage 5 of the tutorial is available:
GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_05_Add_ClayBrec\TutorialF1_05_Add_ClayBrec.xml
Do not overwrite it.

F1 Stage 6—Include Silica Breccia geology

Add contact and orientation points for the SilicaBreccia series. Calculate the model, plot the model geology and compare the results with the source geology image.

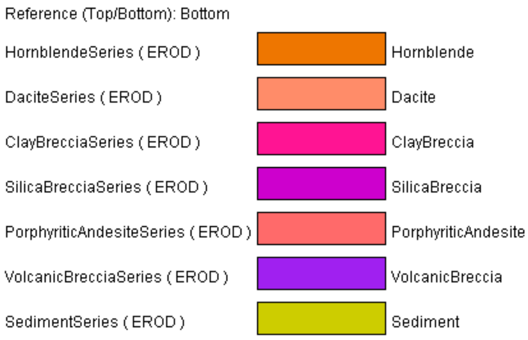


A completed version of stage 6 of the tutorial is available:
GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_06_Add_SilicaBrec\TutorialF1_06_Add_SilicaBrec.xml
Do not overwrite it.

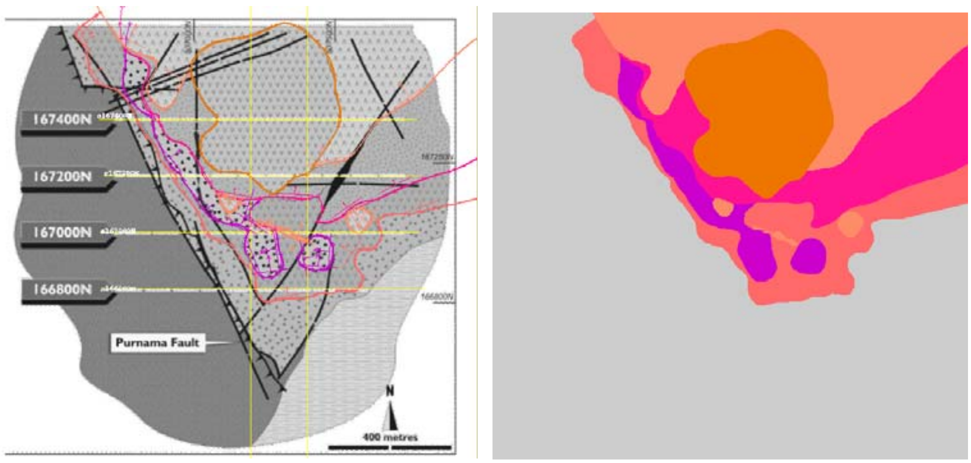
F1 Stage 7—Include Porphyritic Andesite geology

Create the following series below the SilicaBrecciaSeries, but above the UndifferentiatedHostSeries, each containing a single formation:

Series	Formation	Relationship
PorphyrticAndesiteSeries	PorphyrticAndesite	Erode
VolcanicBrecciaSeries	VolcanicBreccia	Erode
SedimentSeries	Sediment	Erode



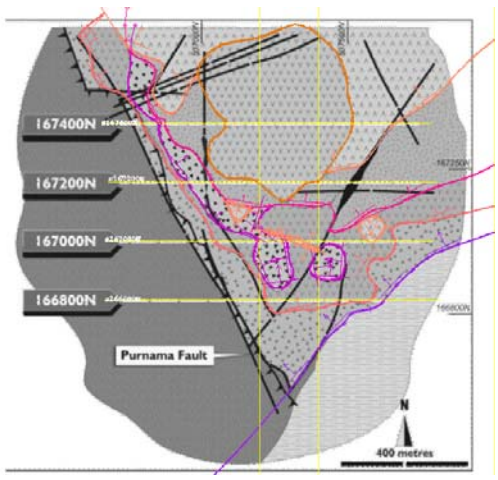
Add contact and orientation points for the PorphyrticAndesite series. Calculate the model, plot the model geology and compare the results with the source geology image.



A completed version of stage 7 of the tutorial is available:
`GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_07_Add_PorphAndst\TutorialF1_07_Add_PorphAndst.xml`
Do not overwrite it.

F1 Stage 8—Include Volcanic Breccia geology

Add contact and orientation points for the VolcanicBreccia series. Calculate the model, plot the model geology and compare the results with the source geology image.



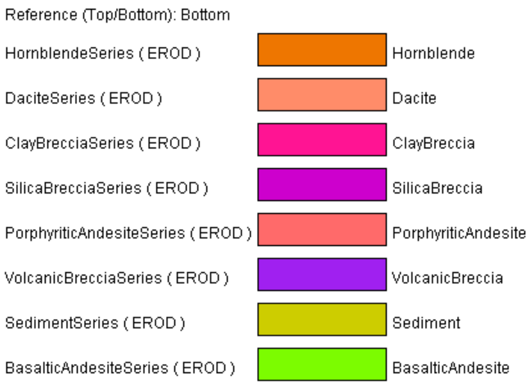
A completed version of stage 8 of the tutorial is available:
`GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_08_Add_VolcBrec\TutorialF1_08_Add_VolcBrec.xml`
Do not overwrite it.

F1 Stage 9—Include the Purnama Fault

Add new series

Create the following series below the SedimentSeries, but above the UndifferentiatedHostSeries, each containing a single formation:

Series	Formation	Relationship
BasalticAndesiteSeries	BasalticAndesite	Erode

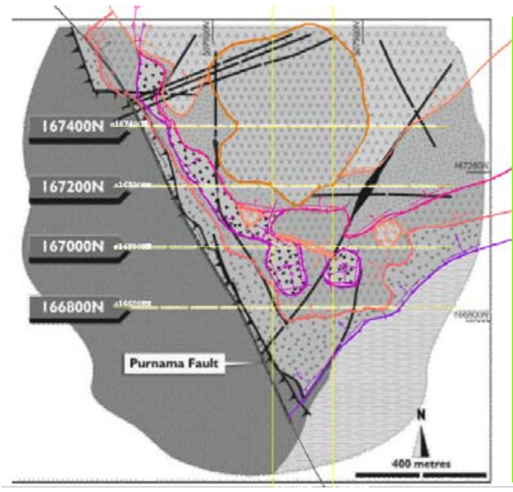


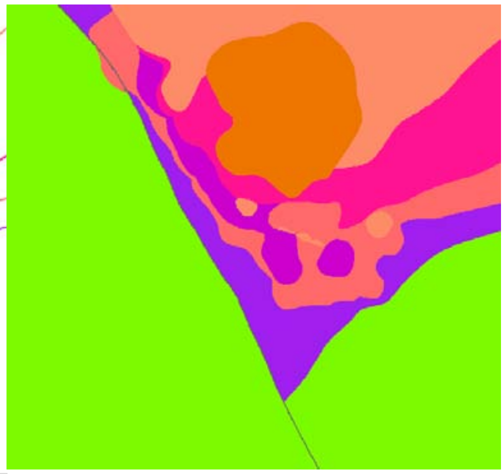
Add the fault

Up to this point I had chosen to ignore the faults … but now decided that at least the major fault along the western edge of the project – the Purnama Fault – had to be included in the model.

Note – Link the Purnama Fault to the appropriate geology series – i.e. those series that the fault must have some impact upon.

Series \ Faults	PurnamaFault	WestSideFault	EastSideFault
HornblendeSeries			
DaciteSeries			
ClayBrecciaSeries			
SilicaBrecciaSeries			
PorphyriticAndesiteSeries	X		
VolcanicBrecciaSeries	X		
SedimentSeries	X		
BasalticAndesiteSeries	X		



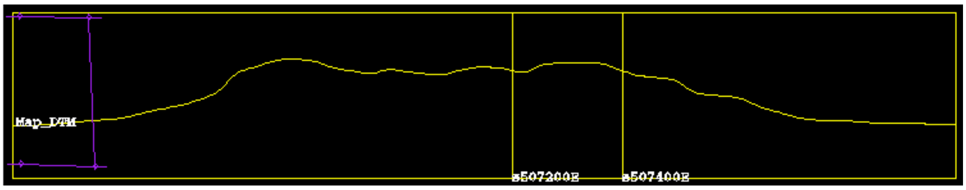


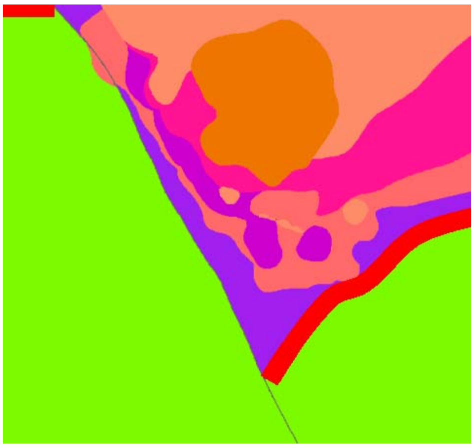
For the moment – ignore the 'green' which is theoretically the Basaltic Andesite. The lower-most defined geology is the Volcanic Breccia (purple) … and since there is further model-space to be 'filled-in', GeoModeller simply fills that space with the formation at the bottom of the pile – in this case, the green Basaltic Andesite.

Note: Important issue

An important question to consider in this model is "Where is the 'bottom' of the (purple) Volcanic Breccia on the west side of the Purnama Fault?"

I had to use some 'construction points' on a section at the very northern edge of the model (Section 167,799N) ; these four 'construction points' have 'associated' orientation vectors which 'face' northwards ... effectively saying that - on the west side of the fault - the Volcanic Breccia is faulted to somewhere 'out of the model'.

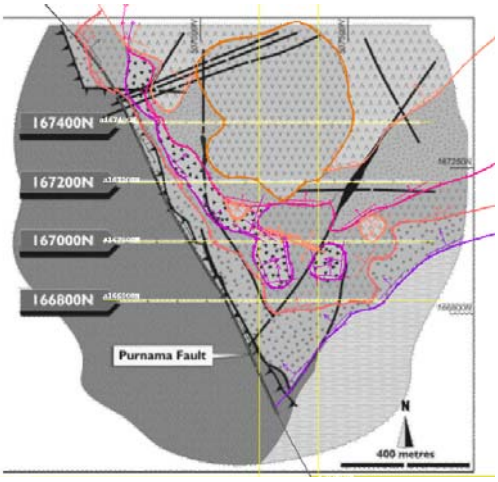




A completed version of stage 9 of the tutorial is available:
`GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_09_Add_Purn_Fault\TutorialF1_09_Add_Purn_Fault.xml`
Do not overwrite it.

F1 Stage 10—Complete the modelling of background geology (Sediment)

Add contact and orientation points for the Sediment series. Calculate the model, plot the model geology and compare the results with the source geology image.

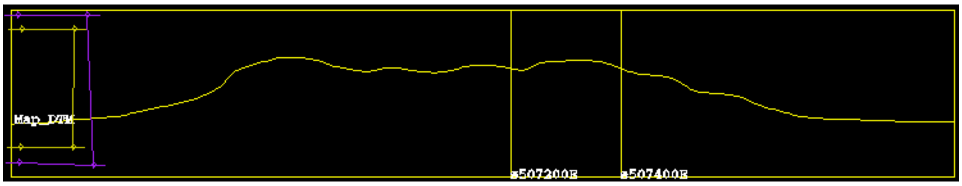


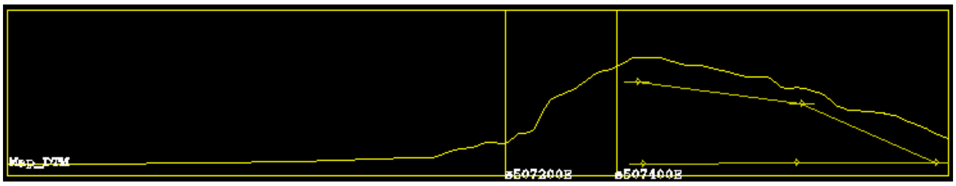
Note – important issue

Again, 'construction points' have been used to define the bottom of the Sediment.

Consider first the east side of Purnama Fault. The south-east corner of the model is all 'Sediment' that just needs to be 'filled-in'. However – if I don't specify the 'Sediment' somehow … then it gets filled in by the unit at the bottom of the pile (the green 'Basaltic Andesite'). However – I cannot really 'see' the bottom of the sediment – because it is somewhere outside the model. Problem solved by putting some construction points on a section at the very south edge of the model (see below).

Now consider the west side of the Purnama Fault. I need to specify something about the Sediment on both sides of the fault … but where? Again – I used 'construction points' on the section at the very northern edge of the model.





Again – note that these 'construction points' have 'associated' orientation data – and they all 'face' to the north.

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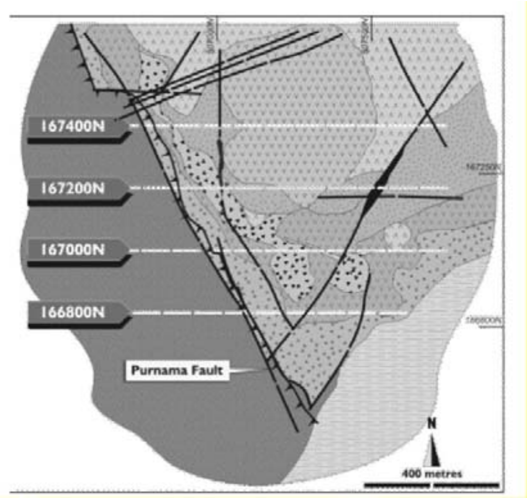
A completed version of stage 10 of the tutorial is available:
`GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_10_Add_Sediment\TutorialF1_10_Add_Sediment.xml`
Do not overwrite it.

F1 Stage 11—Revise the Sediment–Basaltic Andesite stratigraphic order

Whilst the above model is almost OK … I have not really dealt properly with one area of detail.

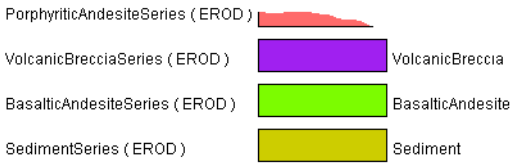
There is actually some of the Basaltic Andesite on the east side of the Purnama Fault … and also it could be considered that the Basaltic Andesite is stratigraphically younger than the Sediment.



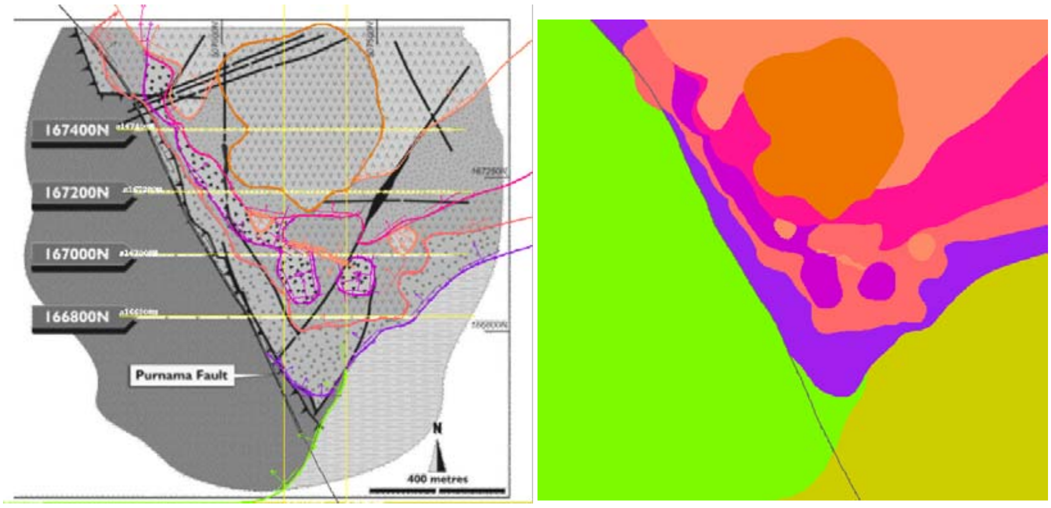
Whilst not being the 'project geologist' … and so perhaps having no right to question their proposed stratigraphic order as supplied on their geology maps … I never-the-less opted to reverse the order of these two units in the pile!

New order of the series in the stratigraphic pile:

Series	Formation	Relationship
…	…	…
VolcanicBrecciaSeries	VolcanicBreccia	Erode
BasalticAndesiteSeries	BasalticAndesite	Erode
SedimentSeries	Sediment	Erode



Calculate the model, plot the model geology and compare the results with the source geology image.

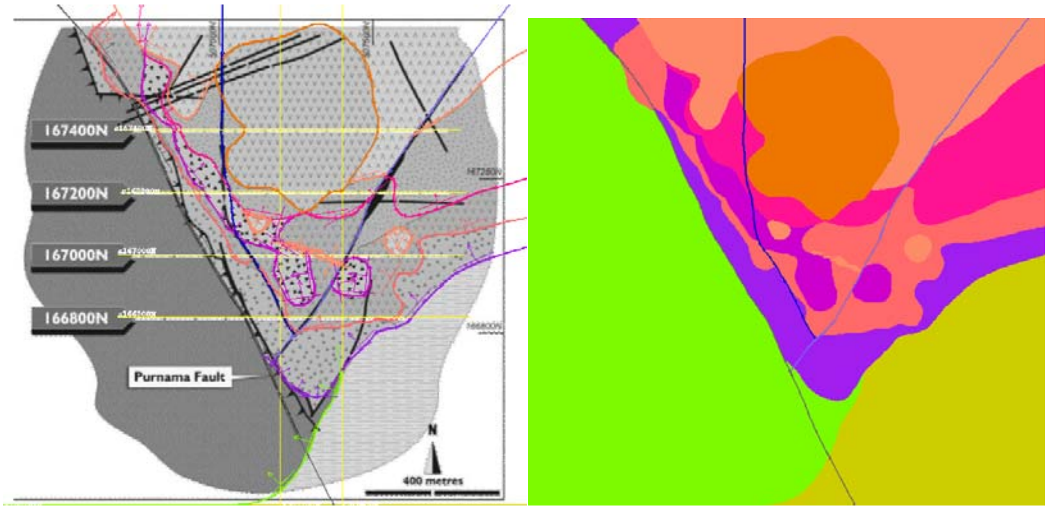


Note again some ‘construction points’ were used. Revised stratigraphic order at the bottom of the pile.

A completed version of stage 11 of the tutorial is available:
`GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_11RevStratOrder\TutorialF1_11RevStratOrder.xml`
Do not overwrite it.

F1 Stage 12—Final model refinement—EastSide and WestSide splay faults

Add the EastSide and WestSide splay faults. Calculate the model, plot the model geology and compare the results with the source geology image.

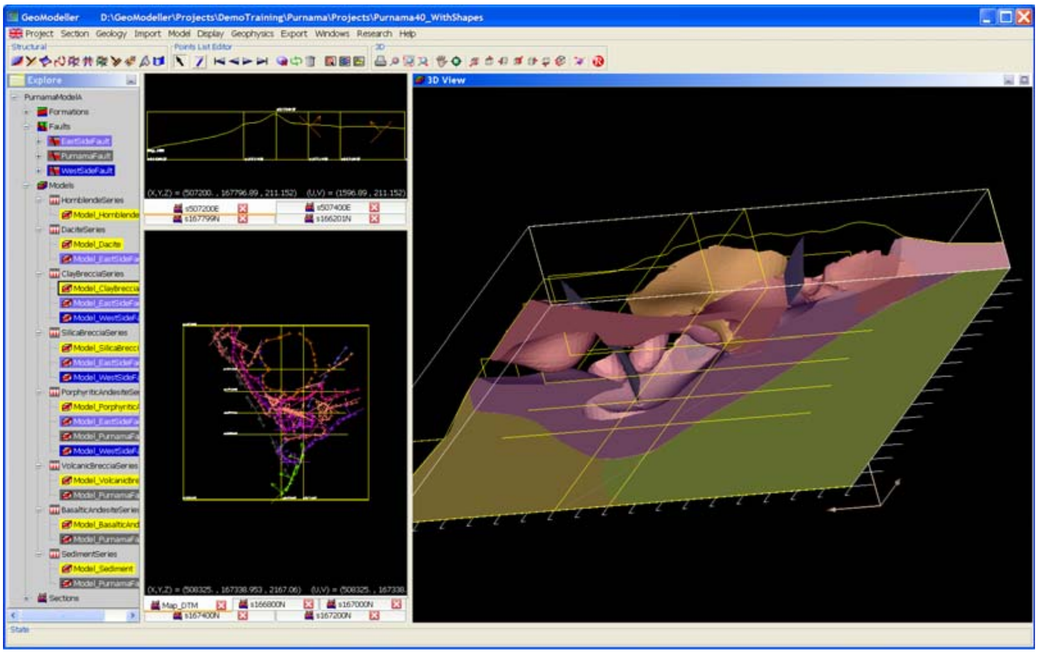


A completed version of stage 12 of the tutorial is available:
GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_12_Add_W_E_Faults\TutorialF1_12_Add_W_E_Faults.xml
Do not overwrite it.

F1 Stage 13—Generate 3D Geology Model Shapes

Using the following resolution, generate 3D shapes for the geology and the fault surfaces.

	X (East)	Y (North)	Z
Model Dimensions	1,700 m	1,600 m	300 m
Required Resolution	25 m	25 m	10 m
nX, nY, nZ	69	65	31



A completed version of stage 13 of the tutorial is available:
`GeoModeller\tutorial\CaseStudyF\TutorialF1\Completed_project\TutorialF1_13_With_Shapes\TutorialF1_13_With_Shapes.xml`
Do not overwrite it.